NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM REPORT 122

SUMMARY AND EVALUATION OF ECONOMIC CONSEQUENCES OF HIGHWAY IMPROVEMENTS

HIGHWAY RESEARCH BOARD
NATIONAL RESEARCH COUNCIL
NATIONAL ACADEMY OF SCIENCES—NATIONAL ACADEMY OF ENGINEERING

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HIGHWAY RESEARCH BOARD
WASHINGTON, D.C.

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AREAS OF INTEREST:
TRANSPORTATION ECONOMICS
ROAD USER CHARACTERISTICS
URBAN COMMUNITY VALUES

HIGHWAY RESEARCH BOARD
DIVISION OF ENGINEERING NATIONAL RESEARCH COUNCIL
NATIONAL ACADEMY OF SCIENCES—NATIONAL ACADEMY OF ENGINEERING 1971

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

Systematic, well-designed research provides the most effective approach to the solution of many problems facing highway administrators and engineers. Often, highway problems are of local interest and can best be studied by highway departments individually or in cooperation with their state universities and others. However, the accelerating growth of highway transportation develops increasingly complex problems of wide interest to highway authorities. These problems are best studied through a coordinated program of cooperative research.

In recognition of these needs, the highway administrators of the American Association of State Highway Officials initiated in 1962 an objective national highway research program employing modern scientific techniques. This program is supported on a continuing basis by funds from participating member states of the Association and it receives the full cooperation and support of the Federal Highway Administration, United States Department of Transportation.

The Highway Research Board of the National Academy of Sciences-National Research Council was requested by the Association to administer the research program because of the Board's recognized objectivity and understanding of modern research practices. The Board is uniquely suited for this purpose as: it maintains an extensive committee structure from which authorities on any highway transportation subject may be drawn; it possesses avenues of communications and cooperation with federal, state, and local governmental agencies, universities, and industry; its relationship to its parent organization, the National Academy of Sciences, a private, nonprofit institution, is an insurance of objectivity; it maintains a full-time research correlation staff of specialists in highway transportation matters to bring the findings of research directly to those who are in a position to use them.

The program is developed on the basis of research needs identified by chief administrators of the highway departments and by committees of AASHO. Each year, specific areas of research needs to be included in the program are proposed to the Academy and the Board by the American Association of State Highway Officials. Research projects to fulfill these needs are defined by the Board, and qualified research agencies are selected from those that have submitted proposals. Administration and surveillance of research contracts are responsibilities of the Academy and its Highway Research Board.

The needs for highway research are many, and the National Cooperative Highway Research Program can make significant contributions to the solution of highway transportation problems of mutual concern to many responsible groups. The program, however, is intended to complement rather than to substitute for or duplicate other highway research programs.

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FOREWORD

By Staff
Highway Research Board

Public officials at all levels of government and other people concerned with transportation legislation, planning, design, and use will find this report of direct application to gaining an understanding of the social, community, environmental, and engineering factors involved in transportation decisions. The broad scope of these consequences of highway improvement (and of other modes) is discussed from the several viewpoints, but discussed in particular are the relationships of highway transportation to the social and economic community changes that may result from the improvement of highways.

Highway engineers, civic leaders, public officials, and the community citizens desire that highways and their improvements serve the purposes of transportation and at the same time be so located, designed, and operated that they preserve and even enhance the aesthetic, cultural, environmental, and economic aspects of the areas they serve. Whether certain consequential effects of highways are favorable or unfavorable, avoidable or unavoidable, tolerable or untolerable often depends on the viewpoint of each person making the valuation. But the real question to be solved in connection with highway improvement projects and programs is to what extent should the technical and economy aspects of the transportation be sacrificed to ease the unfavorable effects on the social, economic, and environmental factors of the community at hand and that far beyond.

This report endeavors to summarize many effects of highway transportation on the highway user and the nonuser in a manner helpful to those officials who have the responsibility of deciding the authorization of new highway improvements, with reference to whether they should be authorized at all, and if so to what location and design.

The report discusses many of the tools to aid in the major decisions and the factors that are involved in the analytical processes that lead to supplying the tools to the decision maker. Detailed procedures are not intended to be an objective of this report; rather, the report concentrates on the underlying philosophy and principles involved.

The study concentrated heavily on the social and community consequences and minimized the discussion of the road-user aspects. This position was chosen because of the publication in 1969 of *Economic Analysis for Highways,* by Robley Winfrey. The advisory committee to the Highway Research Board recommended that this project should exclude detailed discussions of the several topics that are treated in this book. Thus, this report and the book supplement each other and avoid duplication in depth.

All levels of readers, from the analyst to the decision maker, will find material herein that bear directly on their interests and responsibilities. Also, the several disciplines (engineering, economics, sociology) involved in the total systems viewpoints of highway and highway transportation are served. To illustrate the complexity of the total problem of highway location and design with respect to the requirements of transportation and of meeting the local demands and situations, a case example is given in Chapter Fourteen. The report, however, concludes that every project has to be decided intuitively on its own merits and demerits; there is no mathematical model that will lead to the decision.

CONTENTS

ACKNOWLEDGMENTS

The research reported herein was performed under NCHRP Project 2-11 by the Highway Research Board under the general supervision of Paul E. Irick, Assistant Director for Special Projects. G. P. St. Clair, retired from the Bureau of Public Roads, and a long-time active worker in the subjects of economics, finance, and administration, was appointed principal investigator. He was assisted by Carl Zellner, who joined the HRB staff for work on this project. Upon Mr. St. Clair's resignation from the project because of severe illness, Robley Winfrey was loaned to the project on a part-time basis by the Bureau of Public Roads to assume the responsibilities of principal investigator.

The technical phases of the project were completed by Messrs. Winfrey and Zellner.

SUMMARY AND EVALUATION OF ECONOMIC CONSEQUENCES OF HIGHWAY IMPROVEMENTS

SUMMARY This report discusses the theory, concepts, and methodology of the economic and social consequences of highway improvement in a way to aid analysts in their studies and the decision maker in his selection of projects and programs for capital investment. The general subject of economic analysis (including social items) is presented as an integrated comprehensive tool for aiding in the decision process. Special attention is given to the nonroad-user types of effects of highways and highway use as separated from the motor vehicle and road-user effects.

This project was devised to summarize and integrate the results of nine other NCHRP projects. These other nine projects are summarized in Appendix A. This report avoids duplicating much of the content of other publications and the reports on the nine NCHRP projects. This avoidance of duplication has special reference to the book, *Economic Analysis for Highways* (International Textbook Company, 1969), advance text material from which was available to the researchers in 1968.

Because the research project on which this report is written was not designed to do field studies, experiments, or field surveys, or to observe field practice and highway factors, it did not lead to a factual set of findings and conclusions—so often the results of research. Rather, the report puts together facts, theories, concepts, procedures, relationships, and effects of highways in a way to aid in the economic and social understanding of highways in their environment. The main objective is to provide help in the analyses of proposed highway improvements leading to the decision process wherein the decision is to construct or not to construct, and, if to construct, to what location and design.

Economic analysis in its broad scope as a decision-making tool is discussed in Chapter Three, particularly as related to systems analysis and as a decision-making tool. Highway planning, programming, and budgeting are discussed in a similar manner in Chapter Four. The technical factors and procedures of engineering economy analysis for highways are presented in Chapter Five, somewhat as an academic subject. But this discussion lays the foundation for the specific discussion in Chapter Six of the highway user costs and gains that are the main factors dealt with in the analysis for economy of highway investment proposals. Only illustrative values of motor vehicle running costs, accident costs, and other factors are given.

The conflict between the costs and gains of transportation as a function in society and the social and economic factors affected by the transportation that always have existed in any society broke into community-wide open discussions in the 1960's and are discussed in relation to each other in Chapter Seven. This

"bridge" chapter relates the degree of effect of some 24 highway design and engineering factors to about 70 social, economic, and environmental factors that could be affected by highway transportation.

Over time, the economist has developed a set of theories and principles relating society and its actions, and many of them are directly applicable to highway transportation. They may not be generally well understood by engineers or highway managements, but should be. Chapter Eight discusses such economic factors as demand, supply, price, indifference curves, marginal utility, location theory, central place theory, distribution effects, spillovers, and other economic phenomena that are involved in the location, design, and use of highways. The purpose of Chapter Eight is to discuss these subjects in a manner that will help bridge the communication gap between engineers and economists.

Chapter Eight on economic theory blends over to Chapter Nine in which a detailed discussion is given of the social and economic effects of highway transportation. These consequences are discussed in terms of 15 major classes, subdivided into 70 subclasses. These factors are discussed in relation to 12 characteristics: rural, urban, economic, social, right-of-way, corridor, community or system, region or nation, before construction, during construction, short term after construction, and long term after construction. These many economic and social effects are analyzed in detail in Appendix B.

Because identification of the many social and economic consequences of highways and their use should lead to a discussion of their relative values and priorities, the next logical step is to discuss the techniques of their valuation. This is done in Chapter Ten. Rating, ranking, and weighting systems are discussed in terms of their application of the results to the decision-making process, described in Chapter Eleven. The use of computers as a device to use in making the economic analyses and evaluations is presented in Chapter Twelve. Areas for further research and data collection are identified in Chapter Thirteen.

Chapter Fourteen presents an illustrative economic analysis of a hypothetical project location of a section of an Interstate highway route. The analysis first determines the road-user costs and benefits on each of four alternative route locations involving both rural and urban land. The nonuser effects of each route are determined and the whole material is put in shape for use by the decision maker. One unusual feature of this illustrative analysis, although a feature that should always be used when it is applicable, is the inclusion of supplemental interim highway construction within the total land area affected. This supplemental construction during the 20-year analysis period is off the Interstate route under analysis, but such off-route construction would be needed in different degrees and locations, depending on which of the four Interstate alternative locations were adopted.

CHAPTER ONE

INTRODUCTION, CONCEPTS, AND SCOPE

This report on Project 2-11 of the National Cooperative Highway Research Program (NCHRP) covers generally what is known as economic analysis of proposed investments in long-lasting highway facilities. This chapter gives a brief history of the growth of highway economic analysis. The conception and development of NCHRP Project 2-11 is described as it relates to the total program and to the other projects in the same series. The general plan of Project 2-11 is to draw together and present in an integrated manner the results of Projects 2-1 through 2-9.

PURPOSE OF THE REPORT

The purpose of this report is to supply theory, methodology, and discussion of the analysis of the economics and consequences of highway improvements in a way that will aid analysts in making studies and the decision makers in selecting highway improvement projects and programs for investment. An effort has been made to provide those responsible for analyzing highway investments and making decisions thereon with integrated comprehensive analytical decision-making tools. This report discusses the practical, effective, and theoretically valid approaches to economic analysis and the input data as related to highway economy, economics, sociology, and management.

HISTORICAL BACKGROUND OF HIGHWAYS

Long-standing custom and law have made the provision of roads, streets, and highways a public function. Most levels of government—town, city county, state, and federal—contain an agency devoted to that function. To officials of these governments is entrusted the responsibility for making, or providing the information necessary for making, decisions on how, where, and when public monies are to be expended for road construction, maintenance, and operation. In a world of scarce resources not all roads desired by certain citizens should be built, improved, or kept up. Decisions must be made on how the resources made available for road improvement are to be allocated to systems and projects to best fulfill society's needs and to accomplish society's objectives.

Often, in the past and the present, in the absence of rigorous analyses or factual information on which to base decisions, road expenditures have resulted or result from pressures on politicians, professional judgments of engineers, or (at best) the common sense or (at worst) the whim, caprice, or hunches of one or both. Because government, unlike private enterprise, shows no cash profits and losses by which to judge its performance and does not go out of operation, it is difficult to measure the extent of any errors and waste. It is impossible to know how much better (or worse) the present condition of society might have been had the means to more informed decisions been available and used. On the other hand, it is evident from the prosperous state of the economy of the United States and its growth over time that, as a whole, past decisions were reasonably good.

Sufficient problems exist relative to highway transportation and sufficiently informed criticism has been voiced on past and current decisions concerning highway problems to warrant improving the decision process and the means and information used to arrive at decisions. Expenditures for highway transportation now consume an estimated 17 percent of the gross national product (GNP), or 83 percent of the 20 percent share of GNP spent for all transportation (*1-8*, pp. 27-32). This means that road transportation decisions are likely to have large-scale impacts, for good or ill, and the decisions should be correspondingly wisely made by well-informed decision makers.

Road construction in the United States has proceeded in three phases:

1. *The Development Period* (*1607-1900*)—In the period 1607 to 1900 the major goals of transportation were exploration, settlement, and development of what was then a developing nation. Rudimentary access was required to the areas and resources unserved by river or ocean transportation. Some longer trails, post roads, and turnpikes were developed to handle overland wagon trains and post riders. Canals also were built. Shorter routes connected the hinterlands to ocean, canal, and river ports and later to railheads and depots. The natural resources—furs, farmlands, mines, and forests—made accessible by these roads and canals produced sufficiently large payoffs relative to the cost of the access roads that economic analysis was hardly necessary. (The repeated failure of toll turnpike operations, however, indicates that some economic analysis, even then, might have been relevant.) The U.S., by 1921, had a nationwide network of roads totaling about 3.2 million miles (*1-11*, p. 119). That this was a fairly complete system in its coverage is suggested by the fact that only 0.5 million additional miles have been added to it since 1921, and roughly one-half of these are urban streets. (Because of uncertainties in record keeping, the figures of 3.2 million miles and 0.5 million miles should be regarded as estimates.)

2. *The Roadway Surfacing Period* (*1900-1946*)—The introduction of mechanized road transportation, first the bicycle and, soon after, the motor car at the end of the nineteenth century, provided the needed impetus for surfacing the existing mileage. Bicycle clubs and later motorists' good roads associations formed a lobby for public policy supporting the surfacing of dirt roads. The appeal to "get the farmer out of the mud" provided a strong "second" to the motion in a still predominantly rural na-

tion. In spite of these appeals, the amount of surfaced mileage (although it doubled in absolute terms), as a percentage of total mileage rose from only 9 percent in 1904 to 12 percent in 1914 just prior to World War I.

That war brought about a shift in legislative attitudes that no amount of lobbying by road users had been able to do. Motorized troop convoys and the movement of essential war material was greatly hampered by the poor condition of the road system in respect to paving. Trucks were frequently bogged down in the mud. In 1919, Oregon instituted the first motor fuel tax to support road building. By 1929 all states were levying a motor fuel tax. Another result of the war was the "Pershing Map," a plan for a system of strategic highways necessary to the national defense. This was the precursor of the present Interstate system.

From 1920 on, road surfacing proceeded at a comparatively high rate. Total surfaced mileage as a percentage of all mileage increased from 14 percent in 1921 to 52 percent in 1946. The rate of surfacing of previously unsurfaced mileage appeared to be slowing down in the 1960's, indicative that the mileage of roads justifying such treatment was becoming less and that priorities were being placed on other features of highway transportation.

In spite of the stepped-up pace of road surfacing prior to World War II, highway expenditures hovered near $2 billion per year from 1926 to 1941. They remained at about that level even during the Depression when highways were one of the public works undertaken tc provide unemployment relief.

3. *The High-Capacity Period (1964 to —)*—Wartime priorities during World War II cut highway expenditures to half their former figure (*1-11*, p. 78). The deterioration of the highway plant during the war period along with postwar factors (pent-up consumer demand from wartime rationing and saving; population and incomes rising at a more rapid rate; the need to utilize the expanded industrial plant built up during the war; the urge toward full employment; the trend toward urbanization; and the redemonstrated deficiency of the existing highway system as a carrier of defense traffic in wartime) led to a sudden and continuing upsurge in highway expenditure. A consequence of these factors, rising automobile manufacture and registration, and the substitution of automobiles for other transportation modes, mainly rail and transit, aggravated the urban transportation problem: congestion. The emphasis of public policy shifted into a third phase: the provision of more highway capacity to handle the increasing traffic stream.

Toll turnpikes and urban parkways had proved popular in this regard. The earlier idea of a national system of interregional super highways was revived. Urban areas undertook expressway and toll road projects. Accelerated maintenance and reconstruction began to put the deteriorated highway plant back in order. By one year after the war, 1946, disbursements for highways returned to their pre-war level of about $2 billion. In five years, they had doubled to more than $4 billion in 1951; in five more years, 1956, they had doubled again and stood at $8 billion. Annual highway and street expenditures in 1967 had topped $14 billion and were still rising, with forecasts of $16 billion likely by 1970, another doubling. Providing a large share of these totals was expenditures under the Interstate Highway Act, passed in 1956—a plan to build 41,000 miles of super highways connecting most major U.S. cities by 1972. The work was to be performed over a 16-year period at an estimated cost of $50 billion (1967 estimate). The American Association of State Highway Officials is considering a post-Interstate highway program that will require more than $70 billion over a 10-year period.

GROWTH OF THE USE OF ECONOMIC ANALYSIS

The growth in the scale of highway improvements and public expenditures for transportation indicates that economic analyses of proposed investments in highways should be a tool widely used by highway managements. But the use of this tool has only recently shown the advancement that could have been started years ago.

Economic analysis as a management decision tool for highways has been in the literature at least since 1847 when Gillespie (*1-3*) published *A Manual of the Principles and Practice of Road-Making, Comprising the Location, Construction, and Improvement of Roads and Rail-Roads.* Wellington (*1-12*) published an *Economic Theory of the Location of Railways* in 1877, with an enlarged edition in 1887. About 1920 began a continuous appearance of technical papers on the economy of highway design as related to the motor vehicle. The next major books on the subject were:

1. 1931—Johannesson, *Highway Economics* (*1-5*).
2. 1937—McCullough and Beakey, *The Economics of Highway Planning* (*1-7*).
3. 1942—Tucker and Leager, *Highway Economics* (*1-10*).
4. 1952—AASHO, *Road User Benefit Analysis for Highway Improvements* (*1-1*).
5. 1969—Winfrey, *Economic Analysis for Highways* (*1-13*).

Widespread adoption of highway economic analysis was retarded until about 1950 by the lack of adequate motor vehicle running costs and the lack of realization by highway officials that the use of such a management tool offered real advantages over the use of their easily applied professional judgment not supported by an analysis using engineering economy procedures. Certainly, the literature afforded an adequate source of principles and procedures. Even at present (1969) the practice of using economic analysis as an aid to decision on proposals for improvement of highways is short of its potential.

A 1962 survey of state highway departments (*1-4*, pp. 121-32) revealed that about 40 percent of all state departments or divisions within departments "never" used economic analysis. Others used it in varying degrees according to purpose. A second survey (*1-4*, p. 130, discussion by Oglesby) examined 130 highway economy studies and found that of the 95 that included road-user benefit analyses, 68 used the benefit/cost ratio method, but only 7 followed a correct procedure. Errors in analysis appeared in a majority of the reports, the most common ones being omission of annual capital costs, accident costs, maintenance costs, and incremental benefit/cost ratios. Another common error was the assumption of a uniform traffic level for the entire analysis period.

These evidences of nonapplication and misapplication of highway economic analysis, when added to the drastically enlarged scale of expenditures and increasingly ambitious and complex programs, make the need for updated analytical methods and data appear even more imperative. It is this gap that this report attempts to fill to the greatest degree possible under the present state of knowledge.

PLAN AND CONTENT OF REPORT

In the earlier days of business and before the corporate structure, local management, usually the owner, had close contact with all features, functions, and operations of his small domain. But as extent and complexity of function and organization grew, management became less and less in touch with the pulse of operations. Management thus became dependent on advice, reports, suggestions, and various types of analyses prepared by staff or line managers. This same change in the character of management responsibility and management operations is found in highway departments. The net result has been a gradual development of many types of decision-making tools, processes, and analyses available to management in reaching its decisions. These devices to aid the decision-making process are most appropriate to construction programs, new types of programs, and functions that involve a high percentage of the available financial budget.

Unlike private industry, highway departments do not have monetary sales and monetary profits and losses to use as guidelines in the decision process. The goals of private industry are largely profits, whereas the goals of public highway departments are services to the traveling public with the least financial cost, consistent with an adequate level of service and with minimum disruption of environmental activities. Thus, highway departments are more concerned with externalities than is private business, although the current trends are involving private business more and more in community problems.

The evaluation of highway improvements in accordance with the economic and social consequences has brought into the area of highway department management many of the techniques and principles found in private business. This report describes the theory, concept, procedures, and tools and devices used by management in the decision process and endeavors to clarify the terminology and concepts found in the wide scope of available literature.

Figure 1 shows the report's coverage of subject matter and the interrelation of the separate subjects. Following this introductory chapter, the report presents the concept and theory of systems analysis and economic analysis. The general scope of coverage is from concept and theory through analysis procedures to evaluation and the management decision. The chapter numbers are indicated where the major discussion is given on each subject. Blocks without chapter number indicate related subjects not covered in this report.

DESCRIPTION OF NCHRP PROJECT 2-11

Area 2 (in Research Field A: Administration) of the National Cooperative Research Program is concerned with economic studies in the highway research field. With one exception, the studies undertaken (Projects 2-1 through 2-10) up to the time of preparation of this report dealt with the economic consequences of highway improvements, the area of study generally described as dealing with highway costs and benefits. The efforts in the economic studies conducted by NCHRP have been to explore the consequences of highway improvements. Project 2-10, "Future Needs for Oversize-Overweight Permit Operations on State Highways," is primarily administrative in character, and outside of purview of Area 2, which deals with economics.

Table 1 gives the Area 2 projects, the names of the

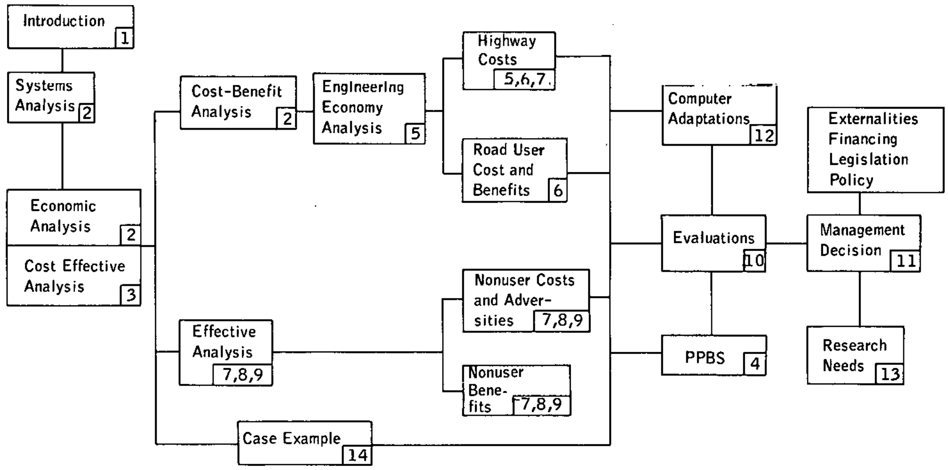

Figure 1. The relationship of the subject matter presented in this report, and some subjects not discussed. Numbers in the blocks refer to chapters where the main discussion of the subject is found.

TABLE 1

NCHRP PROJECTS RELATED TO PROJECT 2–11, THEIR CONTRACTORS AND STATUS

PROJECT NO. AND TITLE		RESEARCH AGENCY	PROJECT STATUS
2–1	Criteria for Highway Benefit Analysis	Univ. of Washington	Report not to be published; summarized in NCHRP *Summary of Progress Through June 30, 1968.*
2–2	Guidelines for the Determination of Community Consequences	Univ. of Washington	Completed—published as *NCHRP Report 18.*
2–3	Analysis of Motor Vehicle Accident Data as Related to Highway Classes and Design Elements	Cornell Aeronautical Lab.	Completed—published as *NCHRP Report 47.*
2–4	The Value of Highway Travel Time, Comfort, Convenience, and Uniform Driving Speed	Texas A&M Univ.	Completed—published as *NCHRP Report 33.*
2–5	Running Cost of Motor Vehicles as Affected by Highway Design and Traffic	Catholic Univ. of America	Completed—published in condensed form as *NCHRP Report 13;* see also Project 2–5A.
2–5A	Running Cost of Motor Vehicles as Affected by Highway Design and Traffic	Dr. P. J. Claffey	Completed—included in *NCHRP Report 111;* report also covers results from Project 2–5.
2–6	Warranted Levels of Improvement for Local Rural Roads	Stanford Univ.	Completed—published as *NCHRP Report 63.*
2–7	Road User Costs in Urban Areas	Catholic Univ. of America	Completed—included in *NCHRP Report 111.*
2–8	Estimation and Evaluation of Diverted and Generated (Induced) Traffic	Northwestern Univ.	Report not to be published; summarized in NCHRP *Summary of Progress to June 30, 1967.*
2–9	Effect of Highway Landscape Development on Nearby Property	Franklin Institute Research Lab.	Completed—published as *NCHRP Report 75.*
2–10	Future Needs for Oversize-Overweight Permit Operation on State Highways	Roy Jorgensen & Assoc.	Completed—published as *NCHRP Report 80.*
2–11	Summary and Evaluation of Economic Consequences of Highway Improvements	Hwy. Res. Board	Completed—published as *NCHRP Report 122.*

research agencies conducting them, and the final reports that have been published.

A detailed abstract of each of the Projects 2-1 through 2-9 appears in Appendix A.

The Book—Economic Analysis for Highways

The scope and content of the final report on Project 2-11 as originally drafted was changed in January 1968 because of the proposed book, *Economic Analysis for Highways* (International Textbook Co., Scranton, Pa.). The revised plan provided that the report on Project 2-11 would omit detailed discussion on those subjects given adequate coverage in this book in the belief that there would be no need to repeat material already available in the literature. This decision places this book in practically the same class as the reports on Projects 2-1 to 2-9; therefore, it is appropriate to describe its contents.

The book contains 27 chapters plus five appendices of reference tables on motor vehicle running costs and extensive compound interest tables. The book lays the foundation for economic analysis for highways in the four chapters preceding the two devoted to theory, concepts, and the application of compound interest. Six methods of analysis for economy are discussed in Chapter 7. Their relative advantages and disadvantages and their limitations and pitfalls are identified. Depreciation, service life, and highway economic costs are described in relation to economic analyses.

The road-user factors of vehicle running cost, travel time, accident costs, and personal preferences are covered. Detailed tables (Appendix A) give vehicle running cost, time consumption, and fuel consumption for a full range of speeds for distance, plus and minus grades, horizontal curves, speed changes, and pavement surface. These costs are given for five vehicle classes: 4,000-lb passenger car; 5,000-lb commercial delivery; 12,000-lb single unit truck; 40,000-lb tractor-semitrailer; and a 50,000-lb diesel 3-S2 tractor-semitrailer.

The remaining chapters are concerned with the nonuser consequences, highways in developing countries, the management decision, needs studies, programming and scheduling, and highway finance and taxes.

Data From Other Sources

At the time of planning of Project 2-11, it was recognized that the nine projects subject to review and synthesis would not supply a complete treatment of the economic consequences of highway improvements. In any planned group of projects, studies of the subject have been made, are being made, and are being planned for the future, outside the purview of the particular planning group. This is fortunate, because it helps to correct mistakes and inadequacies by profiting from the work of others.

It was fortunate for the field of study of Area 2 that the results of other work were available. There never will be complete coverage of the consequences of highway improvement, and decisions about transportation investments must continue to be made without the aid of adequate background data. It was found possible, nonetheless, to supplement the nine studies with the results of other recent and current work, some of it within the family of NCHRP projects. Conspicuous among these are certain projects in Area 8, Transportation Planning—Urban Transportation, which bear on social effects of transportation investments and the evaluation of alternative transportation plans in urban and metropolitan areas. In the study of the value of time and impedance costs, the work by the Stanford Research Institute (*1-9*) and recent work in the same field done at the Chicago Area Transportation Study (*1-6*) were valuable. A great many other sources of data and theoretical analysis were drawn on in attempting to give this report consistency and completeness of treatment. The many publications of the Highway Research Board were a most fruitful source of research results.

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CHAPTER TWO

ANALYSIS PROCEDURES AND CONCEPTS LEADING TO DECISION MAKING APPLIED TO HIGHWAY MANAGEMENT

The needs of a highway department with respect to the management decision process parallel those of private business. Also, the needs may be supplied by similar procedures, involving data gathering, studies, analyses, and testing. Following World War II, systems analyses and operations research developed into popular tools leading to aids to management decisions. Economic analysis, an older recognized tool, may be considered to be a special phase of systems analysis. As background leading to improved understanding of the several analytical procedures to decision making, this chapter discusses the main concepts and methods related to the broad field of systems analysis and operations research.

AIDS TO MANAGEMENT DECISIONS

Many types of aids are available to management for application to the decision-making process; however, the aids themselves are not intended to indicate what the decision should be. The decision is solely up to management and comes as a result of giving just and right consideration to all of the costs and to all of the beneficial and adverse consequences that could result from the various decisions that might be or could be made.

Basically, management is confronted with two broad classes of decisions:

1. Decisions that involve the investment of capital in new long-life properties, such as highway construction, building construction, and acquisition of lands.

2. Decisions that involve operational procedures and techniques; work flow in both headquarters and field offices; and highway maintenance operations, including crew organization.

This report is specifically concerned with the decision process related to capital investment mentioned in item 1.

Figure 2 shows many of the aids available to the decision maker and the relationships between many of the technical terms and concepts involved. Particularly since about 1920, the whole field of management of organizations has undergone great change, basically toward sophisticated concepts involving various forms of mathematical, operational, and qualitative analyses.

Much of the decision process is based on the long-established "scientific method." The scientific method is not a fixed explicit step-by-step method, although there is general agreement that the basic steps are somewhat as follows:

1. Getting the idea of a need or a desire, or recognizing a problem. This is the initial conception that perhaps something should be done.
2. Identifying the characteristics of the solution to the problem or desired solution with some idea as to scope and the correct questions to ask.
3. Developing specific goals, objectives or purposes, and restraints.
4. Setting the specific criteria by which the achievement of the objectives may be measured.
5. Conceiving a plan, a model, an hypothesis, or other type of specific concept of how to accomplish the desired objectives.
6. Evolving a specific design, including experimentation, or a process, or a program to meet the requirements adopted in the plan, model, or hypothesis of item 5.
7. Evaluating the design or plan by economic analysis, pilot testing, scale models, and scientific or mathematical verification.
8. Construction or executing the plan as finally adopted.
9. Observing the feedback from the final operating creation.

SYSTEMS ANALYSIS

Just where systems analysis begins and ends and operations research begins and ends is not definite—and neither is it important. Systems analysis is regarded by some persons as an application of operations research or what the operation research people do. In one way, however, systems analysis may be regarded as having wider application than does operations research. For example, systems analysis is applicable to the study of investment alternatives leading to a management decision. Operations research leads most generally to "how to do" or "how to act." Systems analysis may also lead to the answer of "how," but, more important, it also leads to the answer of "what to do" as well as to "what happens." Note that in Figure 2, operations research is placed in the operations group to the right, independent of analyses of investment outlays.

Definition

Systems analysis is generally defined as a collection of analytical techniques applied in logical order to discover the consequences of proposed changes to certain variables within a "system" on the rest of the system and on its environment. A system has been defined as "a collection of functions and operations dominated by, and controlled for, a set of common objectives" (*2-1*). The systems appropriate for this form of analysis are often distinguished by their diversity, complexity, scale, cost, or some other attribute that renders simple cause-effect analytical approaches inadequate.

Viewpoint

The viewpoint adopted in systems analysis is a comprehensive one (*2-1*, p. 8). The system is seen as an integrated whole formed for the achievement of some desired result(s). Its component parts should be geared to the optimization or success of the system, not to their own optimal functioning. The aim of systems analysis is to describe how the system as a whole can be made to function optimally in achieving its objectives with maximum efficiency, integration, balance, and compatibility of its parts.

The contribution of systems analysis to the planning, programming, budgeting system (PPBS) (see Chapter Four) is as a supporting analysis that traces out all relevant costs and benefits "to whomsoever they may accrue" of the various decision options. Decisions can then be made with greater awareness of likely consequences for the entire context within which the impact of the various proposed changes will be felt. The analysis should show not only the contribution of the various options toward solving a problem or fulfilling a specialized function or objective, but also cost and benefit relationships to other plans, programs, and portions of the budget and to the environment within which their impact will be felt.

Systems analysis may be used to determine how highway improvement affects the social and economic community. Here, systems analysis is applied not only to operations but also to the decision process of whether to make the highway improvement and, if so, how—what design.

Systems analysis provides for stepping up a particular individual question, activity, function, or device under study to include the larger system of which the immediate question is a part. In other words, the attempt is to consider the whole, not just the individual unit, part, or function being examined.

Another important feature of systems analysis is that it includes attention to the feedback or consequences of the action, which in turn may affect the design or choice of decision. The feedback must certainly be considered as part of the system to be studied. For example, in a forecast of traffic to be used in the design of an urban freeway, the effect of the freeway on changing the land use is an important factor to be included. But of equal importance is the increase or decrease in traffic that the change in land use may develop. This increase in traffic is the feedback or one of the consequences of the freeway. Actually, the problem, or system, that should be studied goes beyond the effect on land use and should consider the whole of the

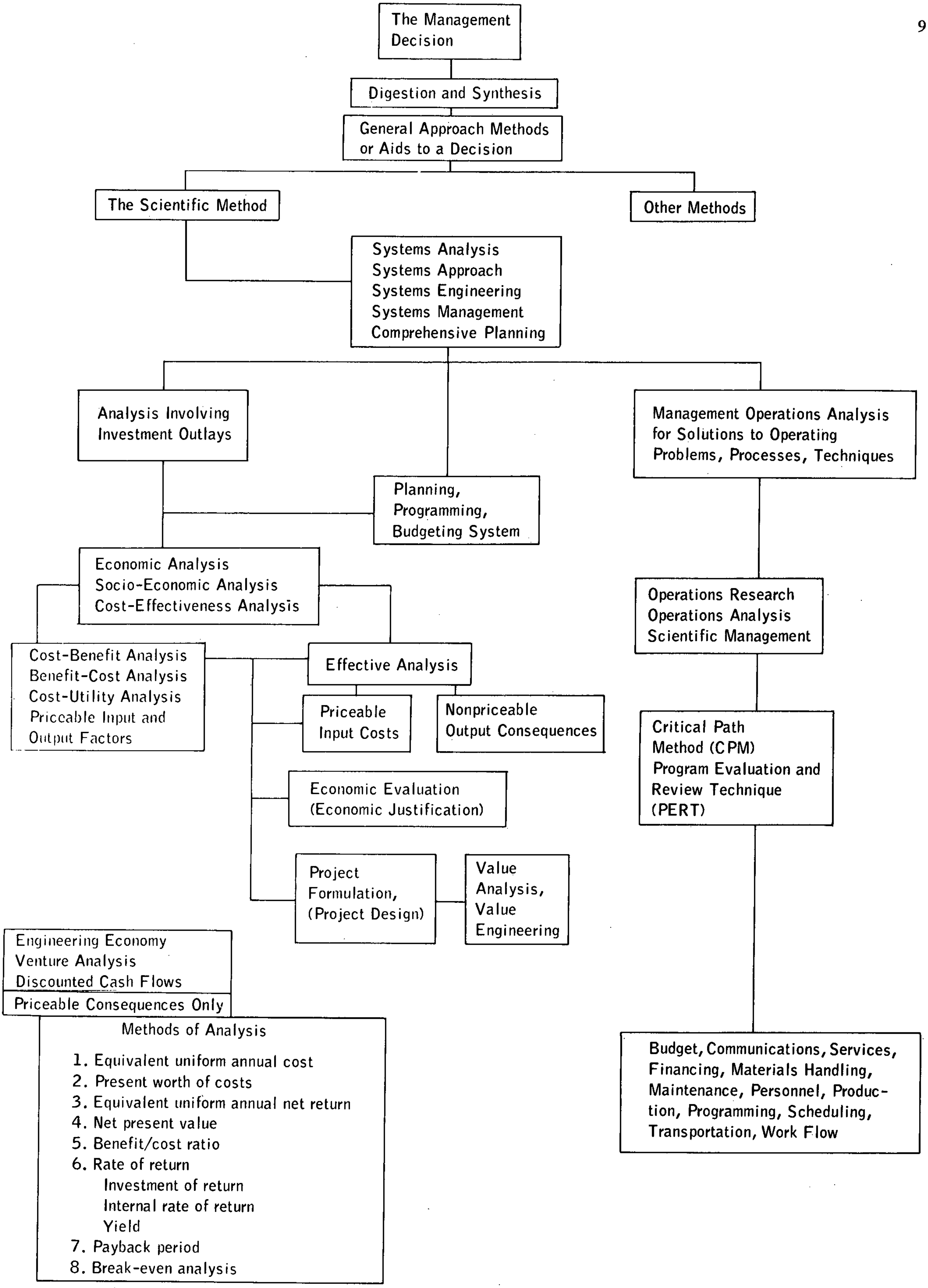

Figure 2. Aids to management decisions.

community affected by the freeway and its consequences on transportation of all modes within the area affected. The social and economic consequences are part of the total system to be included in the systems approach to the design of an urban freeway.

Applied to highway transportation, the systems approach involves studying the effects of both highway and motor vehicles on the highway's total environment, including social, economic, and community activities, as well as all of the physical elements of a highway and its use by motor vehicles.

Systems analysis applied to highways may be divided basically into two closely related but somewhat different subanalyses. First, there is the economic analysis of proposed highway improvements that involve capital investment outlays. Second, there is the systems analysis of highway department day-by-day operations that affect production, employment, communications, and quality of product, including the efficiency of the organization as a whole.

Boundary Limits of the System

Although the concept of systems analysis is that all elements that may or do contribute to the operation under study or that may receive outputs from the operation are included in the system under study, as a practical matter the system elements selected for study are arbitrarily chosen. Figure 3 shows this practice. Each of the elements within the boundary area is analyzed in detail and those elements outside are not, even though the solid and broken connectors indicate that the subsystem within the boundary may be related in some way to the outside elements.

In engineering economy analysis (Chapter Five) one of the principles stated is that "all consequences to whomsoever they may accrue are to be considered." But even this principle is difficult to adhere to in many complex applications. It follows, then, as a practical recourse, that the system studied will include only those elements that are known to be pertinent to the objectives set forth.

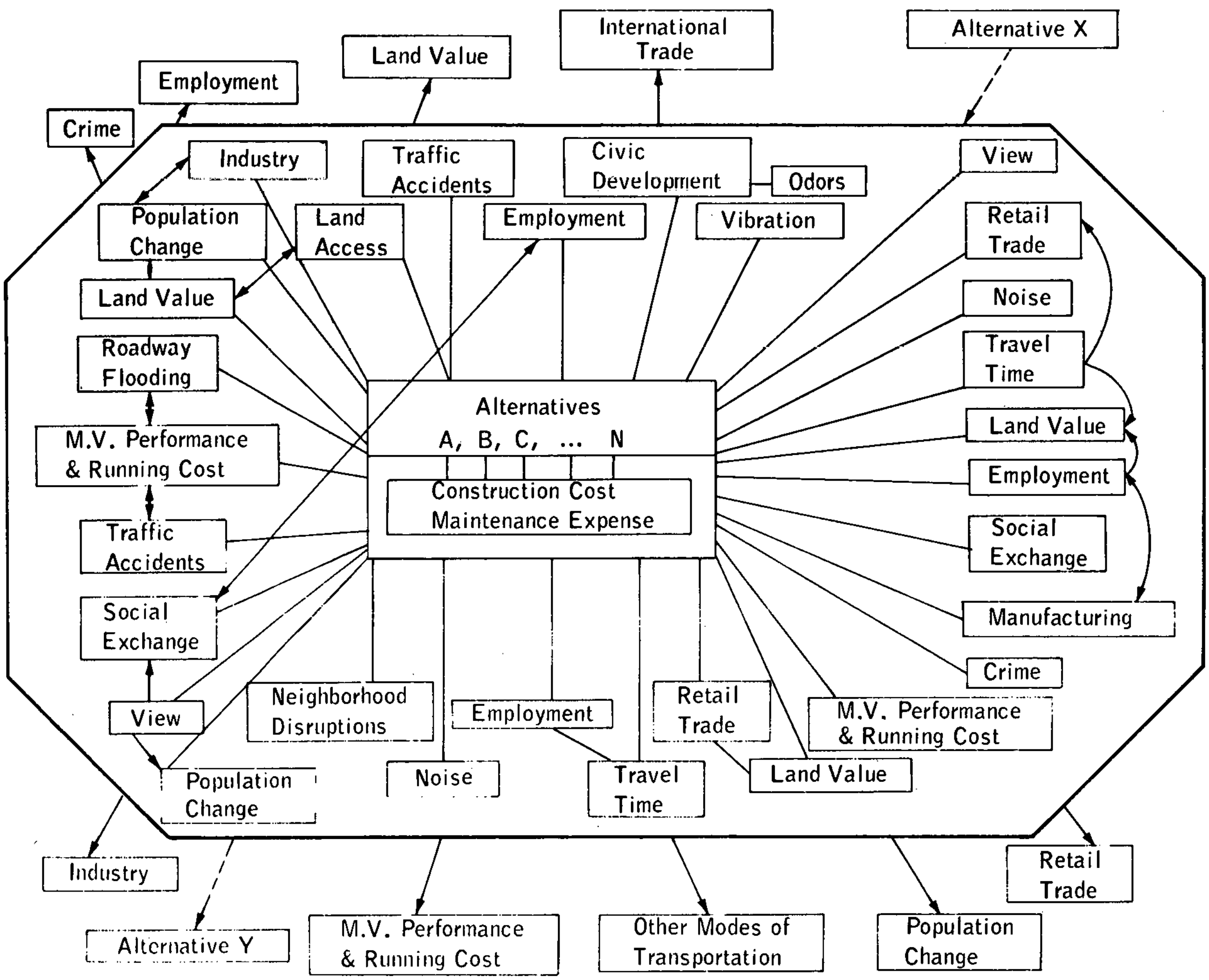

Figure 3. The system boundary and the elements within and without the system as delimited for purposes of the analysis. The analyst cannot be certain of having included all alternatives, and for practical reasons, cost, and time he cannot include all consequences near and far. Arrows denote the direction of the element flow toward consequences. Broken connecting lines indicate uncertainty of existence. Some boxes are repeated to indicate similar factors inside and outside of the boundary and to indicate that within the boundary there are different locations or different characters of the same factors.

In practice, however, perhaps one of the common shortcomings of many economic analyses is the omission of (1) reasonable alternatives of gaining the objectives of the highway improvement, and (2) consideration of some consequences, particularly those in the nonuser category. In the highway user group consequences often omitted in the analysis of the effects of a new highway facility are the effects on the traffic in the community as a whole. Often (but wrongly), just the immediate facility under study and its traffic are considered.

APPROACHES TO COMPREHENSIVENESS

Systems analysis for highways, while attempting to structure and relate the multitude of factors influencing transportation so as to permit the consideration of various alternatives on a total systems basis, need not be confined to the efforts of highway personnel or to the highway factors. In fact, systems analysis in concept demands looking everywhere for alternatives and aids.

Interdisciplinary or "Team" Approach

The team approach involves the adding of persons competent in various relevant specializations to the basic highway team to provide added dimensions to the planning. By working in an interdisciplinary or "team" fashion, each specialist is able to advise, on the basis of his experience and expertise, as to the effects of various alternatives. He may also suggest other means of accomplishing the desired results in a manner that either adds to the benefits or decreases economic and social costs.

This team approach is being used experimentally in some urban areas—architects and landscape architects are employed to create a positive aesthetic impact; sociologists and economists are employed to evaluate and advise on which alignments have more positive socio-economic impacts; etc.

The current experiments will show whether this approach suffers from excessive compromise, said to be typical of things "designed by a committee," or whether results will emerge that are acceptable and optimal for a wide range of factors and impacts.

Inter-Governmental and Inter-Agency Coordination

The proliferation of governments and agencies administering programs at the local level, particularly in metropolitan and urban areas, has created conflict and overlapping.

In the interest of greater efficiency and effectiveness, efforts are being made to provide means for closer coordination of programs and consultation between agencies of governments and civic organizations on how their programs can be mutually supporting or, at least, noninterfering. A prominent example has been the setting up of advisory and review councils for metropolitan transportation studies. Such councils usually consist of political representatives from the affected jurisdictions. Their task is to advise on local plans and goals and the impacts of proposed transportation alternatives on their communities.

Cooperative planning between state, county, and city highway departments has been long-standing in most areas. More cooperation is now occurring between highway and city planning agencies.

The various "super agencies," federal departments and metropolitan governments, with a mandate to plan or operate a variety of functions, have been notably more successful at comprehensive coordination than have inter-agency or inter-governmental advisory committees that talk cooperation but have no powers to implement it. The trend toward establishing federal and state departments of transportation indicates the failure of means other than central executive direction to secure coordination and balance between modes. Although consultation may be helpful in some instances, more super agencies and governments responsible in areas of mutual interest and community bounds are likely to appear. This recognizes that the total functions of government and the community served are affected by or are dependent on the activities of each part. Thus, inter-agency coordination is just another way of exercising the systems approach.

Joint Development

Joint use of land for public and private functions has been practiced for a number of years with varying degrees of success. Basically, it combines the highway improvement with development of other uses of land either within or adjacent to the right-of-way.

Typical examples include use of air rights for buildings above depressed roadways; similar use of space under elevated structures; building in medians or in the quadrants of interchanges; and the "linear city" concept that combines highways with urban-renewal-type redevelopment of abutting corridor land.

This joint land-use approach avoids somewhat the necessity of adjusting the highway to account for environmental impacts by creating an environment adjusted to the highway. The scheme also gives emphasis to systems analysis and to studying "all alternatives" of reaching the objective. In fact, joint development offers the possibilities of widening the objective beyond just the highway service.

STEPS IN SYSTEMS ANALYSIS

The application of systems analysis may follow the steps given previously under "Aids to Management Decisions" for the scientific method. But the steps taken in the systems approach are of themselves not so important as is the practice of applying the systems approach to the fullest extent practicable. Five of the more important steps are discussed in the following.

Problem Definition

The analyst's first task is to define the problem that is given him for solution. The "problem" may be the fulfillment of objectives; or the "objective" may be the solution to the problem. Definition of the problem and a statement of objectives thus come down to the same thing.

Identification of Problem

When there is a "problem" in terms of a malfunction or imbalance in a system, it is particularly important that the analyst be thorough in identifying the real problem and its sources. He must ask the right questions. The causes of perceived effects are frequently not self-evident. The real problem may not be the same as the perceived one. Problem solutions shaped on the basis of symptoms only, incorrectly identified "causes," or incorrectly defined "problems" probably will fail to achieve the desired end-state, the eradication of a problem, or the achievement of an objective. A problem carefully and realistically defined often suggests its own solution, and the solution probably will be a correct one, for the corrective measures will treat causes rather than symptoms. Extensive research into the true nature of the problem is time well spent, and it will often obviate a later waster of analysis, planning, and resources applied to pursuing ineffectual "solutions."

Take a simple example. A condition of "congestion" existed in a downtown street area. Observation revealed that the volume of traffic trying to move in the area exceeded acceptable street capacity. The first reaction of the analysis was that the "problem" was insufficient street capacity. The "obvious" solution was to increase traffic capacity by street-widening. Going back for a second look, however, the analyst noted that most of the cars contributing to the congestion were circling the area in search of parking. If they could be gotten off the street into parking spaces the traffic congestion would be alleviated. The problem was solved by the expansion of parking facilities in the area. Had the first conclusion been acted on there might have been some alleviation of congestion in that the through and parking-seeking traffic would have been given added space in which to move, but the real problem, lack of parking, would have remained along with the potential for recongestion. Those seeking parking spaces would still be present in the traffic stream. In this case, the problem could not be solved by dealing with the symptom—congestion due to lack of street capacity; the solution required dealing with the situation producing the symptom—lack of parking space.

Fundamental Purpose to be Accomplished

Likewise, in developing statements of objectives it is important to push beyond a narrow operational view to the more fundamental purposes to be accomplished. A statement of passenger transportation objectives (neglecting the transportation of goods) might be: "to move more persons with greater safety, efficiency, economy, comfort, and convenience." The ultimate purpose of transportation is to allow persons separated by distance to interact with each other. But this purpose is as well or better served by other means, such as oral and mail communications and the clustering of interrelated land uses. Both of these means decrease the need for physically moving people. Stating objectives in a manner that excludes these options narrows choice, risks inefficiency, and promotes a solution to the status of being the "problem." A better form of the objective statement would be: "to provide the means for spatially separated persons to interact more economically, efficiently, safely, comfortably, and conveniently."

Problem definitions and statements of objectives must be sufficiently precise to indicate the direction in which solutions might lie and to identify criteria by which to judge that the objective has been reached or gauge the amount of progress in that direction.

As part of problem definition, it is important to establish the problem's boundaries, setting them neither so narrowly as to exclude possible alternatives nor so broadly that the problem becomes unmanageable. The level at which the problem exists, the range of variables it significantly affects, and the area over which the decision maker can exert positive control to achieve system objectives will often indicate its appropriate scope.

A third consideration in problem definition is the weighting of the multiple objectives of a system so that each objective is given its proper share in the allocation of resources, operations, and function to achieve system optimization. This aims at avoiding optimizing subsystems or subelements. If each subsystem is allowed to operate in a manner that fully optimizes its own set of objectives it may be out of balance with other subsystems and, unless restrained, may lead to failure to achieve the optimization of the unified goals of the over-all system. Weighting of multiple objectives and the operations of subsystems according to their relative contribution to total system operation can help to eliminate mismatching and imbalance.

This situation may be illustrated by efforts to suboptimize motor vehicle transportation systems within urban areas. Doing so may hinder optimization of the total welfare objectives of the urban population.

Guidelines to Setting Objectives

A variety of complications emerge in the setting of objectives of highway transportation and defining the problems, among which are the following:

1. Uncertainty as to what the objectives should be, in that people sometimes do not know what they want until they have been informed as to what they can have. Choices and solutions not encompassed by the original objectives may emerge. For this reason, objectives should be left tentative, flexible, and subject to change as more becomes known concerning the possible options and the nature of the problem.

2. Vagueness in defining objectives may hinder the formulation of criteria and operational measures of effectiveness by which the desirability of achievement of and progress toward objectives can be judged. Even if it is subject to change, a statement of specific objectives is preferable to one that is general. The other extreme of over-definition may lead to discovery of incompatibility between objectives, a fact that, when existing, needs to be known.

3. Incompatibility of objectives is not always evident at the beginning of an analysis, but may appear later as a result of studying the interactions of subsystems and the system and its environment. This study may result in dropping certain objectives or compromising alternatives. An example might be the objectives of "achieving average peak-hour speeds of 40 mph in an urban area" and "eliminating congestion." Capacity sufficient to permit 40-mph peak-hour speed might induce enough added peak-hour traffic to create congestion anew. A lower speed might be

the compromise necessary to ration capacity and alleviate congestion.

4. Setting of objectives outside the decision maker's area of control should be avoided. System managers can, by proper boundary definition, ensure that their statements of objectives contain only those items that they have the power or ability to effectuate. This does not preclude cooperative arrangements with interacting systems and environmental components or keeping the objectives of the super-system as a frame of reference when shaping subsystem objectives. Objectives of such external systems should not be made one's own objectives, however. Highway officials should always keep in mind the community goals to be aided by highways, as well as the specific objectives of the highway as a transportation device.

5. Objectives should be shaped within a time dimension. System objectives should be neither so elaborate that an overlong delay is required to put them into operation, nor so long-term that the system outlives its users or its utility. Short-time goals may be used to accomplish long-time goals.

Identification of Alternatives

Systems analysis provides for considering all alternative processes, devices, designs, and operations that have some promise (even though slight) of making the objectives reachable. There is no method that will assure identification of all alternatives, because the conception of alternatives is a product of the mind. Group thinking on the problem is helpful; "brain storming" has advantages; and bringing to bear on the proposal persons with diverse backgrounds and disciplines is always worth trying.

Only when all alternatives have been analyzed can reasonable assurance be had that a proper solution has been discovered or that even all good solutions have been considered. The analyst should strive to discover all possible alternatives, and only when he is satisfied that further time, study, and concentration will produce no more worthwhile possibilities should he conclude his efforts to write out all alternatives.

Certain past government programs have been overly narrow in scope. Each department or bureau, confronted with a problem, often has tended to interpret the problem in the light of its own specialized set of interests, responsibilities, and statutory powers. Inter-agency coordination is to be recommended.

A consequence of this narrowness has been a restriction in the range of alternative solutions to problems. Take, for example, the perennial highway problem: traffic congestion. A highway agency confronted with traffic congestion has frequently interpreted it as spelling the need for increased roadway capacity and has limited its alternatives to those providing greater capacity. Such alternatives usually include:

1. Adding lanes.
2. Constructing a new parallel facility.
3. Electronic surveillance and entry control at on-ramps.
4. Limiting access.
5. Reducing of parking and standing.
6. Traffic engineering and control devices (striping, channelization, signal timing, reversible lanes, etc.).

Other alternatives exist but are often not considered, some being outside the purview of the highway agency:

1. Adjusting user fees on toll roads and bridges to encourage off-peak travel.
2. Balancing land-use densities with road and parking capacity through planning and zoning.
3. Congestion tolls on main arteries.
4. Furnishing high-capacity transit modes.
5. Planning new urban forms; decentralization; satellite cities.
6. Pricing: adjusting user taxes and fees so as to ration demand to existing capacity.
7. Providing communication substitutes for travel.
8. Rationing auto production or fuel sales.
9. Regulating, adjusting quantity, or pricing parking to match highway capacity.
10. Special permits to drive in dense areas.
11. Staggering working hours.

Some of these alternatives involve public policy and are virtually "costless" to the highway agency, but perhaps not to society. Others require capital investments and may be quite expensive. Solution of the problem at the least expenditure of resources suggests that alternative solutions requiring only policy changes be explored first, followed by those requiring incremental change to existing plant, and lastly considering alternative investments in new facilities.

An advantage of systems analysis is that by identifying the relevant variables and the cause and effect relationships it allows for a broadening of the range of approaches possible, limited only by the ingenuity of the analyst (*2-4*, p. 42). *All feasible alternatives should be considered.* Their merits and demerits, reviewed briefly in the analysis report, would indicate their appropriateness as solutions and help justify the recommended choice as optimal.

Identification of All Consequences

Similar in difficulty to listing all alternatives for analysis is the problem of listing all consequences resulting from the proposed improvement to a highway system. Often in this phase of analysis, however, locating, quantifying, and pricing the consequences may be more difficult than its conception.

As shown in Figure 3, tracing the effects of a specific highway improvement to all traffic movements may be a hopeless task because of the geographical expanse of the effects. The time consumption and money costs of making the ideal, theoretically complete analysis may be uneconomical. The final results may not be of such magnitude that they would influence the ultimate decision. Here, a study of "all consequences to whomsoever they may accrue" may be tempered in favor of being practical.

The identification of all nonuser consequences—economic, social, and community—may also be short of the ideal, again because of the costly operation required to gather the complete information. Social and economic consequences of highways may reach out to cover the whole country. Thus, the "system" for systems analysis may appropriately be chosen within a short radius from the proposed new facility, as long as all major first-order consequences that would influence the decision are included.

Modeling the System

As an aid to identifying, measuring, and evaluating the subcomponents of the system and their contribution to its optimal functioning and objective fulfillment, systems analysis employs the technique of modeling.

System models may be mathematical (equations, formulae), physical (scale drawings, constructed models), or conceptual (verbal or pictorial images) (*2-9*, pp. 42-43).

The model traces out interrelationships between the various subcomponents of the system and between the system and any super-system of which it may be a part. The objective is to determine the significance of such subcomponents and subsystems in the operation of the whole and their sensitivity to changes in other variables to which they are related.

Once these interrelationships have been identified, it is possible to test the consequences, impacts, or effects of making various alternative changes in the system components, both on the system and on its environment. The reciprocal impacts of changes in the environment on the system can be similarly tested.

The ultimate use of the information derived is as an aid to the decision maker in: (1) choosing among alternative courses of action aimed at the optimal operation of the system within its environment and in fulfilling its objective function; (2) determining whether the outcomes predicted by the model, when evaluated, show benefits exceeding the cost of the proposed changes in the system; and (3) determining the opportune time and place to incorporate the changes into the system.

Modeling a system requires conceptual ability. It is first necessary to define the system's boundaries and its environment. Then its subsystems and subcomponents must be identified and their mutual interrelationships must be traced and measured. Their relationship with the environment and their points of interface also must be similarly accounted for. Finally, the whole must be structured into a comprehensive systems model, mathematized and calibrated, ready to receive the inputs that describe various alternative changes to the system. At all points conceptualization is necessary to identify variables and constants and structure relationships in a manner matching the real-world situation (*2-9*, p. 46 ff). System elements and their degree of interaction are not always self-evident and often require extensive statistical testing for correlation, significance, and sensitivity Because of the greatly increased difficulty in operating the model as it becomes more complex, it behooves the model builder to reduce the whole picture and complexity to the bare essentials required to provide useful and reliable results Often the results are neither useful nor reliable because important matters were left out when the problem was simplified to permit mathematical treatment.

The attempt to show far-reaching consequences of design or change probably will mean not every affected variable can be included in the model. Not all are sufficiently significant; not all can be quantified. For these reasons, it probably will be necessary to add statements to the analysis about the consequences of the excluded variables and give qualitative evaluations where quantification cannot be achieved.

Highway systems analysis, because of the strong interaction between transportation and land use, must give particular attention in modeling to the social factors having an impact on the system. An estimate of future conditions in the highway system environment aids in discovering what disparities probably will occur between the objectives and the real world. This knowledge may affect the choice of alternatives.

For instance, trends might indicate that a central business district is growing in office functions, leading to growing travel demand. Office buildings are being constructed on the sites of present parking lots. One conclusion might be that adding expressway capacity to downtown to accommodate the higher trip levels would increase the demand for parking space at the very time the supply is dwindling. An alternative high-capacity mode to handle the increased travel demands to the area without boosting parking demand might appear a better solution.

Trends and projections of population, employment, age, income, and similar social and economic factors provide a characterization of the environment within which the transportation system will function. They thus provide a backdrop against which to evaluate the system.

APPLICATION OF SYSTEMS ANALYSES TO HIGHWAYS

Highway departments have long been applying the technique of systems analysis, whether or not the activity has been specifically called systems analysis. The foregoing discussion of systems analysis, however, should provide a fuller picture of the concept as currently viewed. To show its wide capabilities of aiding in management decisions, areas of application of systems analysis are listed as follows. This list is not all-inclusive; rather, it is only suggestive of the range of possibilities.

SOME HIGHWAY OPERATIONS AND PROPOSALS FOR INVESTMENT THAT MAY BE STUDIED THROUGH APPLICATION OF SYSTEMS ANALYSIS

1. Economic analysis of proposed investment projects—road-user and nonuser costs and benefits.
2. Planning studies—priorities, coordination, factors included.
3. Transportation system—urban modes and systems, rural arterial and freeway systems, corridor analysis of entire transportation needs (Northeast Corridor, Washington to Boston, for example).
4. Traffic safety improvement programs—driver education, vehicle registration and driver licenses, spot improvement programs, vehicle inspection.
5. Critical path method (CPM) analysis of construction and maintenance operations schedules—preliminary surveys to final inspection and final voucher.
6. Project evaluation and review technique (PERT) applied to construction, maintenance, and management operations.

7. Highway maintenance work management—crew size, crew craft makeup, specialized work crew versus composite area crew, crew and equipment for snow removal.

8. Maintenance organization—central headquarters versus field delegation, spacing and size of field stations, dispersed shops versus central shop.

9. Motor vehicle fleet—operations and management.

10. Priorities—design, construction, maintenance, research.

11. Office operations and administration—purchasing, stock inventories and control, warehousing, accounting, employee training.

OPERATIONS RESEARCH

The scientific method has been broken down into subanalyses or submethods according to no particular plan and no universal practice. Generally, operations research is one application of the scientific method. Operations research, however, in itself is not an application of science, but it applies to an application of the scientific method, including mathematical methods applied to the study of complex problems that cannot be attacked successfully through strict scientific inquiry according to the laws of the sciences. The method of operations research, however, is a logical operation insofar as it brings together all of the factors involved and puts them into a logical functional sequence and logical time sequence. Further, operations research includes the proper recognition of all of the factors that might be involved in the problem at hand.

Many of the techniques within operations research were used by industry in the early 1800's, but operations research as it is known today began in the Operations Section of the British Army in 1938. Scientists from various disciplines worked together as a team to improve existing operations, to adapt new technology and products to operations, and to devise new operations. After World War II, U.S. industry began to apply operations research in industry and business. Operations research entered formal university curricula about 1950.

Operations research is that activity that researches or studies operations—sets of acts performed to accomplish and objective—to improve or increase efficiency or to improve the result and the total process. The many parts and separate acts that make up the whole are studied to seek ways to improve the whole.

Operations research is not a decision tool to be applied to product design, to investment decisions, or to policy setting; rather, it is a system of inquiry undertaken to improve operations of all sorts to gain advantages in using resources—money, machines, and men.

Operations research may be expected to be found in industry, business, military, and government. On a much smaller scale it is applicable to household operations and family activities. The desirability of operations research in the military, industry, and government arises from the complexity of these types of organizations in both function and physical character. No longer can the top executive personally survey and keep in contact with the multi-operations on a daily basis. Further, interests of subdivisions are often in conflict and uncoordinated. Subunits of the organization must operate and be controlled by what is best for the organization as a whole. For instance, in a highway department, the design, construction, and maintenance functions should be operated on a coordinated basis to achieve the best transportation service, rather than as three individual divisions of a single department. Operations research, when applied to the system, can do much toward maximizing benefit to the organization as a whole and toward advancing the utility or satisfactions to the maximum.

Operations research makes use of mathematics, statistics, logic, model building, simulation, and other related sciences and concepts. It attacks the total system involved, and its own operations perform as a system in that all possible tools, concepts, techniques, sciences, and alternatives are brought to bear on the study to reach a good analysis.

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CHAPTER THREE

ECONOMIC ANALYSIS

Economic analysis may be considered to be that division of systems analysis that pertains to the study of investment proposals to determine their economic merits. Economic analysis is interpreted to include the two broad areas of (1) cost-benefit analysis of proposals whose outputs are priceable, and (2) the analysis of the effectiveness of proposals whose outputs are not priceable. Engineering economy is the main analysis under cost-benefit analysis. Included in cost-benefit analysis are two objectives, or purposes, of the analysis. First, there is economic evaluation analysis to determine whether a proposed capital investment project or program will return benefits (returns) in excess of the monetary cost to produce the benefits. The second subanalysis is known as project formulation, or project design, and is performed to determine which alternative project or program will achieve the highest degree of economic efficiency in producing the quality of service desired.

In terms of highway decision making, the highway project is seen as a subcomponent of two larger systems with which it interacts: (1) the over-all highway, road, and street system of which it is a part or link, and (2) the environment in which it operates. The viewpoint of those making decisions concerning highway location and design should be broad enough to encompass both systems. Only in this manner will the problem be viewed in its entirety, as is appropriate when one is acting in the public interest.

SCOPE OF ECONOMIC ANALYSIS

Figure 2 indicates that economic analysis includes socioeconomic analysis and cost-effectiveness analysis. As considered here, cost-effectiveness analysis includes those procedures and concepts that involve comparing input costs to output consequences, whether priced or not. The objective is to reach a specific comparison of cost input to output in the form of benefits, returns, satisfactions, or progress toward goals.

Cost-benefit analysis is restricted to those applications wherein both input resources and output consequences can be priced. Thus, cost-benefit analysis is a cost-effectiveness comparison, on a dollar priced basis. Effectiveness analysis applies to those applications wherein the consequence of the input cost cannot be dollar priced. The broad economic and social effects of highway improvements would be analyzed on an effective basis.

COST-BENEFIT ANALYSIS

Cost-benefit analysis takes place within the context of systems analysis and economic analysis. Cost-benefit analysis can be applied on a project, multi-project, or transportation system basis. For highway analysis, this means discovering the interrelationships between the highway and its users.

Cost-benefit analysis, in the first instance, involves the detailed consideration of alternatives to determine their economics and priorities. This aims at identifying the "high payoff" projects—those projects whose benefits are greatest relative to cost. In highway analysis the "high payoff" projects in engineering terms are those that minimize the total transportation cost (road plus vehicle) for a given level of service using such criteria as equivalent uniform annual cost, maximized net present worth, benefit/cost ratio, rate of return, or other chosen measure of economic efficiency.

Cost-benefit analysis does not cover all aspects of each problem, supply clear-cut solutions, or provide measures that allow full comparison between interrelated programs. Decision makers must input their own judgment and experiences to measure relative worths and make final choices. Cost-benefit analysis has sometimes been objected to because, generally, it ranks alternatives, projects, and programs, or it analyzes a project or a program only on the basis of economic efficiency. If cost-benefit analysis is restricted to those processes involving only the market consequences (mainly the road-user engineering economy analysis), it is true that the analysis produces answers that are direct measures of economic efficiency. In other words, the social and general economic consequences are not included. Both these consequences are included in the effectiveness analysis.

Even though many highway improvement programs and specific individual projects may have an over-all economic or social objective relating to the redistribution of incomes (Appalachia program, for example), usually there is also a direct highway transportation improvement goal. Generally, the main objective of highway investment programs of the cities, counties, states, and federal government is the improvement of highway transportation to decrease its total long-run cost (i.e., increase highway transportation economic efficiency). It follows that the welfare objective of redistribution of incomes or the exploitation of undeveloped resources is seldom even the minor objective of highway improvement as carried on year to year by the highway departments at any government level. The nonuser consequences are economic or social spillovers, or externalities, to the main objective of increasing the economic efficiency of highway transportation and are given deserved consideration in connection with effective analysis.

Cost-benefit analysis includes *engineering economy* analysis that endeavors to identify that engineering design producing the lowest long-run total dollar cost consistent with providing the level of transportation service desired. (See Chapters Five and Six for detailed description.) The analysis for engineering economy is basically a comparison of the highway cost with the road-user cost in an effort to produce the minimum total transportation cost. Of necessity, this analysis deals with the highway elements and those consequences of highway design that can be quantified and priced on a dollar basis.

Acceptance of Cost-Benefit Analysis

Cost-benefit analysis, although widely accepted by engineers and economists and applied by many industrial executives and government officials, is not necessarily universally accepted as a decision aid. The faults attributed to it usually arise from not thoroughly understanding this management tool, either in its analysis stage, or in the application of the results of the analysis. A better understanding of cost-benefit analysis often reveals that it results in information to be used by a decision maker in the process of choosing between alternative courses of action, not in a final decision itself.

It is sometimes objected that cost-benefit analysis does not always lead to the right answer or that the whole analysis is subject to personal bias. When the different procedures within cost-benefit analysis are applied correctly, the answer obtained is a reliable one. It is true that a specific answer in terms of a rate of return or a benefit/cost ratio depends on the input factors. These input factors, however, will be selected by the analyst so as to represent the most probable or representative values applicable to the particular circumstances. To indicate the relative influence of his choice of factors on the final answer, the analyst often will make a sensitivity analysis using both lower and higher numerical values for those factors that might control the relative choice between alternatives. This helps remove the bias that might be introduced by an arbitrary selection of a single interest rate or value of time, for instance.

Cost-benefit analysis has been found a useful tool in the management process. When the analysis procedure is correct and the results are used in a proper way, it is as applicable to government activities as to private industry.

Faulty results from cost-benefit analysis usually arise not from the method but from its application by analysts who do not thoroughly understand the concepts and procedures involved and who may make fundamental errors within their own analysis. Other criticism, often justifiable, stems from using results in an incorrect manner. One frequent misuse lies in substituting the result of the analysis for the decision itself. Another is failure to recognize that the answer does not carry the precision or the reliability that is often found in many analyses and calculations in the engineering and physical sciences.

It is not the errors in the total process of economic analysis that restrict an outright acceptance of the process and its answers; rather, it is the normal limitations of the process. Such limitations include quantifying all factors, selection of the factors themselves, and knowledge that the analyst may not have used all consequences to whomsoever they may accrue. It should be realized the economic analysis is based on (1) forecasts, (2) an assembly of often only part of the factors needed to make a complete analysis, (3) estimates of cost and benefit under conditions that preclude exact measurement and pricing, and (4) the use of certain values of specific factors that may not be fully acceptable to other analysts or to those who apply the results of the analysis.

Many persons accord to economic analyses a confidence and reliability that is not supported by the concept of the analysis itself. Although the analysis proceeds in a scientific manner and is objectively carried out, the end result comes from a series of judgments, estimates, selection of factors, forecasts, and opportunities of the analyst to affect the final answer. These human judgments are of the same type and are made in the same impersonal way as is the final judgment of the decision maker who uses the economic analysis (hopefully in the way it is meant to be used) in his decision process (i.e., simultaneously using all other pertinent information to reach a decision on what to do).

EFFECTIVENESS ANALYSIS

Economic analysis is divided into two categories—cost-benefit analysis and effectiveness analysis (Fig. 2), based on priceability of consequences. Effectiveness analysis has to do with the social and economic benefits and adversities of highway improvements. These consequences are of such nature that often they cannot be quantified or dollar priced. Effectiveness analysis proceeds on a basis that, although the highway cost can be presented in dollars, the effectiveness of these highway costs in producing desirable goals can be described only in qualitative statements because not all the benefits and adverse consequences can be presented on a dollar basis. Therefore, under effectiveness analysis the answer is a descriptive or qualitative statement of the effectiveness of the highway construction in reaching goals. This is in contrast to the answer under engineering economy which might be a financial rate of return on the investment, a benefit/cost ratio, or other numerical index of economic effectiveness.

Where over-all planning and decision making are called for, the entire highway system or transportation complex may be the subject of systems analysis, as contrasted to systems analysis of individual projects. This introduces greater complexity and more variables but maintains the same subject of analysis: (1) the highway system, and (2) its environment, the total system in which the highway function is a subsystem. The "environment" includes both the relevant "community" (from the village to the nation, according to the scale of the "system" under analysis) and the natural environment. This means tracing out the socio-economic effects of the highway on the community and its ecological effects on the balance of nature. The massive scale of highway expenditure, use, and impacts suggests that the highway should not be considered in isolation. All factors and operations involved must be considered in order to reveal a truer estimation of total costs and total net benefits.

In general, the terms "user and nonuser" and "market and nonmarket" express the basic concepts involved in engineering economy and effectiveness analyses. All of these consequences of a social and economic nature are natural results of highway improvement and, although they can be softened or redistributed, they cannot be totally eliminated. The unfavorable nonuser consequences are not a part of the basic objective of improving highways, and they are not desired, but that does not make them secondary. On the other hand, some of these consequences are highly favorable and are desired, but nevertheless they cannot be called secondary consequences, because they are a prime result of the highway improvement even though they are not a major objective. The phrase "nonmarket consequences" is applicable to those consequences that cannot be dollar priced. These consequences are tangible because they can be seen, felt, described, mentally realized, often enumerated, and specifically located. Therefore, the term "intangible consequences" is also rejected as a term descriptive of the consequences that are not market priceable.

Engineering Economy Versus Effectiveness

A distinguishing characteristic of effectiveness analysis is that it does not lead to economic evaluation in the sense that it is accomplished in the engineering economy analysis. Neither is effectiveness analysis applicable in a precise way to project formulation of the details of engineering design. These two statements, however, neither preclude making a determination that a proposal is or is not economically socially desirable nor do they preclude altering engineering designs to achieve a greater utility or satisfaction from the proposal or to reduce the unfavorable consequences.

Both cost-benefit analysis and effectiveness analysis are naturally applicable to the economic analysis of proposed highway improvements on a project basis, a system basis, or a program basis. In the United States, the basic objective of probably 99 percent of all proposals for improving highway transportation is to improve transportation, in contrast to creating additional social values or general economic values related to welfare. Cost-benefit analysis relates itself directly to the analysis of the economy of highway transportation, considered solely from the objective of transportation efficiency. Effectiveness analysis is an analytical tool by which the nontransportation consequences can be evaluated relative to the cost and benefits accruing to transportation as such.

Nonengineering Factors Involved

The cost-benefit analysis is basically restricted to those alternative designs and applications that are the responsibility of the engineer, or which, when analyzed for economy, involve the judgments normally exercised by the engineer. This does not mean, however, that the same principles of analysis cannot be applied to activities nonengineering in character that involve some sort of a decision of management based on comparative cost or comparative economy. The selection of types of office machines and office systems and the installation of a computer system are examples of instances where the principles of engineering economy can be practiced, although the applications themselves are not engineering in character. In addition, in the highway field there are many factors of a nonengineering character important to the economy and to the social well-being of a community that do not involve the responsibility of the engineer, but of which the engineer should be cognizant. In the end, the decision maker will give such nonengineering factors such consideration as is desirable on a project-by-project or system basis.

Many of these broad-scaled economic and social factors affected by highway design cannot be priced on a dollar basis. Aesthetics is an outstanding example in this area. Effective analysis is one available tool by which these social and economic factors can be brought into the focus of the decision maker.

By bringing into his study all of the factors related to the economy of transportation and the nontransportation social and economic factors, the analyst is applying systems analysis. In this analysis, the objective is to provide the decision maker with some guidelines by which he can measure the desirability of the ideal transportation design against the creation of unwanted consequences in the community social and economic areas. These two analyses—cost-benefit and effectiveness—are the tools whereby the analyst can develop information for the decision maker to assist him in finding a desirable balance or an acceptable trade-off between these two broad groups of consequences and objectives.

Basic Concept of Effectiveness Analysis

In practice, the basic process of effectiveness analysis consists of comparing for a series of alternative schemes the individual costs of gaining an objective to the degree or extent that each alternative approaches the objective or goal. Effectiveness is that quality of net satisfaction or net acceptability measured in terms of what is desired as 100 percent fulfillment of the goal. Figure 4 shows this concept. It shows the level of effectiveness associated with increasing input cost levels. It also depicts the "region of diminishing returns" past which increments of cost no longer produce an equal or greater increase in the level of effectiveness. As an example, in Figure 4 the measure of effectiveness may be decreased noise level or decreased number of persons dislocated. Modifying highway location and geometric design to reduce unfavorable consequences probably would increase transportation cost, but these two unfavorable social factors would be reduced in their unfavorable consequences (i.e., the noise level would be lower and the number of people dislocated would be fewer).

From the nature of effectiveness analysis the analyst must expect to encounter disappointments. The disappointment of greatest magnitude is usually lack of input data of the quantity and quality necessary to an analysis. To carry out an effectiveness analysis it is necessary to use estimates, to seek expert opinions, and to use trial values of certain factors over a range from minimum to maximum. Although these substitutes for facts (or at least reliable engineering estimates) may cast some uncertainty over the results of analysis, such outcome is really not serious. The decision maker will still have in the analysis an aid to his decision that is much better than having nothing at all. The decision maker will make proper use of the effectiveness analysis if he will keep in mind how the analyst arrived at his results.

MEASUREMENT OF EFFECTIVENESS IN TERMS OF GOALS

In terms of the goal to be reached by proposed specific highway improvements it may be advantageous to list both positive and negative goals. The road-user goal may be positively stated as: (1) a reduction of the total cost of motor vehicle transportation to the lowest possible total necessary to achieve a given level of service, including speed, safety, comfort, directness, and operating economy. A second positive goal could be stated (2) to enhance the environment, trade, social exchange, and welfare of all people to the maximum possible while achieving the goal with respect to the economy of transportation. The negative goal that could be stated is (3) to achieve the ideal in transportation economy with the minimum of harm or adverse consequences to the nonuser and to the community at large. Therefore, the highway designer and ultimately the highway decision maker have the responsibility of achieving that specific highway design that will find the least objectionable compromise between minimizing the direct total cost of transportation (highway plus road user) for a given level of service, maximizing the favorable nonuser consequences, and minimizing the negative or undesirable social consequences. In the end result, therefore, it is seen that no single goal can be accomplished to maximize or minimize one particular factor without affecting the degree to which other goals are reached. The result is the necessity of finding the over-all compromise that approaches each of these three individual goals, at least to the minimum acceptable level. Perhaps a highway improvement has never been made in the motor vehicle age without affecting adversely to some degree a limited number of individuals or some of the community factors.

The consequences of highway improvement may consist of two sets of costs and two sets of benefits. Costs include (1) the highway cost of construction, maintenance, and operation, and (2) the social and economic cost falling on the community and nonuser. Benefits are (1) those directly received by the highway user, largely through reduction in the cost of motor vehicle operation, and (2) the nonuser benefits of a social and economic character that result from the highway improvement and its use.

CHARACTERISTICS OF THE NONMARKET FACTORS

The analysis for the economy of highway design to achieve the desired goals for highway transportation is applied to the various economic and economy factors that can be both quantified and priced. These factors embrace primarily the highway construction, maintenance, and operating costs and expenses on the one hand and the motor vehicle and highway user expenses on the other. By combining these two groups of costs and expenses the total transportation cost and cost reductions are obtained.

The nonmarket items subject to effectiveness analysis often cannot be priced either on the cost or benefit side, and sometimes cannot be quantified. They must be dealt with through isolation, qualitative description, and comparison. These are the factors in highway improvement and economic analysis that must be evaluated largely on a subjective basis and in terms of the over-all goals of the community and the public's preferences with respect to social and economic values.

Table 10 and in Chapters Eight and Nine are listings of the general social and economic factors of a nonuser

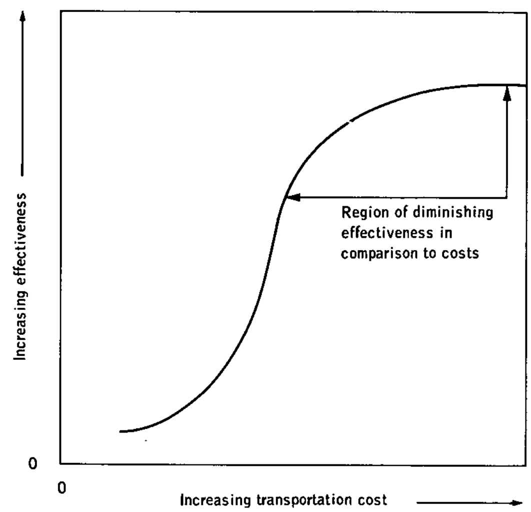

Figure 4. Level of effectiveness associated with increasing cost levels.

character. These are the consequences that are subject to analysis under effective analysis. They are the items that are most frequently mentioned by those persons who object to the location, design, or basic need for specific highway improvements or highway systems.

The social and economic consequences of a specific highway facility vary in magnitude, intensity, scope, importance, acceptance, rejection, and in other values with each specific location and conditions. They are not described here because the Table 10 listing is generally self-descriptive.

APPLICATIONS OF EFFECTIVENESS ANALYSIS TO HIGHWAY TRANSPORTATION

Effectiveness analysis finds its primary application in highway transportation to those proposals, most often in urban areas, that create significant consequences of a nonuser nature. These consequences may be grouped into social and welfare economic classes and are brought about because the highway location and its use disrupt social customs, practices, and conventions, and often alter the economic patterns of individuals and groups. In these situations, effectiveness analysis may be applied to transportation system planning as well as to individual project design. Perhaps its most important application is in individual project design because it is in this situation that the adverse consequences of highway improvements come into sharp focus. These types of projects in urban areas create intense and widespread community discussion and opposition. The decision maker thus finds it highly desirable to have available adequate analyses of the economic and social consequences of the proposed project as related to the specific features of highway design.

Highway Design and Effectiveness Factors

Briefly, some of the highway design factors that affect the social and economic character of a community may be classified into two groups: (1) the specific center-line location of the highway, and (2) the engineering features of design, including the choice and form of construction materials.

Under route location, the main elements that contribute to favorable and unfavorable social and economic consequences relate to the existing and future land uses and to the tendency to separate community areas one from another. It is readily seen that a proposed new highway in an urban area is bound to require hundreds of acres of land already fully developed in a variety of uses. Regardless of the type of land use affected, the proposed highway location will attract its own group of objectors. These objectors generally consist of the individuals directly affected. But also presenting themselves will be those concerned about the social aspects in a broad concept, the city beautiful planners, the historical preservationists, and the land developers. Also, there are attracted to the discussion circle a few individuals supposedly representing the city and its over-all goals who purport to know a great deal about transportation, its location, feasibility, and service to a given community.

Other than the location of the highway, the features of engineering design within urban areas often meet with objections that relate primarily to the geometrics of the highway structure and the aesthetic values of the type of construction material to be used. Whether an urban freeway is to be elevated, located at the level of surrounding streets, or depressed are aesthetic factors; these are also factors that may tend to physically divide the city. For bridges and elevated structures of all types the architectural designs with respect to texture, shape, and proportions are aesthetic factors of real importance.

When the foregoing social and economic factors are considered in terms of the limitations of engineering design of an efficient transportation plant, it is readily seen that a large number of alternative highway designs are possible. The selection of an acceptable design or a preferable design from among these alternatives must be a process involving a high degree of subjective decisions as well as objective decisions in an effort to provide the community with that plan with the most advantages and with the least disadvantages.

Decision Making and Effectiveness

Should it be possible to quantify and to price on the market the large number of social and economic factors involved along with the priceable highway and motor vehicle user factors, the total decision process would be relatively simple and lead to an answer that probably would be readily accepted. In the real world, however, not all social and economic factors are priceable on the market. Therefore, the decisions have to be partially subjective. No decision maker can prove the correctness or preferableness of his decision in a way to satisfy all of the outspoken preferences coming from the public.

Another way of looking at the application of effectiveness analysis to highway design is to consider that it is applicable in all of those cases of highway improvement that involve public goals that are not specifically transportation goals.

The complexity that could be involved in effectiveness analysis is indicated somewhat by the tabulation of social and general economic factors in Chapters Seven, Eight, and Nine. The specific factors involved, their importance, magnitude, intensity, and character will vary from location to location and will be influenced by the specific character of the highway facility being considered.

PROCEDURE FOR APPLYING EFFECTIVENESS ANALYSIS

The usual goal of a proposed highway improvement is to improve the quality of highway transportation service and to lower the total cost of highway transportation over the particular facility involved. In achieving this goal, attention should be given to minimizing the nonuser adverse consequences, but each of these goals cannot be simultaneously accomplished, so compromise alternatives must be considered.

Four-Step Procedure

A suggested procedure for accomplishing the effectiveness study and analysis could be as follows:

1. Design the highway facility as a transportation facility with the goal being to find that particular highway design that minimizes the total cost of transportation (i.e., the total highway cost plus the total road-user cost is at a minimum, consistent with providing the quality of transportation deemed desirable). This step involves more or less ignoring the nonuser social and community consequences. This step is to provide a base from which to depart on a study of other design alternatives for the purpose of reducing the adverse nonuser consequences and increasing the favorable nonuser consequences, usually at an increase in transportation cost.

2. Identify, isolate, and quantify (when possible) the nonuser consequences, both favorable and unfavorable, as related to the most favorable highway design reached in Step 1. Step 2 provides a comparable base of the nonuser consequences that parallels the base for the road-user design in Step 1.

3. Alter the highway design or location or both by a series of design alternatives so chosen that (1) the favorable nonuser consequences are further improved, (2) the unfavorable nonuser consequences are lessened, or that (3) both (1) and (2) would be accomplished.

When it is not possible to find an alternative highway design that would both increase the favorable consequences and reduce the unfavorable consequences, perhaps the preferred choice is to reduce the unfavorable consequences and let the favorable consequences increase or reduce as they may. This step is for the specific purpose of testing how much total transportation cost will have to be increased to achieve a desirable reduction in the unfavorable social and economic consequences.

4. Analyze, describe, and compare the results expected from each alternative design developed in Step 3 on a cost-effectiveness basis by comparing the increases in highway cost and increases in road-user cost to the changes resulting in the nonuser consequences. This analysis will relate increments of increase in total highway transportation cost to the nonuser incremental decreases and increases in the

favorable consequences and direct reduction of the unfavorable consequences.

It is realized that in this final comparison in Step 4 the nonuser consequences will not be dollar priced, but in some cases certain factors can be quantified. But in any case, the changes can be identified and discussed on a qualitative basis. This discussion should bring into focus the increase in total transportation cost and the softening of the social and economic handicaps as compared to the basic ideal highway design set forth in Step 1.

The three curves in Figure 5 illustrate the foregoing procedure and how the different alternatives analyzed relate to each other as well as to the social and economic consequences.

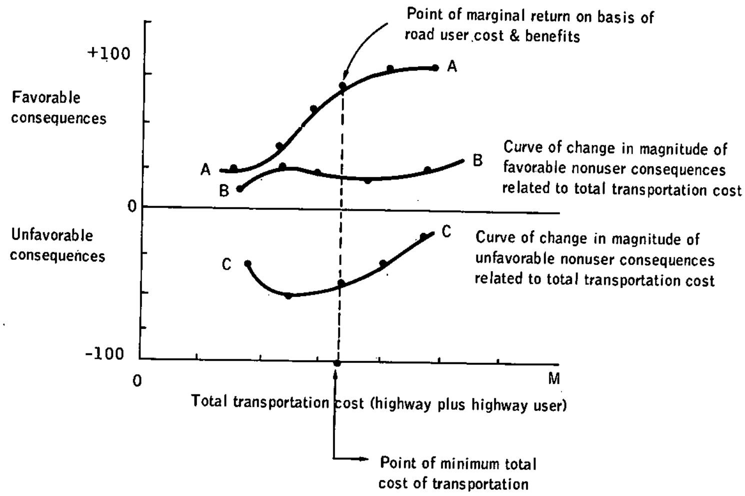

Figure 5. Curves to illustrate how the user and nonuser consequences from a specific highway improvement project may vary depending on the route location and other design features.

Basis for the Four-Step Procedure

The process of effectiveness analysis is basically preparing the supporting material the decision maker may use in deciding on the extent of trade-off of favorable and unfavorable consequences between those falling on the highway user and those falling on the nonhighway user. Bearing in mind that the foregoing procedure suggests starting with designing the highway improvement facility to minimize the combined highway cost and highway user cost, the compromise is largely one of increasing the direct transportation cost in favor of either increasing the nonuser beneficial consequences or decreasing the nonuser detrimental consequences. This process endeavors to find that balance between the road-user consequences and the nonuser consequences that best represents the viewpoint of the larger public in such a way that the benefits will accrue to the maximum number of people and the detriment to the minimum number of people. Of course, the number of people is not the sole criterion involved, because the magnitude and quality of the consequences and who they fall on is a substantial factor.

It is emphasized that it is not the responsibility of the highway designer or of the economic or social analyst to come to any decisions as to the preferred alternatives considered in Step 3. But it is their responsibility to bring into focus the community consequences and to identify all people involved. To do this, the designer and the analyst need to analyze all practical (feasible) alternatives. The decision maker then has before him a good economic and social basis of reaching his decision. It is the decision maker's responsibility to give weight to the prime objectives of the highway improvement in terms of the transportation goals and, at the same time, give just the right weight to the favorable and unfavorable nonhighway user consequences that are affected by the decisions relative to achieving the transportation goals.

CONSTRAINTS AFFECTING DESIGN ALTERNATIVES

Under the conditions of unlimited financial resources, unlimited technology, and unlimited vision it might be possible to produce a highway design that would eliminate all of the unfavorable consequences and maximize all of the favorable consequences while producing the most efficient transportation plant. But such situation is not to be found in the real world, so the highway designer and the economic analyst must study a series of alternatives, none of which may produce ideal design.

Some of the constraints under which highway design and effectiveness analysis must be considered are as follows:

1. General nontechnical factors:
   a. Capital budget limitations.
   b. Available material resources.
   c. Calendar time available for the total process from conception to the opening of the facility to traffic.
   d. The interference with and interface with other community public works projects and other features of community plans.
2. Engineering design features:
   a. Practical limit of vehicular capacity that can be designed into one highway.
   b. Minimum traffic lane width.
   c. Minimum ramp curvature.
   d. Maximum degree of curvature.
   e. Maximum vertical grade.
   f. Minimum clearances—horizontal and vertical.
   g. Vertical and horizontal sight distance.
   h. Foundation material available.

In the design process and in the analysis of the designs with respect to their cost-effectiveness, often no ideal solution is available to overcome or to materially reduce a negative consequence. Perhaps it is for this reason that in many urban areas highly desirable highway improvements have been considered 5, 10, and more years before the community was willing to accept any decision. In the end, a decision was accepted on a compromise basis and perhaps was short of satisfying all sectors of the community.

CRITERIA FOR MEASURING EFFECTIVENESS

In the economic analysis of a proposed highway improvement, both priceable factors (highway and motor vehicle) and nonpriceable factors (nonhighway user) normally will be considered. The criteria for judging the merits of the series of alternative highway designs cannot always be stated quantitatively or according to some chosen index system. (See Chapter Ten.) Further, the worthwhileness of a specific consequence may be positive on one project and negative on another. This reversal in sign may be the result of local community goals and values, or the result of the local physical situation. For example, one community may be willing to accept a certain location for an urban freeway, despite the fact that 387 families must move, because such location ties in exceptionally well with urban renewal plans, and new housing for the 387 families presents no problems. In contrast, another community may object strongly to a freeway location that moves only 152 families.

Specific Criteria That May be an Index to Effectiveness

When a proposed highway improvement is subject to cost-effective analysis, criteria of the following character may be developed by the analyst and arranged by alternative designs for the decision maker to study.

Criteria That May Measure Cost-Effectiveness

1. Highway design factors:
   a. Highway costs per vehicle-mile.
   b. Highway costs per vehicle served.
   c. Motor vehicle running cost per vehicle-mile.
   d. Cost of accidents per vehicle-mile.
   e. Travel time through facility.
   f. Average traffic speed.
   g. Traffic delays—number and lapsed time.
   h. Distance of travel.
   i. Service level.
2. Transportation factors:
   a. ADT served.
   b. Peak-hour ADT.
   c. Demand.
   d. Number of people served.
   e. Tons of cargo served.
   f. Frontage roads and access points to land uses.
3. Personal preferences:
   a. Comfort—stopping, weather, waiting, standing, crowdedness, turns, distances.
   b. Convenience—steering, gear shifting, walking, directions of routing.
4. Social factors:
   a. Traffic noise level disturbance.
   b. Air pollution.
   c. Protection against crime.
   d. Number of families displaced.
   e. Number of businesses displaced.
   f. Number of jobs eliminated or relocated.
   g. Relative restriction of or building of social activity.
   h. Consequences to educational programs.
   i. Neighborhood disruption.
5. Community factors:
   a. Total acres of land taken for right-of-way.
   b. Acres of park and recreational land taken.
   c. Acres of cemeteries or number of graves removed.
   d. Acres of business and industrial land taken.
   e. Number of historical landmarks removed.
   f. Number of churches moved.
   g. Number of schools moved.
   h. Number of public buildings taken.
   i. Number of parking spaces removed or created.
   j. Services to adjacent land and its uses.
   k. Services to protective services—police, fire, health.
   l. Flexibility of route choices and emergency routings.
   m. Degree that community goals are served.
6. Aesthetics:
   a. View obstructions or view creations.
   b. Beauty of structures.
   c. Overhead, grade level, or depressed elevation.
7. Nonuser direct benefit factors:
   a. Service to urban renewal.
   b. Resultant improvement of private property.
   c. Creation of open space.
   d. Improvement of drainage and of waterfronts.
   e. Joint use of rights-of-way—parking, recreation, parks, commercial outlets.
   f. Attraction of new business and industry.

Identifying Degree of Effectiveness

The foregoing factors are suggestive of the factors that an analyst may list for each highway design alternative, together with some description of the severity, extent, quality, importance, and magnitude involved. As stated in Chapter Ten, this report does not recommend the development of subjective dollar prices for use in models design to indicate the preferred alternative. However, often it will be possible to quantify the factors (such as the number of families moved, acres of land taken) to give a relative index of severity of the factor. Also, just a plus and minus sign or a yes and no score will be helpful in indicating relative values. In any case, in the cost-effectiveness analysis, a summarization of the nonuser factors involved in each highway design alternative will afford degrees of effectiveness for each alternative.

Chapter Ten gives some schemes that may be used in evaluating the nonuser consequences and in determining the relative influence of the highway design alternatives on the nonuser consequences. Chapter Eleven also contains some suggestions.

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CHAPTER FOUR

HIGHWAY PLANNING, PROGRAMMING, AND BUDGETING SYSTEM (PPBS) AS A DECISION-MAKING TOOL

The ever-increasing complexity and size of businesses, industries, institutions of all types, and governments (and their individual operating agencies) has led their respective managements to seek improved methods of decision making and of control of operations. One of the newcomers in governments is the planning, programming, budgeting system (PPBS). This system—a form of systems analysis—provides for an over-all preparation of the budget on a functional and goal basis, including a support of the budget program items by specific cost-benefit or cost-effectiveness analyses. This chapter discusses the PPBS as a tool for highway departments. The system is closely related to evaluation of the economic and social consequences of highway improvements.

FRAMEWORK FOR DECISION MAKING

In the highway field, "management" consists of highway department officials, commissioners, administrators, and engineers. They are charged with the task of procuring the most efficient and effective additions to the highway plant within a given budget allocated by the legislature or fixed by prior law, and as controlled by public policies.

Public policy determines generally the character and scale of the highway program through laws and appropriations passed by the legislature representing society. Such policies reflect certain socio-economic consequences that society desires and expects to occur as a result of highway investment. As improvements to the highway are made under these policies and the true socio-economic consequences become apparent, there is continuous feedback from society concerning satisfaction or dissatisfaction with the consequences. On this basis, policy makers continually revise policies for the guidance of those carrying them out. They set budgets according to the scale of society's desire for highways relative to its other public needs and resources. They define the general form of the product that society appears to demand in return for its investment.

Specific management decisions on which roads to improve, how, where, and at what cost are, or should be, made on the basis of these policies and factual information resulting from analyses of benefits and costs and socio-economic consequences. Unlike the private entrepreneur, whose primary objective is maximizing profits, the public administrator is obliged to consider the *total* effects of expenditures on the society of which he is a representative and to count *all* benefits and costs "to whomsoever they may accrue."

These requirements to consider more factors than confront the entrepreneur, including a host of factors not convertible to dollar terms, in the context of programs of large dimensions in their costs and potential impacts, has led to the development of special techniques to aid governmental decision makers.

The latest and most promising version of such analytical techniques, designed to account for the enlarged scope and increasing complexity of government programs, is the planning, programming, budgeting system (PPBS). This system is here considered as a framework for decision making by governmental highway agencies. PPBS is a working tool devised to assist management in making the best practical allocation of resources to its programs, with special application to government agencies. At top level (Congress, a legislature, or an agency head) the problem is to arrive at the kind, level, and mix of programs that will best provide for the objectives and interests of the people being served.

A PPB system, although it can be tailored to the requirements of one department or agency, is primarily intended for implementation throughout a government as a whole. It functions under the legislative organization and under the chief executive. Reacting to the demands of the electorate and lawmaking body, the executive sets objectives and guidelines for his administration. The agencies responsible for the production of goods and services to meet the public's demands convert the executive guidelines to more specific operational objectives. From these, their analytical and planning staffs develop the options available to meet the demands. The options are transmitted to the executive for decision. Those he approves are developed by the agencies into plans and programs, budgeted, and executed.

In the discussion to follow, it is assumed that a PPB system is in effect across the board. The text describes the operation of a highway agency's planning and budgeting activity within that context, gearing its operation to the consideration of the ultimate governmental and social functions it fulfills and the alternatives and opportunities for coordination with other agencies.

Systems analysis combines information on the transportation system and the environment in which it operates and with which it interacts. This synthesis demonstrates the extent to which the socio-economic benefits sought by society and its policies may occur, at what expenditure of economic resources, and at what social cost.

Inputs to the over-all systems analysis include two related but independent subanalyses: (1) the engineering economy analysis of the highway facility to determine its feasibility and efficiency as part of a plant producing transportation services (see Chapters Three and Six), and (2) effective analysis which defines the external social and economic effects or "nonuser" impacts of highway investment (see Chapters Three, Eight, and Nine). Both analyses should be considered by the decision maker to determine whether the total effects are in harmony with society's policies and represent desired consequences and goal fulfillment.

In both engineering economy analysis and socio-economic analysis, potential costs and benefits must be considered and weighed. This consideration requires (1) identification of all consequences, (2) their evaluation and/or quantification to the extent practicable, and (3) a means for analyzing whether the desired effectiveness is achieved.

It should be emphasized that PPBS and its supporting analyses provide a framework, a set of integrated tools, to *aid* the decision maker in reaching a decision. These analyses do not have the ability and cannot be given the responsibility of arriving at a decision in and of themselves. The decision remains the task of the legally responsible public officials or body.

PLANNING, PROGRAMMING, AND BUDGETING SYSTEM

In the federal government, the PPBS was developed in the Department of Defense where the complexity is maximum, the budget the largest, and the uncertainties are many. The following brief background of PPBS provides for a better understanding of the section to follow on the PPBS process.

Background of PPBS

The postwar growth in the number, magnitude, and complexity of government programs at all levels crystalized a long-felt need for more rational public decisions and better allocation and use of scarce public resources along with improved tools for accomplishing both.

With one of the largest budgets to support a host of competing missions, the Department of Defense was the logical agency to first experiment with and apply more rigorous techniques for measuring the effectiveness of different alternatives applicable to the many missions. The result was the "Planning Programming Budgeting System (PPBS)" instituted by the Department in 1961. In 1965 the President of the United States, acting through the Bureau of the Budget, prescribed the use of PPBS by the principal agencies of the federal government. Since then, its application to the decision-making arena of state, county, and city governments has been explored, most notably by the State-Local Finances Project of the George Washington University (*4-1*).

Goals and Concepts of PPBS

The goal of PPBS is the making of more rational decisions on the allocation of resources among alternative means to governmental ends, with the ultimate goal of improving society at large. Relevant information on objectives, available resources, and the full implications—benefits and costs —of alternative courses of action is developed and made available to the decision maker by PPBS.

These aims (rationality, efficiency, effectiveness) and the techniques used to reach them (program and performance budgeting, marginal utility analysis, cost-effectiveness analysis, cost-benefit analysis) are not new. The contribution of PPBS is the systemization of the analytical process to include these aims and techniques, unifying and clarifying them and integrating the factors with the budget and appropriation processes.

By employing these concepts and their associated techniques, a working relationship is set up between the decision maker and the analyst. This requires the decision maker to:

1. Articulate his goals.
2. Become aware of total costs in terms of dollars, resources, and negative effects on community goals other than those under specific study.
3. Make the decision; an act not necessarily made easier by PPBS, but reached from a better informed position.

The responsibility of the analyst includes:

1. Providing a broad range of factual information and informed estimates.
2. Identifying and describing the consequences likely to result from the possible decisions.

The key contribution of PPBS is in the process of planning, making policy decisions that lead to specific budgets, and multi-year plans for programs. A program, in these terms, is an integrated set of activities that leads to the achievement of a specific goal or purpose. The yearly budget is a short-term plan for the use of resources in implementing program decisions.

GOVERNMENT-WIDE PROGRAMS AND OBJECTIVES

Although a PPB system can be instituted in one department or agency and relate to its own specialized objectives, ideally the system should be government-wide and applied to all functions and objectives. In that the programs of several agencies probably will interrelate in pursuit of a common objective, their activities can be better put in perspective and evaluated according to their respective contributions to some end. Program budgets are thus formulated on the basis of government-wide functions and objectives rather than on a fragmented agency or object of expenditure basis. The full and true cost of programs to fulfill specific objectives will then emerge, along with evidence of overlap, redundancies, detriments, complementarities, and substitutions that will aid in coordinating and economizing expenditures and efforts.

Once the total government-wide objectives are established, they can be categorized into elements of a program structure. An example of possible broad categories of such a program structure is:

1. Public safety.
2. Public health.
3. Public education.
4. Economic development and welfare.
5. Housing, planning, and community facilities.
6. Parks and recreation.
7. Transportation.
8. Communication.
9. Administration (executive, legislature, court system).

Statements of objectives related to each element of the program should be:

1. As specific as possible.
2. In terms that allow quantitative measurement to the extent possible (although not omitting those that can be described only qualitatively).
3. Assigned to one category but have their mutual interdependence recognized (programs related to more than one category may be included in other categories on a "non-add" basis to avoid double counting of costs).

Within each category subcategorizations of objectives and elements can occur. Under "Transportation" the breakdown in Figure 6 might apply.

The functional program structure improves the decision maker's perspective by demonstrating how activities can substitute for and complement one another in furthering government objectives, encouraging comparative evaluation of approaches, and suggesting the need for new ones.

For instance, under "Transportation" the decision maker, in attempting to fulfill a transportation-related objective, has revealed to him a variety of options for use singly or in combination:

1. Choice of modes.—A variety of substitutes and complements among modes is possible, matching mode to the function, objective, or purpose it is to serve. Performance and capacity requirements can be tested against the comparative capabilities of the various modes, their complete system requirements and costs, initial and future year, and

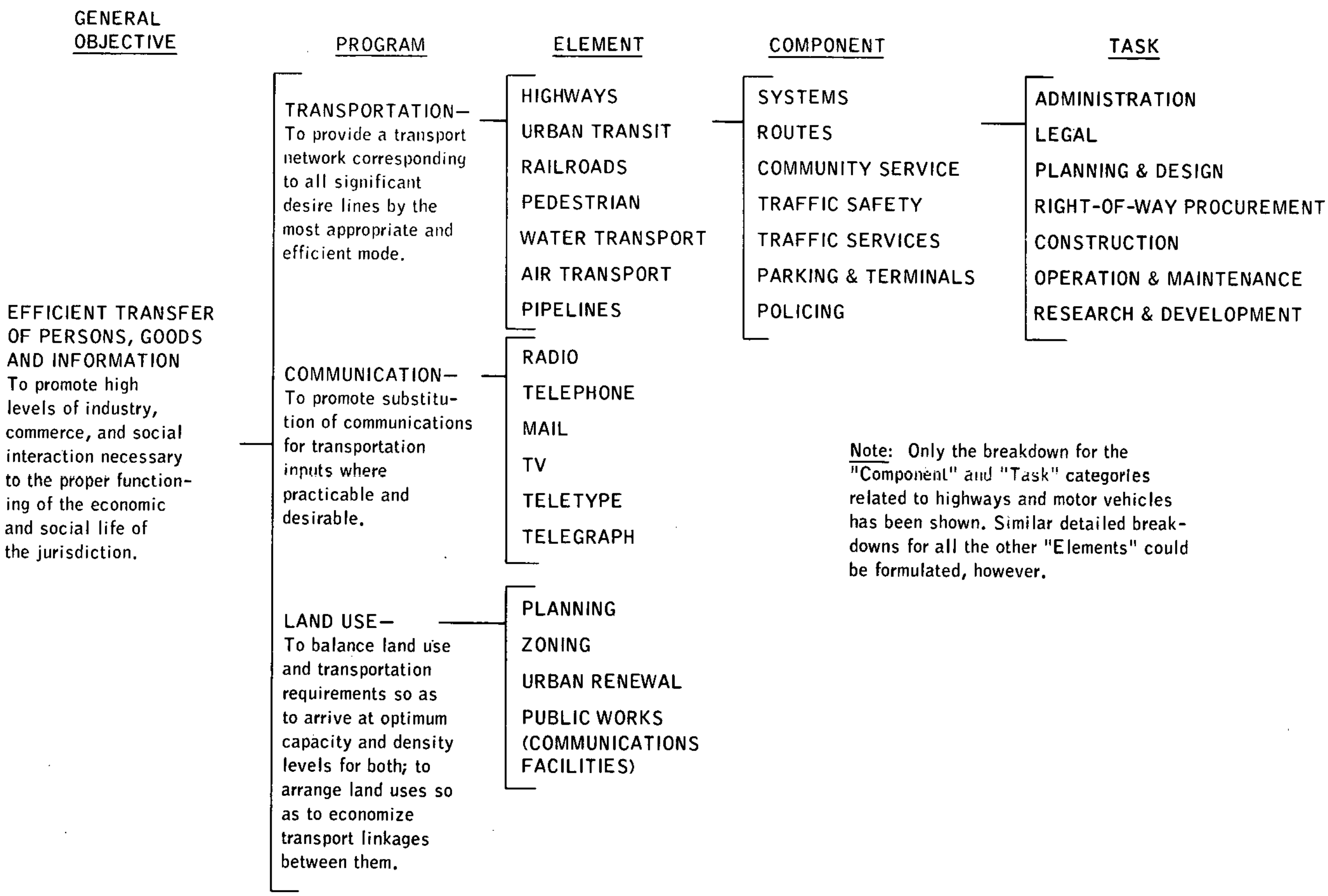

Figure 6. Transportation programs in a PPBS context.

their capacity for expansion, to arrive at an optimum choice.

2. Choice of activity location.—Because it is the separation of activities in space that gives rise to the demand for transportation, a rationalization of spatial relationships affecting the relative location of homes, jobs, businesses, and social and recreational opportunities, through land-use planning and regulation, can eliminate or lessen the requirement for transportation and economize its costs.

The decision maker, acting within an objective-oriented framework such as that shown in Figure 6, is thus encouraged to integrate a variety of programs and examine a number of alternatives in arriving at the means of fulfilling objectives effectively and efficiently.

APPLYING THE PLANNING, PROGRAMMING, BUDGETING SYSTEM

Although this report does not present the PPB system in detail it gives some description of how the system is operated. Some of the following description is patterned after the PRC study (*4-3*), a publication directly relating PPBS to transportation.

Procedure of Applying PPBS

The following (*4-3*, Vol. II, pp. 2-94) indicate the main steps to be considered in applying PPBS to a specific function of government—transportation in this case.

1. Program formulation:
   a. Identify current transportation *objectives.*[1]
   b. Develop quantifying schemes by which to measure the objectives.
   c. Define and quantify the needs associated with each objective.
   d. Identify current *goals*[2] in quantitative terms and time requirements.
   e. Develop the program structure, oriented toward the objectives.
2. Program analysis:
   f. Determine the total program dollar cost.
   g. Determine the net benefits (and consequences) of each element of the total program and its alternatives.
   h. Make cost-effectiveness analyses of alternative programs and alternatives within programs.
   i. Make cost-goal sensitivity analyses aimed at establishing levels of operation for each program.
   j. Make cost-restraint analysis.
   k. Develop total cost—total benefit matrix.
   l. Determine the share of each program's total cost to be covered by the specific agency concerned.
3. Presentation of total program:
   m. Write program memoranda:
      (1) Write multi-year program output (achievements) plan.
      (2) Write program costs.
      (3) Write program and multi-year financial plan.
   n. Translate total program and financial plan into a fiscal budget request.

[1] An objective is a broad agency direction or general purpose, intent, and end to which the agency directs its efforts.

[2] A goal is a specific output with time and space dimensions, the accomplishment of which constitutes advancement toward a specific objective.

Explanations of Step by Step Procedure

1. *Identify current transportation objectives.*

The first step in applying a PPB system is identification and categorization of the objectives desired by the people and expressed through their government. Objectives will necessarily relate to the objectives of society, of the community, and of the individuals. Government has the dual responsibility of attending to individual citizen wants and needs as well as to the collective wants and needs of the larger community. Where the two differ and conflict, the need arises for resolution via the political or judicial processes. Nevertheless, a first-round identification of goals is vital, with their priorities and relative weights left to be hammered out in public debate.

The objectives formulated for transportation should demonstrate their relationship to the fundamental purposes of transportation as an instrumentality for realizing other objectives and supporting other activities. For example, transportation interrelates with objectives for employment, economic development, and recreation, and interacts with comprehensive planning and land-use control. Objectives that state measures of service, scale, or efficiency are to be avoided in favor of ones that describe desirable future conditions of the individual and of the community.

The following list of national transportation objectives, from the PRC study (*4-3*), are offered as illustration of national objectives:

1. Primary:
   a. To provide for economical movement of people and commodities.
   b. To assure safe movement of people and commodities.
   c. To encourage the swift movement of people and commodities.
   d. To achieve price equity on the transport of people and commodities.
2. Secondary:
   a. To build excess capacity into the public transportation system in order to move people and commodities in time of national defense emengencies.
   b. To maintain men and equipment to augment national security forces.
   c. To enhance our position of prestige in the world.
   d. To preserve the health of the people of the nation.
   e. To preserve aesthetic elements in the nation.
   f. To develop or furnish access to recreational facilities.
   g. To safeguard sound patterns of urban development.
3. Tertiary:
   a. To promote the economic development of a designated area.
   b. To increase our knowledge of the ocean and atmosphere.
   c. To develop and preserve United States fisheries.
   d. To promote fair wages and equitable working conditions for transportation employees.

e. To conserve the nation's natural resources.
f. To prevent illegal entry of persons and goods into the United States.
g. To furnish emergency postal services.
h. To improve the United States balance of payments deficit.
i. All other.

2. *Develop quantifying schemes by which to measure the objectives.*

Specific objectives require specific measures or quantitative criteria by which to judge progress toward their accomplishment. The measuring device is easier to establish for simply stated objectives than for complex stated objectives. The measuring unit may be custom-devised for each objective, although a universal measuring unit for all objectives would be helpful. Units that could be used are of the order of fatalities, traffic accidents, traffic speed, ratios of traffic capacity to vehicle registrations or vehicle-miles, user costs, travel time, accountable standards of design, or some level of traffic service quality.

3. *Define and quantify the needs associated with each objective.*

The transportation objectives take on realistic significance when they are expressed in terms of identified and quantified needs. The specific needs express the objective in terms of its character, size, and difficulties related to its accomplishment. The system requirements, its deficiencies, its projected growth, and demands placed on it are items related to needs.

4. *Identify current goals in quantitative terms and time requirements.*

Based on the description and quantification of transportation needs associated with each objective, the planned achievements (goals of effectiveness accomplishments) for each year can be stated. Goals may be set for each objective in the aggregate and within subphases or functions, and geographically. The goals should be expressed in quantifiable terms in order to provide for measuring progress toward their achievement.

5. *Develop the program structure, oriented toward the objectives.*

The total program should be expressed in terms of those factors that will relate it to the transportation objectives and specific elements that will permit decision makers to view the program by its parts or phases. A suggested structure is: (1) transportation objective, (2) type of program (promotional or regulatory), (3) transportation mode, (4) function, and (5) program element. A structure of this general type will permit decision makers to compare objectives in terms of cost and trade-off in levels of support. Further, the transportation heads will see in one phase the whole of the program elements and their resources allocated to each objective.

6. *Determine the total program dollar cost.*

The program analysis consists of three basic phases: (1) aggregation of program costs by alternatives, (2) aggregation of program consequences by alternatives, and (3) comparisons and analyses of costs and consequences as related to program items and alternatives. The financial costs at issue are those of both the private and public sectors. Further, within government all costs are wanted regardless of level of government or agency within a level. A systems approach is in order.

7. *Determine the net benefits (and consequences) of each element of the total program and its alternatives.*

Paralleling the assembly of the monetary costs of each program element is the assembly of the net benefit associated with the costs. Benefits need to be quantified and priced where possible (road-user consequences) and quantified when possible, even though not priced (nonuser consequences). In some instances the consequences can be described only qualitatively. Measures of the effectiveness of the alternatives in accomplishing the goals or objectives should be established.

8. *Make cost-effectiveness analyses of alternative programs and alternatives within programs.*

The cost inputs are compared to the consequential outputs by program alternatives. The procedures follow those established for the several types of economic analyses, including cost-effectiveness and cost-benefit analyses. The specific objective here is to gain information bearing on which program alternatives and which alternatives within a program item are preferred as measured by their relative costs and effectiveness in reaching goals or objectives. These analyses will provide a basis of selection of program items and alternatives as those offering the most favorable opportunities for achievements.

9. *Make cost-goal sensitivity analyses aimed at establishing levels of operation for each program.*

Economic analysis embodies judgments as to input factors and forecast of critical factors within the calculations. On a program basis, the time element is important. A program may be scheduled for completion in 2 years, 5 years, or 10 years. An analysis is in order to determine the optimum period over which to plan the operations. The rate that positive benefits (payoffs) can be realized with respect to input costs is a critical factor in this sensitivity analysis.

10. *Make cost-restraint analyses.*

Related to the levels of program operation are the restraints that may be imposed on technical operations of a given agency. There are legal restraints; administrative, regulatory, and procedural restraints; labor, trade and employee restraints; and community blocks involving attitudes, approvals, and agreements. The analyst needs to consider these constraints with respect to their effects on the cost of the program, the timing of operations, the designs and technical aspects involved, and progress that can be achieved once the program is under way.

11. *Develop total cost—total benefit matrix.*

Throughout the program analysis effort is directed toward (1) identifying the best alternatives in the program mix, and (2) the best alternatives of achieving a given goal or objective and its level operation. The results of these many analyses need to be brought together in a summary form whereby the whole program by elements can be related by cost and benefit factors. Included should be all costs and benefits, private and public from far and near. The decision makers need to see the whole program from all sides.

12. *Determine the share of each program's total cost to be covered by the specific agency concerned.*

Because the total program is prepared and analyzed on the basis of "all alternatives" and all "consequences to whomsoever they may accrue" it becomes necessary to separate from the total input costs those financial supports that are proposed for the specific agency concerned, as well as for other agencies that will have to support the program to make it operative.

13. *Write program memoranda.*

The program formulation and its analysis require a large total man-hour effort, many decisions, and explorations. When finalities are reached, it is in order to prepare written memoranda on the operation to provide (1) a record of accomplishment, together with supporting data, analyses, concepts, and decisions, and (2) the results and recommendations for use by higher authority.

Systematic identification and analysis of alternative means to reach government objectives is the cornerstone of PPBS. The analytical process involved results in the key output of a planning, programming, budgeting system. These results may be presented in "program memoranda"—clear, concisely written analysis documents that summarize and describe the cost and benefits of various alternative ways to carry out government programs and fulfill objectives.

The analysis process proceeds in two steps: (1) preliminary analysis, and (2) "in-depth" analysis.

Preliminary Analysis.—The preliminary analysis phase involves the moderately rigorous identification and documentation of the following:

1. The real objectives.
2. The major feasible alternatives.
3. Best estimates of total program costs implied by each alternative for every year considered.
4. Best estimates of benefits expected to result from each alternative for the same set of years (estimates may be more qualitative than quantitative at this point.)
5. The major assumptions and uncertainties related to each alternative.
6. The impact of the proposed programs on other programs, agencies, levels of government, and on private organizations.

In-Depth Analysis.—The follow-up in-depth analysis to the preliminary analysis involves:

1. The making of cost-effectiveness, cost-utility, cost-benefit or systems analysis studies using the analytical tools of professional disciplines.
2. Refinement of the six information categories of the preliminary analysis with more precision and detail; quantifying costs and benefits to the extent possible for all alternatives considered feasible based on the preliminary analysis.
3. Preparation of a program memoranda containing the results of the analysis for submittal to decision makers.

13a. *Write multi-year program output (achievements) plan.*

The output plan indicates the expected product resulting from the expenditures contained in the financial plan. "Output" includes the major services and goods to be produced. The output should be shown in quantitative terms to indicate the magnitude of each program, or in qualitative terms where the magnitude cannot be adequately expressed numerically. For example, the output of highway expenditure might be expressed in number of new miles added, number of old miles repaired or maintained; also by average travel times between various locations at various times of day; accident rates and costs; and finally by the impact on over-all objectives such as economic development, transport rates, and commodity prices.

In formulating the output plan, the pitfall of placing exaggerated emphasis on those outputs for which numerical measures are available should be avoided. Doing so may lead to preference for low pay-off programs whose values are known with certainty over innovative programs whose pay-offs may be potentially great but which involve greater risk and uncertainty concerning the magnitude of future output.

13b. *Write program costs.*

The cost estimates for each program should include all proposed disbursements pertinent to it, regardless of fund, organization, unit, or source of funds. The estimates should cover direct and indirect and current and future costs. As an example, highway program costs would include right-of-way acquisition, construction, landscaping, maintenance, lighting, marking, traffic control, police patrols, administration, and any public parking facilities. Parking and police might fall under different organizational units but must be considered as part of the system costs of carrying out a highway program. They are integral parts of an operational highway system and vary according to its growth and extent. Total program costs include both capital investments and operating expense.

Information on the nature and source of funds supporting each program is significant in arriving at decisions. Funds available often imply constraints on decisions. This especially is true in highway program financing where some activities are supported by motor fuel tax revenues and others are supported from the general fund or bond issues. The amount required from each source to keep the program in balance is an important consideration.

Back-up detail for each program should provide information on: (1) total program costs, (2) projections of road-user tax incomes, and (3) net program funding needed from other sources.

To accomplish these tasks, improvement of government cost analysis capabilities probably will be required. Cost factors and their relationships will have to be traced out so that all pertinent costs can be assigned to each program and estimates can be sharpened to allow rapid costing of alternatives within programs.

13c. *Write program and multi-year financial plan.*

The financial plan shows projected outlays for each element of the program structure corresponding to the decisions made and included in the output plan. It is usually stated in terms of dollars in that they are considered the scarce resource that is to be budgeted. However, supplies of land and skilled manpower may also at times be included as constraints, showing them in separate tables.

The output and financial plans, prepared in a format similar to Figure 7, comprise a detailed construction and maintenance program often made up for a five-year time period, including the budget year. In highway planning, considering the long lead times required for planning, engineering and construction, and the advantages of prior purchase of right-of-way, a longer budget and/or program period may be desirable.

The multi-year financial plan should be formulated so as to maintain a balance between expenditures for current investment and operations and the requirements for their support and operation in future years. Present decisions, especially those concerning investment, imply future-year fund commitments and benefits. For example, road building in the present results in future policing and maintenance costs, whereas safety hazard elimination done now reduces future-year accident costs. Current decisions should be made with a realization of their future-year outputs and expenditures, so as to achieve order, balance, and efficiency in ongoing programs. Estimates of time-phased expenditure requiriments and outputs, made on the basis of these considerations, should comprise the data entered in the financial plan. The estimates for future years need not be as precise as those for the current budget, considering the uncertainties involved.

When one is developing the coming year's budget, however, the estimates should be sharpened as much as possible. To avoid burdening the planning-programming process with a requirment for such detail and precision it is desirable to keep the preparation of the multi-year financial plan and the current budget document somewhat separate, but coordinated by both program and time factors.

The multi-year output plan displays the expected product resulting from the decision to expand the budget as set forth in the financial plan. Measurement of the output in numerical values may be difficult due to the qualitative and/or uncertain nature of some outputs. Words descriptions of the expected output would be appropriate. However evaluated, the measures derive from individual program analyses or "program memoranda." These must be examined to obtain the full and detailed perspective on what each specific program is expected to accomplish.

The multi-year financial plan shows the cost of planned

Level 1st	Level 2nd	Program Categories*	FY 1969 Actual	FY 1970 Current Estimate	FY 1971 Budget Year Estimate	FY 1972 Program Estimate	...	Total Costs 1971-75
VII		Transportation						
	A	Highways 1. Systems 2. Routes 3. Traffic Safety (also under Public Safety) 4. Traffic Services 5. Parking & Terminals 6. Community Services 7. Policing						
	B	Urban Transit						
	C	Railroads						
	D	Pedestrian						
	E	Water Transportation						
	F	Air Transportation						
	G	Pipelines						
	H	Communications as Transport Substitute						
	I	Unassignable Research, Planning, Support Activities						

* In practice, more category levels would be needed to display the individual government activities/programs.

Figure 7. Multi-year program and financial plan, FY 1971-1975.

programs over a span of years. By showing total time-phased costs, better perspective on the financial implications of decisions is gained.

The final financial and output plan documents should be reviewed to ensure that they: (1) emphasize the program's purpose and how it relates to government objectives, and (2) are oriented to ends rather than means. For example, highway costs per lane-mile may be good indicators of work-performance efficiency and help control and evaluate current operations but do not in themselves provide a true measure of *output*. They must be considered "means" rather than "ends" oriented. Work-load statistics likewise are questionable for inclusion in budgets but may appear in output plans where appropriate.

14. *Translate total program and financial plan into a fiscal budget request.*

At every government level there are prescribed forms, contents, and procedures related to budget or appropriations requests, whether for a city council, a county board, a state legislature, or the congress. The PPBS result must be arranged in the prescribed form and passed through designated individuals to the final decision makers. The last step in the PPBS is to translate the product of the whole effort into the prescribed form of document.

BENEFITS OF PPBS TO DECISION MAKING

Even with the many inherent limitations with PPBS, the exercise of making an analysis with available data, the asking of penetrating questions, the considering of alternatives, and the systematic presentation of information relevant to the problem can help sharpen the decision maker's judgment and improve the quality of decision making. Even if it is imperfectly carried out, as probably will be the case, it is able to ameliorate a number of the problems of present planning and budgeting processes:

1. Concentration on physical requirements for a function without developing and evaluating alternatives on a cost-benefit basis.
2. Special one-time studies without provision for continuing systematic review and analysis.
3. Insufficient range of alternatives considered.
4. Lack of objective basis for evaluating the cost-benefit relationship of proposals.
5. Lack of examination of the costs and benefits of varying the scale of the proposal or of other ways to fulfill the objectives.

The analyst must be aware of limitations in the form of constraints: political, legislative, and budgetary. These items form constraints only in the short run, within which the analyst must optimize resource allocations. In the long run, where the analyst can demonstrate the advantages to be gained from altering policies or funding levels or, conversely, show the penalties resulting from present constraints, it may be possible to overcome them. When one is deciding what funding levels are appropriate within the time horizon, consideration could be given jointly to the costs and benefits that apply at various levels. Using marginalism, it may be found that the marginal or added returns stemming from incremental cost additions are sufficiently attractive to justify a higher funding level.

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CHAPTER FIVE

HIGHWAY ENGINEERING ECONOMY

This chapter presents and discusses the general theory, principles, concepts, and applications of engineering economy (economic analysis) to highways. Although written for application to highway transportation, it is a generalized discussion of engineering economy analysis. Its purpose is to provide a background essential to making an economic analysis, using the results of an economic analysis, and understanding the remaining chapters. This chapter is based largely on the literature and discussions with persons within and without highway practice who have knowledge of engineering economy.[1]

As presented, highway engineering economy is not intended to include all cost and all net benefits of highway construction, but only those factors that are affected directly by highway engineering decisions and that can be dollar priced. Therefore, highway engineering economy analysis deals primarily with highway costs, motor vehicle running costs, and other cost or benefit factors pertaining to the road users.

DEFINITIONS AND EXPLANATIONS

Although engineering economy has been practiced in the United States and is found in the literature since 1840 or earlier, it is a subject often still not understood and often misapplied. This section sets forth definitions, concepts, and objectives so that a common understanding of engineering economy [2] may be reached.

General Terms

The literature on economic analysis as a general subject does not disclose specific meanings of such terms as:

1. Economic analysis.
2. Cost effectiveness.
3. Benefit-cost analysis.
4. Cost-benefit analysis.
5. Engineering economy analysis.
6. Value engineering.
7. Value analysis.

The intent, however, is to use these terms to infer some type of relation between cost input and the economic [2] consequences resulting from that cost input. In terms of the results obtained, the endeavor is to achieve the goals with the maximum of satisfaction obtainable for a given cost, or a given level of satisfaction at a minimum of cost. Perhaps "cost effectiveness" may be considered to infer the broad concept.

Cost-benefit infers a comparison of costs to benefits (goals or satisfactions) by some chosen method. Engineering economy is a cost-benefit type of analysis in which engineering is the predominant area of application. Engineering economy analyses follow highly developed procedures.

Economic analysis may be assumed to be all inclusive of those studies whose purpose is to compare economic costs and economic and social consequences as a device to aid in making a decision of whether to accept, modify, or reject a proposal for investment.

Value analysis, or value engineering, is that process of examining designs or products to determine whether the design or product can be altered (or abandoned) in a way to reduce its cost of procurement or operation without impairment of its service, safety, or other desirable qualities.

In this report the terms most frequently used are economic analysis, cost effectiveness, engineering economy, and economy.

Engineering Economy

Engineering economy has to do with the analysis of proposed engineering works, equipment, and processes for the purpose of comparing the worth of the economic gains expected to result from the proposed investment with the economic cost required to produce the gains. Engineering economy is a comparison of the input cost with the net output of revenues, benefits, gains, or profits to determine whether the proposed design or whether the proposed facility is economically feasible. In addition to determining economic feasibility, the process of analysis is also used to determine the most economical design with reference to those factors of design over which the engineer has some choice.

The phrase "engineering economy" comes from the well-established practice in the field of engineering design, construction, and operation of determining the most economical design process or method to achieve the desired results. Economy is based on the dollars required to construct and to operate the facility and on the dollar value of the net benefits, or gains. Primarily in the field of engineering, engineering economy has been applied in those areas that deal specifically with the measure of the dollars (or other monetary unit) involved. In the business world, these dollars are involved in purchase price, construction price, or manufacturing price, the income dollars from sales, and the ultimate determination of profit.

In much of the application of the principles and procedures of engineering economy to highway transportation there is no dollar cash sales or income involved. However, there are the dollar values of the benefits to the road user, or to the community as a whole, that are the equivalent of income when they can be priced on a dollar basis. It is always possible, of course, to estimate the costs of construction, operation, and maintenance of a specific public works or highway proposal.

The term engineering economy implies that a formal type of analysis is made in which the time value of money is considered and in which the analysis follows well-accepted procedures. However, a design engineer is actually practicing engineering economy when he estimates the construction cost of one design to accomplish a particular objective, such as a bridge across a river, and compares that cost with the cost of alternative designs. The alternative designs (to accomplish the same objective) in this case may be for different construction materials or they may be simply different geometrical arrangements. The design engineer is attempting to find that design that will take care of the traffic volume and the live load on the bridge, and will perform the service intended of a bridge, including freedom from flood damage, at the lowest total construction cost and maintenance cost over time.

Compound interest theory is involved in the analysis for economy of proposed highway facilities because the

[1] For an extensive discussion of highway engineering economy, see Winfrey (*5-11*).

[2] This report uses the words "economy" and "economics" with specific differentiation. Economy means the husbanding of the dollar; thrifty decision-making; or conservation of resources. Economics is used in the broad concept of wealth; exchange of resources; and the production, distribution, and consumption of resources. The practice of economy affects economical factors, but economics exists, often without economy.

cash flows of the dollars are often spread over a period of time; i.e., there is the initial construction cost, a possible subsequent investment, such as resurfacing of a pavement, and there is involved the yearly expense of operation and maintenance of the facility. In addition, where the facility affects the performance of traffic, there is the annual expense of the movement of traffic over or through the facility; this is a part of the total transportation cost. The discounting ability of compound interest is used to bring all of the cash flows over a particular chosen period of time into a common time focus. In this case, all future anticipated cash flows are discounted at a specific interest rate back to their equivalent values as of the date of analysis. Thus, to understand and perform economic analysis for the economy of proposed public works or highways, it is essential that the analyst have a good working knowledge of the theory and principles of compound interest.

History of Highway Engineering Economy

Highway engineering economy can be traced back to as early as 1847 when Gillespie (*1-3*) discussed the relative economy of line, grade, horizontal curvature, roadway surface, and construction methods. His early publication dealt with the construction of roads for use by horse-drawn vehicles, yet the principles stated by him at that early date are equally applicable today.

In 1877, Wellington (*1-12*) published the first edition of *Economic Theory of the Location of Railways*. That book is often quoted and cited as the beginning of engineering economy in the United States. Gillespie's book, however, is an earlier reference. The main emphasis on highway engineering economy, however, came at the beginning of the automotive era, principally about 1920 when research began on the effect of line and grade and roadway surface on the fuel consumption and tractive resistance of motor vehicles. This type of work was active in the 1920's and into the 1930's. One of the main objectives was to show the economy of paved surfaces or even gravel surfaces over the commonly existing dirt or natural soil roads that prevailed to about 1920, mainly, of course, in the rural areas.

Highway engineering economy has been under more or less continuous study and research from the period of 1920 to the present day. However, starting about 1950, renewed emphasis was given to the subject, with particular reference to improving the methods of analysis and to collecting and updating the motor vehicle performance data, running cost data, value of travel time, and other factors involved in the analysis. Also, about 1950, work began on the economic and social values of highway improvements as distinguished from those factors that are solely road-user consequences. Particularly in 1956 when construction of the 41,000-mile Interstate system began, renewed activity in the application of the principles of engineering economy occurred with direct use in locating route sections of the Interstate system with reference (1) to the road-user economy, and (2) to the effects on the social and economic factors affected by specific route locations.

Objectives of the Analysis for Engineering Economy

The objective of the analysis for engineering economy is an important concept in its field of engineering. A basic objective of any analysis for the economy of a proposed engineering works is to analyze all possible alternatives of providing the facility that will render the required service as an aid to reaching the ultimate decision on what to do. Thus, the analysis for economy of proposed highway improvements may be regarded as the development of an aid for the ultimate decision maker (i.e., the individual body or organization responsible for the decision on whether to build the construction and what design to build). This analysis for economy gives the decision maker a tool to use in reaching his decision. The tool is an economic measure of the relative economy involved between the several alternatives of design that were analyzed.

In this particular type of analysis, only those factors that involve the input and output consequences that can be evaluated on a dollar basis are included. Certain other economic and social factors of consequences involved are not included in the analysis for economy because they cannot be priced on a dollar basis. These irreducibles (or nonmarket items, as they may be called) involve a broad scale of consequences, including the effects on business and industry and the community factors that are altered because of the highway improvement. These items are considered separately and given such weight as the decision maker thinks is reasonable.

Application of Engineering Economy to Public Works

Although the basic applications, theory, and principles of engineering economy have been worked out as applying to industrial engineering, with particular reference to the manufacturing industry, they are equally applicable to public works wherein it is possible to price the cost and to price the beneficial and adverse consequences. The analysis is particularly adaptable to all forms of transportation and to water resource projects.

As discussed in Chapter Four, there is currently a renewed interest in the aspects of engineering economy that are a part of the planning, programming, budgeting system being installed in the federal government and certain state and local governments. The object is the same in either case: to ensure that there is a sound economic, economy or social basis for budget items to the extent that they can be priced either on an economy basis or at least an effective basis and compared with the beneficial consequences that are to be expected. No doubt renewed emphasis will be placed on making an engineering economy analysis of every proposed highway improvement project and other forms of public works as an aid to deciding whether to include the improvement in a given construction program. The idea of budgeting on an economic basis for, say, a five-year period is made a part of the PPBS so that those who approve budgets can have a better picture of the values to be received from appropriations, and also so that they can see far enough ahead to realize what they are being committed to when they approve a first stage of a multi-stage improvement proposal. In the highway construction and reconstruction activities there is hardly a single type of proposed improvement to any highway facilities that cannot be analyzed by the principles of engineering economy.

Highway Economic Evaluation Versus Project Formulation

The economic analysis of proposed highway facilities to determine their economy has two general applications. The first is to determine the monetary feasibility of a proposal; i.e., to determine whether the value of the benefits received, particularly with reference to the road user, exceeds the long-term cost or sacrifices required to produce the benefits. If the benefits exceed the cost, the facility would be rated as having economic feasibility and, from this viewpoint, would be subject to acceptance. On the other hand, further analysis is needed to determine the details of engineering design, because an over-all economic evaluation of a proposal is usually made without getting down to the close details of engineering design.

Project formulation is that type of economic analysis the engineer practices to determine the design of greatest economy. Project formulation includes such analyses as the comparison of one route location with another, the comparison of reducing the grade from a 6 percent to a 5 percent to a 4 percent to a 3 percent, the choice of engineering materials, or whether to build an open cut across a mountain ridge or to tunnel. These types of analyses are to determine the economy of engineering design and are part of the second broad phase of engineering economy generally known as project formulation, or economy of project design. Unfortunately, many writers on the subject do not distinguish between these two objectives of engineering economy analysis. It is true that they are similar in character and methodology, but their objectives are decidedly different, and, therefore, in many cases the input data are not necessarily the same. In fact, the analysis for economic feasibility is followed by many additional analyses in the process of achieving the final detailed designs for a major project as a whole.

Highway System Analysis Versus Project Analysis

The analysis of an individual proposed construction project for the comparative economy of the several possible alternatives has had perhaps more emphasis in the past than has the application of engineering economy to a so-called transportation system type of analysis. Nevertheless, the general principles and factors involved are applicable to both types of proposals. It is a comparatively straightforward procedure to make an analysis for the most economical grade, economical curvature, or type of design for almost all of the highway facilities when reduced to simple individual projects. The analysis of a transportation system such as a freeway system for an urban area or a freeway system for a state highway system can be made following the same general principles of analysis and procedures. A different approach to the estimate of the values of the factors involved is required, but the same general principles of analysis and procedure apply.

Relation of Engineering Economy Analysis to Financing Highway Improvements

The analysis for economy (i.e., to determine that particular design or alternative of design that will result in the minimum long-term total cost) is not related to the financing of the construction and operation of the improvement, but it is a type of analysis that precedes a decision to build or not to build and, therefore, a decision to finance or not to finance. Whether a proposed highway improvement is financed from current road-user or other incomes or whether it is financed from the sale of bonds does not affect the relative economy of the proposal. The financing, however, may affect the economics of the local community. The proposal is to improve a certain highway facility, and the analysis for economy is for the purpose of determining whether the proposal has economic feasibility or, if it does have economic feasibility, to determine what particular design gives the greatest economy. Thus, from this viewpoint, how the project is financed really does not affect its economy although it may affect its financial solvency (e.g., a toll road must repay its bonds at interest or be counted "infeasible").

This does not mean, however, that the type of financing may not to some extent affect the use, particularly so if the facility were a toll facility as opposed to a free facility. The basic economy would exist in either case at the same level; the only difference would be that in one case the facility might be designed for a different volume of use than in the other case. When one bears in mind that the objective of the analysis for economy of proposed highway facilities is for the purpose of furnishing help in decision-making, it is readily seen that economy is just one of the factors involved in the total decision process. When the proposed facility does not show economy of use, the decision maker still may elect to construct the facility on the basis that the noneconomy items (i.e., the social and general economic factors) are so valuable that the facility is justifiable on these grounds rather than on the grounds of the economy to highway transportation. In that case, the economy study measures the sacrifice being incurred to achieve the noneconomy ends.

Consequences of Highway Improvement

Highway improvements have three important consequences:

1. They affect the cost of motor vehicle travel as well as the volume and the routing of traffic.
2. The highways result in considerable economic and social change within the community directly affected by the highway improvement.
3. Improved highways have a marked effect on certain national aspects of economic and social changes, including migration of the population.

These three groups of consequences are discussed only briefly here because they are more properly treated in Chapters Eight and Nine. It is essential, however, to understand that the analysis for engineering economy is generally restricted to those consequences, beneficial changes, and adversities that are directly related to the road user and motor vehicle use. The community changes and the national general economic and social changes are put in the classification of the nonuser consequences.

In general, the road-user consequences are reducible to dollar values because the economic changes can be quantified and priced in terms of the running cost of the motor vehicles, accidents, and the travel time per trip. Thus, for any proposed improvement to the highway transportation system it is generally possible to make a reliable estimate of the changes in the cost of operating a vehicle, accidents, and the travel time. The estimates of these consequences can thus be reduced to dollar values and included in the study of the economy of the proposed facility along with the highway cost of construction and maintenance. On the other hand, the community consequences and the general national consequences are in the form of irreducibles or nonmarket items, even though they may be tangible consequences, because no way yet has been found to quantify or price them on a reliable basis so that they could be considered in combination with the road-user consequences. (See Chapters Nine and Ten.)

The best practice is therefore to restrict the analysis for engineering economy to the priceable consequences related to the motor vehicle and the road user. The ultimate decision-making process can give to the general social and economic community nonpriceable consequences such consideration as the decision maker may think correct for each particular situation. This process in no way indicates that the general social and economic consequences are of less importance than are the road-user consequences, but separates them primarily because of necessity in the process of making an economic analysis.

Although the road-user factors of comfort and convenience and impedance to uniform travel speed are tangible, they generally are not included in the engineering economy analysis. The reason is that no scheme has yet been devised whereby these factors can be quantified and priced in the same sense as are the motor vehicle running costs and travel time. These factors, therefore, become another set of irreducibles, or nonmarket factors. The decision maker, however, should take them into consideration in electing whether to go ahead with the proposal to designate the particular location and design features of his choice.

In the past 10 years or so, certain writers and spokesmen have endeavored to argue for a system of economic analysis whereby all of the social and economic consequences could be put into one formula or model such that the end numerical quantity as calculated would give an index to the desirability on an over-all basis. Such procedure (Chapter Ten) is hardly practical or feasible because of the most difficult problem of quantifying and pricing many of the social and economic factors. But, even if they could be quantified, their pricing is a dangerous proposition because the price varies so from place to place, time to time, and person to person. Rating and ranking systems have been proposed, but these schemes merely express personal judgments.

It is the sense of this chapter on engineering economy that the analysis and discussion is limited to those road-user consequences that can be reliably priced on a market basis and measured in connection with the cost of the construction of the highway and its maintenance and operation.

FACTORS INCLUDED IN THE ANALYSIS FOR HIGHWAY ENGINEERING ECONOMY

Some of the major factors involved in the analysis for highway engineering economy are discussed to further develop the relationships involved and the objectives sought. The nature of the analysis is such that degrees of judgment must be exercised by the analyst with reference to input factors and scope of his application. The factors discussed include selection of alternatives, cost factors, benefit factors, interest (vestcharge) rate, analysis period, and terminal value.

Choice of Alternatives

The economic analysis of highway improvements, as with other applications of economic analysis, is to aid management in making decisions. One of the principles of the analysis is that all possible alternatives of accomplishing the purpose should be considered, and those alternatives that show good promise of achieving the objectives are to be analyzed in detail.

"All alternatives" includes two alternatives often overlooked: (1) the null alternative (i.e., abandon the existing facility or service or forego constructing any new facility for a new service), and (2) retaining the existing facility or service as is and not even building a supplemental facility (i.e., the "do-nothing" alternative).

Because the proposals for highway improvements usually are for the purpose of improving existing travel services, the null alternative will almost always result in a decision that the service cannot be abandoned. True, however, individual *facilities,* such as a bridge or a section of a route being reconstructed, may be abandoned; but the service is continued by construction of a new facility at a different location. In all but a minute percentage of the total number of proposals for construction of highway facilities and services, the need to continue the service or to supply a new service is established by management decision based on a review of the factors involved. The decision that the need exists is most often an obvious decision.

The existing situation is usually adopted as one alternative as a natural and logical inclusion. The existing highway facility or provision for transportation service is usually chosen as the base from which to measure the differential costs and benefits (gains) to be expected from the alternative means of improving the highway service.

Other than the null alternative and retaining the existing facility and service, the other alternatives will consist of various route locations, geometric designs, structural designs, choices of materials, or of traffic control devices to gain the improved service sought.

Highway Cost and Motor Vehicle Cost

The design of the highway affects the running cost of motor vehicles and traffic accidents. It also affects the construction, maintenance, and operating costs of the highway facility. Therefore, it is part of the analysis for economy to test out different alternatives of design for the highway facility that will render the desired quality of transportation service, such as a certain normal attempted travel speed, and provide adequate capacity in the form of vehicles per hour to satisfy the travel demand. The alternatives are many to achieve these results, because there are many variables with the geometrics and structural design factors. The analyst, however, is responsible for testing out each reasonable design alternative together with the running cost of the vehicles under such design to achieve that design that produces the lowest total cost of transportation (highway plus motor vehicle costs) considering all of these factors.

Road-User Costs and Benefits

The benefits to the road user of highway improvements arise almost wholly from reducing the cost of travel from its present level. Travel cost reductions and benefits include: (1) reductions in motor vehicle running cost, (2) reductions in travel time, (3) reductions in traffic accident cost, and (4) increase in personal satisfactions not otherwise accounted for. Thus, these travel factors are related to the alternatives of highway design in the normal procedure of calculating the relative economy of the alternatives being considered.

Analytical Factors

The discount rate, analysis period, and terminal value are factors involved in the analysis for engineering economy that are judgment factors selected for each specific analysis. These factors are discussed to a limited extent to afford a better understanding of their role in the analysis. See Winfrey (*5-11*, Chap. 5 to 10) for additional details.

Compound Interest

As previously indicated, the analysis for the economy of proposed highway facilities uses a factor by which to combine cash flows at different time periods to equivalent values at a common point in time such that they can be added or otherwise manipulated to give a true indication of the relative magnitude of costs and of benefits. One of the principal applications of the theory of compound interest is to be able to take a single initial investment in a highway facility, add the ensuing year by year maintenance expenses, and combine and reduce the two forms of expense into a single lump sum such as present worth, or a uniform continuing annual• basis such as the equivalent uniform annual cost. Although the term "compound interest" or the word "interest" is frequently used, other forms of the word are common. Discount rate is one, which is applicable for the reason that "discounting" means the lessening of the numerical or dollar value of a future sum to bring it back to the present sum. A word coined for this purpose is "vestcharge" [Winfrey (*5-11*, Chap. 6)], for particular use in analyses of proposed public works or private works in which no actual interest on money to be paid or received is to be expected, nor is a specific cash return on an investment, such as is found in investments in business or investments in stocks and bonds, to be expected. Vestcharge means a charge against the investment in public works or personal property, such as a family automobile or home, in which there is the sufferance of lack of opportunity for cash return because of this investment.

It is conceded by all who understand engineering economy and, in general, by economists that an analysis for economy or determining the annual cost of owning and operating a public works or private works should involve a factor representing the cost of money involved, because such investment deprives the supplier of the investment funds from earning a return, particularly a cash return, by investing his money elsewhere.

One sound reason for including a discount rate in the analysis for economy is that it is universally accepted that money does have a time value. This is proved by the fact that individuals, corporations, and governments borrow money at specific interest rates in order to have the money today to satisfy a particular need rather than waiting until some future time when the money could be amassed from incomes and savings to provide the desired total lump sum. There is no reason why this same concept of the time value of money should not be incorporated in the analysis of the economy of proposed improvements to highway systems.

The theory and principles of compound interest and the particular formulas involved are not discussed in this report because they are common to a large assortment of books on economics, finance, and engineering economy. The basic six formulas are shown in Figure 8 so that their form can be understood. These basic six formulas have been solved, and the resulting tables are available in many books on economics, finance, engineering, and engineering economy (*3-6, 5-10, 5-11*).

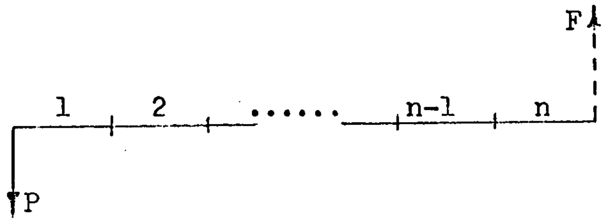
Selection of the Vestcharge Rate

There is no formula available by which the discount rate to use in a particular analysis can be determined. The rate must be chosen as a matter of judgment. The exercise of judgment involves analysis of what is applicable to the particular proposal for investment of funds considering the risk and uncertainties involved and the cost of money to those who will pay for the facility. In general, the reference books on this subject state that normally the discount rate to use should be higher than a normal interest rate to be paid on money borrowed by the highway agency responsible for the construction, and yet lower than the highest interest rates charged on personal loans or that road users pay on the financing of automobiles and charge accounts at department stores.

Perhaps a satisfactory rate to use in the analysis for economy of proposed highway improvements would vary between a minimum of 6 percent and a maximum of 15 percent, depending on the risk and uncertainties involved and the particular situation. In the concept of public utility regulation, perhaps 7 percent might be a reasonable rate; this rate of return is not unusual in the electric, water, and other forms of public utilities. Considering the risks and uncertainties involved and the dynamic character of highway improvement, a rate higher than that used in public works water resources projects would be in order.

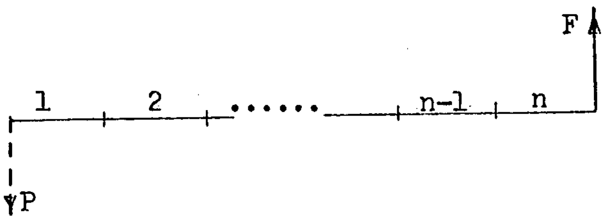
The cash flow diagrams represent the position of the person owning the cash who deposits in or withdraws from an interest bearing fund. Downward is outgo, or deposit, and upward is income, or withdrawal. Solid arrows represent known cash flows and dashed arrows represent unknown cash flows, or solutions of the equations.

DIAGRAMS	EQUATIONS



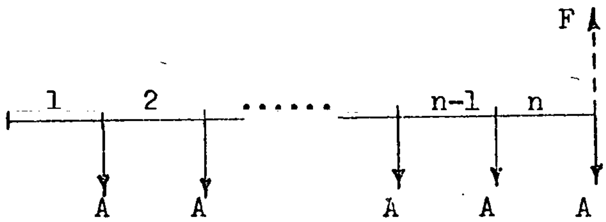
Compound amount withdrawal at the end of n periods to which a single present deposit will accumulate:

$$F = P(1+i)^n; \quad CA = (1+i)^n \tag{1}$$



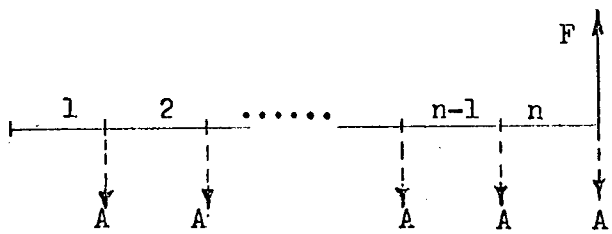
Present worth payment equivalent to a single sum to be withdrawn at the end of n periods in the future:

$$P = F\frac{1}{(1+i)^n}; \quad PW = \frac{1}{(1+i)^n} \tag{2}$$



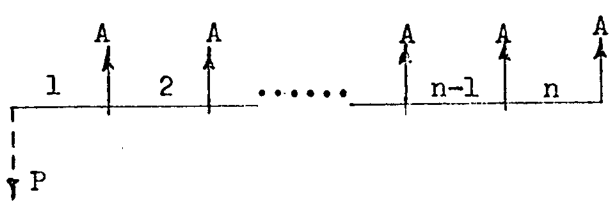
Compound amount withdrawal at the end of n periods to which a series of n uniform period-end deposits will accumulate:

$$F = A\frac{(1+i)^n - 1}{i}; \quad SCA = \frac{(1+i)^n - 1}{i} \tag{3}$$



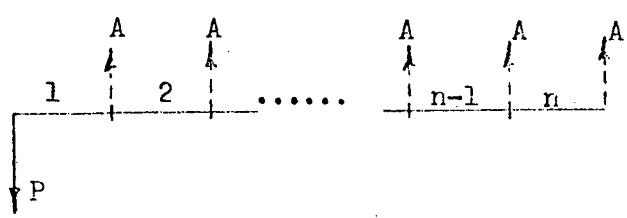
Sinking fund uniform period-end deposit that will accumulate to a given sum withdrawal at the end of n periods:

$$A = F\frac{i}{(1+i)^n - 1}; \quad SF = \frac{i}{(1+i)^n - 1} \tag{4}$$



Present worth payment equivalent to a series of n uniform period-end withdrawals:

$$P = A\frac{(1+i)^n - 1}{i(1+i)^n}; \quad SPW = \frac{(1+i)^n - 1}{i(1+i)^n} \tag{5}$$



Capital recovery with interest; annuity that will return in n period-end uniform receipts a given present deposit plus period interest on the unreturned portion:

$$A = P\frac{i(1+i)^n}{(1+i)^n - 1}; \quad CR = \frac{i(1+i)^n}{(1+i)^n - 1} \tag{6}$$

Figure 8. Cash flow diagrams and the six standard compound interest equations (based on the period-end step convention). Source: modified from Winfrey (5-11, p. 83).

The rate is also related, of course, to the current rate in banking circles. As of 1969, such interest rates were comparatively high; therefore, these rates should be reflected in the choice of vestcharge rates to use in the analysis for highway economy. The people are paying approximately 6 to 8 percent per annum interest rates on home mortgages or, usually, more than 7 percent considering the "points" or other costs incident to securing home loans. Considering the risks and uncertainties, a rate used in the analysis of highway improvements for their economy or equivalent uniform annual cost of operation should be in excess of the rate paid on home mortgages.

Risk and Uncertainty

Because the analysis for economy of proposed highway improvements is an analysis that is based wholly on the future, certain risks and uncertainties are involved. The analysis is a study of the probable future consequences resulting from proposed improvements to the highway system; therefore, all factors are estimates. The construction cost, the maintenance cost, and the operating cost of the highway facility must be forecast on a basis of expected prices, and the maintenance and operating cost have to be forecast for a time period, or analysis period, beyond the completion of construction. In addition, it is necessary to forecast the volume and mix of traffic to use the facility, as well as the running costs of the vehicles and values of time of the travelers. Because of the future characteristic of the analysis for economy, these risks and uncertainties will always prevail.

There is a difference in meaning between the words risk and uncertainty. Risks are generally considered to be such consequences as can be reasonably well provided for in the analysis (e.g., there are risks involved in accidents, the risks involved in the storms and floods that may cause damage to a highway facility). Risks are predictable within a range based on statistical probabilities. There are many types of uncertainties, such as the advancement of technology and inventions that may alter materially the highway use or the use of a particular kind of a vehicle. The uncertainties of people themselves with respect to their use of the facility are present. In the past, despite all the efforts made to make reasonable forecasts of highway use, the end result is that the forecasts have been in error, usually underestimating traffic use, but occasionally overestimating it.

In general, it is an acceptable practice to increase the discount rate used in analysis in accordance with the risks and uncertainties involved. However, some economists have proposed that the normal discount rate based on the cost of money and factors other than risks and uncertainties be used in the analysis and that the provisions for risks and uncertainties be injected into the estimates of costs and benefits. This practice is of doubtful acceptability, particularly in the field of engineering, because there is not a good basis of trying to allow for extra cost, or extra automobile operating expense, or extra highway maintenance expense merely on the basis of risks and uncertainties. The preferred practice seems to be to estimate construction, maintenance, and other highway costs and the associated motor vehicle running cost on the basis of sound pricing and to take care of any risks and uncertainties involved in the selection of the discount rate to use in the analysis. It is acknowledged, however, that this practice will discount all factors equally, not withstanding that only certain factors may possess the elements of risk or uncertainty.

It is well known that the higher the discount rate, the less are the present values of future cash flows. For this reason higher rates have an advantage over low rates by lessening the effects on the analysis of far-into-the-future costs and benefits that are most affected by uncertainty.

Analysis Period

The period of time over which an analysis is to be made should be controlled not by the service life of a facility from the standpoint of its physical durability or adaptation to satisfying the service demanded but should be based primarily on the ability of the analyst to forecast the future. One of the principles of analysis for economy is that the benefits to be received from the facility should be included in the analysis over the same future time as are the forecasts of highway costs. Because perhaps 20 years is a maximum for a general highway facility for which the traffic volume can be estimated within an acceptable degree of reliability, it is probable then that the analysis for economy should likewise not exceed a period of 20 years. On the other hand, for specific types of facilities, particularly for traffic control devices, a period much shorter than 20 years would be in order. The main thing is to stay on sound ground insofar as estimates of the future are concerned. In this connection it must be realized that the analysis for economy does not require calculation of the total cost of owning and operating the facility over its total useful life. The object is simply to make an analysis for the anticipated economy of use and design as a basis for management decision of whether to construct, and, if so, to what particular design.

In project formulation, however, the type of materials to be used or particular devices may have different service lives due to variations in physical durability. It is important in that case to make the analysis over the best estimate of service life that can be achieved An example of this type of approach is in the selection of type of pavement materials, with particular reference to rigid or flexible construction. The same is true in the comparison of steel versus aluminum versus concrete for certain types of structures.

Terminal Value

Certain types of highway facilities and appurtenances may have a terminal value (residual value or salvage value) at the end of the period used in the analysis. Such value is, in effect, a recovery of invested capital and becomes a factor that reduces the capital cost from the level of the original investment.

In most analyses for economic evalaution and for project formulation the terminal value may be assumed to be zero. Its discounted value is often small, its value is highly uncertain, and, as between mutually exclusive alternatives, its value will not vary appreciably. Therefore, its omission will usually not affect the results significantly (*5-4*). There is one type of analysis, however, where terminal value may be significant. When two machines (vehicles) or two kinds of materials (concrete and bituminous) are being compared, terminal value should be included in the analysis when there is a substantial difference in the terminal value as between the alternatives.

ANALYTICAL METHODS FOR ECONOMY ANALYSES

Over the years, analysts performing economic analyses on various kinds of proposals in private industry and in public works have evolved certain analytical methods. The most common ones and those directly applicable to highway transportation are:

1. Equivalent uniform annual cost method.
2. Present worth of cost method.
3. Equivalent uniform annual net return method.
4. Net present value method.
5. Benefit/cost ratio method.
6. Rate of return method.

The literature deals widely with the methods of economic analysis and shows the shortcomings and merits of the different methods. There is a variety of opinion with respect to certain of their aspects. This chapter does not go into the details of these methods, although it is desirable to explain them sufficiently well so that the analyst in the highway field will understand them and can make his choice of method, knowing the philosophy and concepts that support the method. See Winfrey (*5-11,* Chap. 7) for detailed discussion of these methods.

Basic Characteristics of the Methods of Analysis

The six methods of economic analysis compare the future streams of costs and benefits in such a way that, for a specific future period of time, the analysis discloses the comparative uniform annual cost, the probable net return on the proposed investment, or the ratio of return, to investment cost. For highways, the net return here indicated is in the form of dollar values of gains, or benefits, measured by reduction of highway costs or of road-user costs, dollar values of satisfactions, or dollars' worth of other sought-for consequences. Each method applies the principles and concepts of compound interest as the device to recognize the differences in the worth of money over time. Each method also uses as input data the future negative (outflow) and positive (inflow) cash flows of money required to produce the gains.

Each of the six methods is based on the concept that the objective is to maximize the benefits and to assure that any incremental investment in a highway facility will produce at least benefits or gains of an equal or greater amount than the incremental investments.

Definition of the Six Methods

Equivalent Uniform Annual Cost Method

The equivalent uniform annual cost method reduces all estimated future net cash flows for highway capital investment, highway maintenance, highway operating expenses, and motor vehicle expense to one single, uniform annual sum that is equivalent to all disbursements over the analysis period. Thus, the process seeks to identify that alternative that has the lowest total cost of highway transportation (highway costs plus highway user costs). The alternative having the lowest equivalent uniform annual cost of transportation is the more economical of the alternatives compared. The present worth of this equivalent uniform annual cost is exactly equal to the solution by the present worth of costs methods.

Present Worth of Costs Method

The present worth of costs method reduces all estimated future net cash flows for highway capital investment, highway maintenance, highway operating expenses, and motor vehicle expense to one single equivalent sum at zero time. This total sum plus compound interest earnings on its undisbursed balances year to year would finance all of the highway disbursements and highway-user expenses set forth in the cash flow schedule. That alternative having the smallest present worth of total transportation costs is the one of greatest economy. The present worth of the costs multiplied by the capital recovery factor gives the exact equivalent uniform annual cost as calculated by the equivalent uniform annual cost method.

Equivalent Uniform Annual Net Return Method

The equivalent uniform annual net return method is the equivalent uniform annual cost method to which is added an income factor or benefit factor as a positive number. The answer indicates the amount by which the positive equivalent uniform annual income exceeds (or is less than) the negative equivalent uniform annual cost. That alternative having the largest positive equivalent uniform annual net return is the alternative of greatest economy. This method involves a cash income flow factor, usually absent in highway analyses; therefore it is not further considered.

Net Present Value Method

The net present value method gives the algebraic difference in the present worths of both outward (negative) cash flows and inward (positive) flows of incomes or benefits. It is the same in principle as the present worth of costs method, but includes the factor of annual income (benefits) as an income factor. The method is conceptually related to a business venture that produces a cash sales income. That alternative having the largest net present value is the alternative of greatest economy.

Benefit/Cost Ratio Method

The benefit/cost ratio method expresses the ratio of equivalent uniform annual benefits (or their present worth) to the equivalent uniform annual costs (or their present worth). Any alternative that has a benefit/cost ratio greater than 1.0 is economically feasible.

Rate of Return Method

The rate of return method identifies the vestcharge rate, or discount rate, that equalizes the discounted value of the negative costs and the positive benefits over the analysis period.

Basic Equations for the Six Methods of Analysis

Formulas, or equations, from Winfrey (*5-11*, Chap. 7) for numerical solution by the six methods of analysis for economy follow. The formulas use the concept of the cash flow diagrams wherein cost of investments and annual expenses of highway maintenance or road-user expenses are negative and plotted downward and the flows of income of benefits are positive and plotted upward from the horizontal base line representing time.

Notation Scheme

The factors and terms in the several equations correspond to the following notations, in addition to those given for compound interest terms:

$EUAC$ = equivalent uniform annual cost.
$PWOC$ = present worth of costs and expenses.
$EUANR$ = equivalent uniform annual net return.
NPV = net present value.
B/C = benefit/cost ratio.
ROR = rate of return.
$MARR$ = minimum attractive rate of return.
I = construction investment at time zero or at any time subsequent to time zero, suitably identified as I_x, or the equivalent present worth of all investments.
T = terminal value at end of analysis period.
K = total uniform annual expense of administration, A, traffic services and highway operations, J, and highway maintenance, M.
K_G = equivalent uniform annual K when K grows as a uniform gradient.
K_E = equivalent uniform annual K when K grows exponentially.
U = uniform annual road-user costs, exclusive of road-user taxes, but inclusive of travel time value and accident costs when so designated.
U_D = equivalent uniform annual road-user benefits, being the difference in road-user costs between a pair of alternatives.
U_G = equivalent uniform annual road-user costs under a gradient growth of traffic volume.
U_E = equivalent uniform annual road-user costs under an exponential growth of traffic volume.
U_T = equivalent uniform annual road-user tax payment or revenue.
R = uniform annual gross income from sales revenue, receipts or their equivalent, or gross benefits. R is inclusive of return of investment (depreciation) and return on investment (net profit).
R_G and R_E = equivalent uniform annual R when either a gradient or exponential increase is present.
R_D = difference in the equivalent uniform annual receipts of a pair of alternatives.
B and P = subscripts indicate, respectively, the base alternative (often the existing situation or defender) and the proposed alternative (the challenger).

Equations for the Six Methods of Analysis for Economy

The six methods of solution for the economy of alternative proposals may be written correctly in several different forms by using different compound interest factors and different input factors. For instance, either compound amounts or present worth may be used, more than one investment may be involved, annual expenses and road-user costs may be stated in terms of gradient or exponential increases (or decreases), and there may or may not be a terminal value factor.

The following equations [1] do not include any capital investments put in place subsequent to the initial, or first, investment at $n = 0$. Subsequent capital investments may be included in the solutions by treating them in the same manner as the initial investment, but taking care to see that the money sums involved are transferred to the same point in time.

The following ten equations illustrate the general forms of the equations to use; where the gradient and exponential factors are shown it is for the purpose of illustrating one possible form of the equation.

$$EUAC = -I(CR,i,n) + T(SF,i,n) - K - U \quad (1a)$$

$$EUAC = -I(CR,i,n) + T(SF,i,n) - K - K_G(GUS,i,n) - U_E \quad (1b)$$

$$PWOC = -I + T(PW,i,n) - K(SPW,i,n) - U(SPW,i,n) \quad (2a)$$

$$PWOC = -I + T(PW,i,n) - K(EPW,i,n) - U(EPW,i,n) \quad (2b)$$

$$EUANR = -I(CR,i,n) + T(SF,i,n) - K + R \quad (3a)$$

$$EUANR = -I(CR,i,n) + T(SF,i,n) - K - K_G(GUS,i,n) + R_G \quad (3b)$$

$$NPV = -I + T(PW,i,n) - K(SPW,i,n) + R(SPW,i,n) \quad (4a)$$

$$NPV = -I + T(PW,i,n) - K(SPW,i,n) - K_G(GPW,i,n) + R(EPW,i,n) \quad (4b)$$

$$B/C = \frac{-(U_{GP} - U_{GB}) - (K_{GP} - K_{GB})}{-(I_P - I_B)(CR,i,n) + (T_P - T_B)(SF,i,n)} \quad (5a)$$

$$B/C = \frac{-(U_{GP} - U_{GB})(SPW,i,n) - (K_{GP} - K_{GB})(SPW,i,n)}{-(I_P - I_B) + (T_P - T_B)(PW,i,n)} \quad (5b)$$

ROR (Solve for i by trial)

$$0 = -(I_P - I_B)(CR,i,n) + (T_P - T_B)(SF,i,n) - (U_P - U_B) - (K_P - K_B) \quad (6a)$$

$$0 = -(I_P - I_B) + (T_P - T_B)(PW,i,n) - (U_P - U_B)(SPW,i,n) - (K_P - K_B)(SPW,i,n) \quad (6b)$$

[1] Modified slightly from Winfrey (*5-11*, p. 129).

Note that the B/C ratio and the ROR equations are expressed in terms of the differences between a pair of alternatives; the other four equations are expressed in terms of a single alternative.

Of the foregoing equations, the $EUAC$ and $PWOC$ will give negative answers because all the cash flows are disbursements. When the NPV is negative, disbursements exceed income, and when it is positive the income exceeds the disbursements—all expressed on a present worth basis. The B/C ratio ordinarily will be negative because the numerator (benefits) usually will be positive and the denominator (costs) will be negative; when the numerator is positive, affix a positive sign to the B/C ratio; when the numerator is negative it means that the net benefits are negative and the alternative would not be further considered.

Stating the B/C ratio equation as shown results in keeping the same signs as in the cash flow diagram, and the sequence of the base alternative (B) and of the proposed alternative (P) is the same in all terms.

ILLUSTRATIVE APPLICATIONS OF THE METHODS OF ANALYSIS

The five methods for analysis for economy and their basic equations are illustrated by application to the four mutually exclusive alternative proposals in Table 2. These alternatives, typical of proposals for highway improvements, are unlike those in competitive industry, as is evident by the absence of any direct sales income. Any increase in the annual highway maintenance and operating expense or in the road-user expenses (growth of ADT) is assumed to be included in the equivalent uniform annual amounts set forth in Table 2. Alternative A is assumed to be the existing facility. Its service cannot be abandoned.

Equivalent Uniform Annual Cost Solution

The solutions by the equivalent uniform annual cost method are:

$$EUAC_A = -(\text{sunk})(CR,8\%,10) + (\text{sunk})(SF,8\%,10) - 11{,}000 - 240{,}000 = -251{,}000$$

$$EUAC_B = -140{,}000(CR,8\%,10) + 10{,}000(\text{SF},8\%,10) - 9{,}000 - 186{,}000 = -215{,}174$$

$$EUAC_C = -160{,}000\ (0.14903) + 12{,}000\ (0.06903) - 8{,}000 - 184{,}600 = -215{,}617$$

$$EUAC_D = -190{,}000\ (0.14903) + 15{,}000\ (0.06903) - 10{,}600 - 175{,}800 = -213{,}681$$

Present Worth of Cost Solution

The solutions by the present worth of costs method are:

$$PWOC_A = -11{,}000\ (SPW,8\%,10) - 240{,}000\ (SPW,8\%,10) = -1{,}684{,}230$$

$$PWOC_B = -140{,}000 + 10{,}000\ (PW,8\%,10) - 9{,}000\ (SPW,8\%,10) - 186{,}000\ (SPW,8\%,10) = -1{,}443{,}834$$

$$PWOC_C = -160{,}000 + 12{,}000\ (0.46319) - 8{,}000\ (6.71008) - 184{,}600\ (6.71008) = -1{,}446{,}804$$

$$PWOC_D = -190{,}000 + 15{,}000\ (0.46319) - 10{,}600\ (6.71008) - 175{,}800\ (6.71008) = -1{,}433{,}811$$

Net Present Value Solution

The net present value method cannot be applied to each alternative separately because there is no income (sales) resulting from the individual alternatives. However, by considering any two alternatives as a pair, the equivalent of an income (benefit) is available in the form of the difference in the road-user annual expense between the pair of alternatives. On the basis of pairs of alternatives the solutions are:

Alternative B compared to A:

$$NPV = -(140{,}000 - 0) + (10{,}000 - 0)(PW,8\%,10) - (9{,}000 - 11{,}000)(SPW,8\%,10) - (186{,}000 - 240{,}000)(SPW,8\%,10) = 240{,}396$$

TABLE 2

SET OF MUTUALLY EXCLUSIVE ALTERNATIVES FOR ILLUSTRATIVE SOLUTIONS

		ALTERNATIVE [a]			
SYMBOL AND CASH FLOW ITEM		A	B	C	D
I	Initial investment or the initial investment plus the present worth of any subsequent investments ($)	Sunk	140,000	160,000	190,000
T	Terminal value ($)	Sunk	10,000	12,000	15,000
K	Equivalent uniform annual maintenance and operating expense ($)	11,000	9,000	8,000	10,600
U	Equivalent uniform annual road user expense ($)	240,000	186,000	184,600	175,800
i	Rate of vestcharge per annum and minimum attractive rate of return (%)	8	8	8	8
n	Analysis period (yr)	10	10	10	10

[a] The alternatives A, B, C, D are assumed to serve the same traffic volume.

The 240,396 may be checked by finding (1) the series present worth of the difference in the *EUAC* of alternatives B and A, and (2) by taking the difference between the present worth of the costs of B and A:

$$EUAC_B - EUAC_A = (-215,174 + 251,000)(SPW,8\%,10) = 240,395 \text{ (checks)}$$

$$PWOC_B - PWOC_A = -1,443,834 + 1,684,230 = 240,396 \text{ (checks)}$$

The fact that the net present value of Alternative B as compared to A is positive proves that Alternative B is preferred to A. Solution of the other pairs for their net present value will produce results that agree with the difference in net present worth of costs, already calculated by the present worth of costs method.

These net present values are:

$$NPV_{BA} = PWOC_B - PWOC_A = -1,443,834 + 1,684,230 = +240,396$$

$$NPV_{CB} = PWOC_C - PWOC_B = -1,446,804 + 1,443,834 = -2,970$$

The *NPV* is negative; therefore, Alternative B is preferred to C.

$$NPV_{DB} = PWOC_D - PWOC_B = -1,433,811 + 1,443,834 = +10,023$$

Alternative D is preferred over the other three.

When compared to Alternative A, Alternative D will have a greater net present value than the 240,396 of B over A:

$$NPV_{DA} = PWOC_D - PWOC_A = -1,433,811 + 1,684,230 = 250,419$$

Benefit/Cost Ratio Solution

The benefit/cost ratio is also computed by comparing pairs of alternatives because, standing alone, a single alternative has no base from which to calculate the net gains or benefits. First, compare Alternative B to A. The comparison will be made using equivalent uniform annual costs in preference to present worths:

$$B/C_{BA} = \frac{-(186,000 - 240,000) - (9,000 - 11,000)}{-(140,000 - 0)(CR,8\%,10) + (10,000 - 0)(SF,8\%,10)} = 2.78 \text{ (B is preferred)}$$

$$B/C_{CB} = \frac{-(184,600 - 186,000) - (8,000 - 9,000)}{-(160,000 - 140,000)(CR,8\%,10) + (12,000 - 10,000)(SF,8\%,10)} = -0.84 \text{ (B is preferred)}$$

This ratio is less than 1.0, so Alternative C is not desirable compared to B. Next, compare D to B.

$$B/C_{DB} = \frac{-(175,800 - 186,000) - (10,600 - 9,000)}{-(190,000 - 140,000)(CR,8\%,10) + (15,000 - 10,000)(SF,8\%,10)} = 1.21 \text{ (D is preferred)}$$

Alternative D is the preferred selection because D is superior to B, B is superior to A, and B is superior to C. It is not necessary to compare either C or D to A (the existing facility), because the first solution proved that B is superior to A, so A is no longer a contender and need not be compared against C or D.

In the foregoing solution for the benefit/cost ratio it will be observed that the existing Alternative A was used only once, because Alternative B proved to be superior to A. For illustrative purposes A was compared also to C and D, and C and D were compared to B:

CHALLENGER	DEFENDER	INCREMENTAL B/C RATIO
B	A	2.78
C	A	2.52
D	A	2.35
C	B	0.84
D	B	1.21

Each proposal is better than the existing A, but D with the lowest ratio of 2.35 compared to A is the best choice when compared to B and C. This example proves the necessity of comparing each alternative with each other alternative. Actually, the computations are not made in each comparison, but the comparison is made by logic. For instance, if D is superior to B and B is superior to A, then D is also superior to A. This same procedure is applicable with the rate of return method, and the same ranking of proposals will be found.

Rate of Return Solution

The rate of return solution will be made on the basis that the minimum attractive rate of return is 8 percent. The procedure by using pairs of alternatives is the same in principle as that used in the net present value and benefit/cost ratio methods. First, compute the rate of return of Alternative B compared to A, using the equivalent uniform annual cost procedure:

$$0 = -(140,000 - 0)(CR,i\%,10) + (10,000 - 0)(SF,i\%,10) - (186,000 - 240,000) - (9,000 - 11,000)$$

Try 40 percent rate:

$$0 = -140,000\ (0.41432) + 10,000\ (0.01432) + 56,000 - -1,862$$

Try 35 percent rate:

$$0 = -140,000\ (0.36832) + 10,000\ (0.01832) + 56,000 = +4,618$$

Interpolate between 35 percent and 40 percent:

$$35\% + 5\% \left(\frac{4,618}{6,480}\right) = 35 + 3.56 = 38.56\%$$

The 38.56 is greater than 8%, so compare C to B:

ROR of C over B:

$$0 = -(160,000 - 140,000)(CR,i\%,10) + (12,000 - 10,000)(SF,i\%,10) - (8,000 - 9,000) - (184,600 - 186,000)$$

Try 5 percent rate:

$0 = -20{,}000\ (0.12950) + 2{,}000\ (0.07950) + 2{,}400$
$= -31$

Try 4½ percent rate:

$0 = -20{,}000\ (0.12638) + 2{,}000\ (0.08138) + 2{,}400$
$= +35$

The rate of return is approximately 4.8 percent, which is less than the minimum attractive rate of return of 8 percent, so Alternative C is dropped as compared to B.

Next, compare D to B:

ROR of D over B:

$$0 = -(190{,}000 - 140{,}000)\,(CR,i\%,10) + (15{,}000 - 10{,}000)\,(SF,i\%,10) - (10{,}600 - 9{,}000) - (175{,}800 - 186{,}000)$$

Try 10 percent rate:

$$0 = -50{,}000\ (0.162745) + 5{,}000\ (0.062745) - 1{,}600 + 10{,}200 = 777$$

Try 12 percent rate:

$$0 = -50{,}000\ (0.176984) + 5{,}000\ (0.056984) - 1{,}600 + 10{,}200 = 36$$

By interpolation, $ROR = 12\% + \left[\frac{2\%}{(777 - 36)}\right] 36 = 12.1\%$

The rate of return of 12.1 percent is greater than the minimum attractive rate of return of 8 percent, so Alternative D is preferred to B. Alternative D, therefore, is the best choice of the four alternatives. This finding agrees with the four other methods of analysis.

DISCUSSIONS OF THE METHODS OF ANALYSIS

When the five (or six) methods of economic analysis are understood the question "Which method is the best?" is recognized as a pointless inquiry. Each method is best in its own way, for certain applications and when used by certain individuals. This section discusses the merits, limitations, and characteristics of the methods of analysis for the purpose of gaining a better understanding of them. Each analyst and each decision maker can reach his own conclusion as to his own preference.

General Application

Each of the five methods of analysis for the economy of proposed investments in highway facilities and services has its own individual characteristics and preferences insofar as applications are concerned. In general, however, the methods, when properly handled, will indicate the same preferred choice among mutually inclusive alternatives for accomplishing a given purpose. In the ranking of independent projects, the projects will be ranked in the same order by any of the methods so long as the mathematical calculations are carried out with the proper procedure. However, the individual numerical answers vary greatly in their concept and in their magnitude. Some analysts and certain decision makers may prefer one form of answer to another. On the other hand, because of the particular characteristics of the proposals being considered, not all of the methods can be applied to every situation. The form of data available will sometimes dictate the choice of methods. In other applications, the amount of work involved in the form of detailed calculations will be a controlling factor in the selection of the method to apply.

There are two important similar yet distinct applications of the general methods of the analysis for economy of proposed investments. They are mentioned subsequently in the discussion on the individual merits of the methods. These two general applications are:

1. An analysis to determine the economic evaluation or economic feasibility of a proposal (i.e., trying to determine whether the returns, gains, or benefits therefrom will exceed the cost to obtain these returns, incomes, or benefits). This economic analysis must have some form of base from which to measure the economic gains. In highway applications, this economic base is usually the existing transportation facility and services, assuming that the proposals are in some way to improve the quality of level of service of now-available highway transportation.

2. In the second general application the objective is to determine the details of design that are preferable from the standpoint of economy. This type of analysis is called project formulation, and it is for the purpose of comparing many different kinds of construction materials, geometric shapes, structural designs, and other types of engineering possibilities required to reach a certain goal of transportation service. In many of the highway applications for the analysis of economy of proposed improvements, the application is most often for the purpose of project formulation rather than for economic evaluation. In general, however, project formulation follows economic evaluation on the basis that the proper constituted authority has requested that a certain highway facility be designed for future construction.

Equivalent Uniform Annual Cost Method

The equivalent uniform annual cost method has long been used in engineering, in both highways and industry, to determine the preferred design, preferred type of material, or the preferred type of equipment to accomplish certain objectives. In this particular method, the comparison is made by computing the equivalent uniform annual cost of all the cost factors for each of the alternatives being analyzed. In highways the total cost is the highway cost plus the highway-user cost. Thus, it is readily recognized that this method permits determining the economic evaluation, or economic feasibility of the proposal, only as a choice between proposals on the basis of their annual economic cost.

The method is applicable to each individual proposal separately (i.e., it is not necessary to have a pair of proposals). On the other hand, the final answer of equivalent uniform annual cost indicates only the cost comparison with anything that is chosen as a standard of comparison. Most often, this standard is other alternatives, including the equivalent uniform annual cost of the existing situation, should there be one.

For this reason, it is important to realize that the economic annual cost method is not applicable unless the levels (quality) of service between the alternatives being considered are equal. For instance, in an analysis to determine the best location of an urban freeway, the usual situation is that different locations of the freeway attract different volumes of traffic and different composition of traffic. Therefore, the equivalent uniform annual total transportation cost on each of the alternatives being examined may vary greatly because of the traffic volume. It follows then that the alternative having the lowest equivalent uniform annual cost will not necessarily be the better selection; probably that alternative having the lowest average daily traffic will have the lowest equivalent uniform annual cost. This probably would not be the facility returning the most gains in terms of serving total travel demand.

A common type of application of the equivalent uniform annual cost method is in selecting certain features of design that in no way affect directly the running cost of the motor vehicles over the highway, but the choice is strictly between a geometrical shape or between types of materials. A good illustration of this application is determining the comparative economy of a flexible pavement design versus a rigid pavement design assuming, of course, that in each case the design quality is such that it does not affect the running cost of the motor vehicles. In this particular case there is no measure of benefit to be received, except that it is assumed that the benefits to be received from the two types of pavements are equal. Therefore, the choice of design must be based entirely on the comparative uniform annual cost of the two designs.

It is concluded that the equivalent uniform annual cost method is not applicable to comparison of mutually exclusive alternatives or the ranking of independent alternatives, when the level of service to be afforded by the different alternatives are not substantially the same. Neither is the equivalent uniform annual cost method applicable in determining the economic evaluation of proposals, where input costs must be compared to output gains.

Present Worth of Costs Method

The present worth of costs method is comparable in every respect to the equivalent uniform annual cost method because the present worth of cost is directly reducible to the equivalent uniform annual cost simply by multiplying by the appropriate capital recovery factor. Similarly, the equivalent uniform annual cost method may be reduced to the present worth of cost method simply by multiplying by the series present worth factor to reduce an annual stream of costs to their present worth.

Because of the direct convertibility of the two methods, the applications of the two methods follow the same criteria and same restrictions. It may be mentioned, however, that for many types of proposals being analyzed it may be first necessary to calculate the present worth of cost in the process of determining the equivalent uniform annual cost. When this situation prevails, a reliable answer is given simply from the present worth calculations and it is unnecessary to take the latter step to convert to annual cost.

Net Present Value Method

The net present value method was devised primarily as a direct method of analyzing individual proposals that have in themselves a measure of income (sales) or a measure of direct gain, such that the net present value becomes the difference between the gross incomes over time and the net costs over time. When this situation prevails, present worth of the difference, or the net present worth, becomes a direct indication of the economic desirability of economic feasibility of the individual proposal. As between mutually exclusive or independent proposals, those having the greatest positive net present value when discounted at a common interest rate would be choice because the dollar value of net returns would be the greater.

In highway transportation studies related to existing highways the net present value method need not be further considered because of the usual absence of a measurable income or gain by individual alternatives. The usual method of measuring a gain is by comparing the costs and benefits of a pair of alternatives; the benefit or gain measured is the difference between the total costs of the pair—that is, the gain is a reduction in costs. As shown by the preceding applications of the methods to the sample problems, the net present value method is identical in result with the present worth of costs method and also the equivalent uniform annual cost method, when the difference in costs of two alternatives is considered.

When one is considering development roads to be constructed for the explicit purpose of access to undeveloped agriculture lands, timber, minerals, or other unexploited natural resources, it is possible to use the net present value in its conceptual design. In this application, the roadway investment becomes an investment chargeable to the cost of developing and marketing the resources. The resources are sold to produce a sales income so that a net present value can be calculated for the individual proposal to determine its economic feasibility. Nonhighway costs involved in producing and selling the products would be included also.

Benefit/Cost Ratio Method

The benefit/cost ratio method has been popular in the highway field, primarily because this is the method illustrated in the AASHO publication (*5-1*) on road-user benefit analysis. The method has no particular objectionable features and is reliable. The benefit/cost ratio method does, however, require some method of measuring the net gain or net benefits to be expected from a proposal. Usually, this benefit is accomplished by measuring the differences in total road-user costs between a pair of alternatives, one of which, in economic evaluation work, could be the existing situation. In project formulation the same principle is followed and the net difference in road-user costs of two alternative designs is used as the measure of the benefit in the benefit/cost ratio calculation.

Position of the Annual Expense Factor in the Benefit/Cost Ratio Fraction

In the use of the benefit/cost ratio method, the analyst must decide whether he will place the annual operating expense of the highway, mainly highway maintenance expense, in the numerator of his fraction as a deduction from gross user benefits, or whether he will place the maintenance factor in the denominator of the fraction as an addition to the highway capital cost. Except in the special situation when the benefit/cost ratio is 1.0, the magnitude of the ratio calculated depends on the position of the annual highway cost maintenance factor. The literature is not specific on this point because, although the difference has been pointed out in several publications, no one has taken the trouble to make an analysis on a theoretical or practical basis.

Winfrey (*5-11*, Chap. 7) concludes after an analysis of this factor that it is more appropriate to put the annual highway maintenance and operating expenses in the numerator as a deduction from road-user benefits than to put it in the denominator. However, it is acknowledged that reliable results will be obtained regardless of which practice is followed.

Position of Terminal Value Factor

The same question can be raised with respect to the terminal value of the structure or investment. It is as logical to consider the terminal value as a beneficial income and to put it as a positive factor in the numerator as it would be to put it in the denominator as an adjustment in the annual capital cost of the facility. The literature does not raise this question. However, the preference could be to consider the terminal value as a part of the capital cost factor and put it in the denominator when the emphasis is to be on gains from capital consumption. Because of the far future considerations, the terminal value could be considered as an income at the time received and placed in the numerator.

Rate of Return Method

The rate of return method computes the rate of return to be expected on a particular investment. As such, it has a close relationship to the benefit/cost ratio method, except that the measure of economic gain is expressed as a percentage in the same sense that industry, private business, and investors express their success as a rate of return on their investment. To those decision makers who like to deal in such terms as "rate of return on investment," the rate of return method gives them the form of answer they desire. On the other hand, the benefit/cost ratio method expresses the gain in a ratio, but does not indicate the magnitude of the rate of return.

The rate of return method usually is solved by trial as is shown in the preceding examples. An objection to this trial method is that two, three, or four trials are often required before the final answer is determined. When it is realized that the rate of return answer is exactly the same discount rate that would be used in the benefit/cost ratio method to produce a ratio of 1.0, the similarity of the two methods becomes obvious. Also, it is the discount rate in the net present value method that would produce a zero net present value.

As with the benefit/cost ratio method, the rate of return method requires some measure to determine the gains or benefits. The usual method is to treat a pair of alternatives and consider the difference in road-user costs as being the equivalent of a gain or income. Both the benefit/cost ratio method and the rate of return method are used to determine economic feasibility of proposals, because the rate in itself is an indication of the earning capacity with respect to cost. Each of the methods can be used on individual projects, or proposals, however, when there is some measure of economic gain or return, such as there is in the business type of ventures that lead to a sales income. Perhaps the only real objection to the rate of return method is that for certain unusual and rarely encountered situations it is possible that two rates of return will solve the equation, bearing in mind that the rate of return sought in the rate of return method is that discount rate that will equate the negative cash flows of cost and the positive cash flows of income to zero.

The normal type of proposals encountered in industry as well as in highway transportation is that the usual sequence of the cash flow pattern is first making an investment in new facilities or the purchase of new machines, which is a negative cash flow that is then followed by an annual series of positive cash flows in the form of incomes or their equivalent in dollar values, gains, or benefits. It is possible, however, in the most unusual type of industrial application, particularly in the petroleum industry, to find a rare occasion when there is a stream of incomes that precedes a major main negative flow of cash investment. In such cases, it may be possible to find two rates of return that will satisfy the requirement of reducing the present worth of the negative and positive cash flows to a net zero value. In the highway field, this situation is just not likely to occur. In fact, in the real world of highway transportation it is practically inconceivable that one would ever have an occasion to examine the economic evaluation of highway proposals that would result in a two-or-more-solution situation in the rate of return method. Perhaps in a form of stage construction that called for a major capital investment late in the analysis period a multi-rate solution might be encountered. Therefore, this specific and bona fide objection to the rate of return method of an analysis for economy may be disregarded in its application to highway transportation.

The rate of return method involves the controversial factor of whether the method makes the automatic assumption that its returns of cash are reinvested at the rate of return given by this solution, as contrasted to the minimum attractive rate of return, such as would be used in the benefit/cost ratio and net present value methods. The literature on the reinvestment assumption and its significance is not conclusive (*5-11*). The subject is not discussed here, but it is mentioned merely for information.

Other Factors to be Considered

In the illustrative examples of applying the five methods of analysis to four mutually exclusive alternatives, each with a 10-year analysis period, it is seen that the methods arrive at the same project as being the most desirable from the standpoint of economy. In this application each of the five methods was handled by comparing the difference between the alternatives. It so happens, however, that in the equivalent uniform annual cost method and the present worth of costs method, the individual calculation was performed separately for each alternative, but in the end the answers were compared on a differential basis. In the other three methods it was necessary to start the analysis by using the difference in the cost and the difference in the benefits as measured by a pair of alternatives. This device is necessary in order to develop a factor that is the equivalent of income or gain. The two projects were used as a pair so that one could be used as the base from which to measure the gain. When properly handled, these methods give consistent results that agree with each other.

It is necessary, however, in all analyses, regardless of the method of analysis used, to be sure that the analysis period used is comparable between the mutually exclusive alternatives. This is especially necessary in the present worth method, because in that method the total present worth depends on the number of future years that the income streams or cost streams will prevail. In the equivalent uniform annual cost method, the number of years of analysis is not a factor, because the first cycle of cash flows is implicitly assumed to repeat itself. The validity of this assumption should, therefore, be established. Alternative methods of equating project analysis periods are to specify use of the net revenues from the short-lived alternative over the lifetime of the longer-lived one, or to specify a terminal value for the long-lived alternative at the end of the time period of the short-lived alternative.

Sensitivity of the Factors in the Analysis

Although the methods of analysis for economy as described have indicated that specific values such as the discount factor, the analysis period, and terminal values are fixed factors for each analysis, it should be realized that some of these factors, particularly the vestcharge rate and the terminal value and analysis period, are chosen by judgment exercised by the analyst or other official concerned. The final indication of economy and the choice of the most economical alternative may depend on the magnitude of these input factors. For this reason, it is generally desirable that the analyst make two or three solutions using a range of values (i.e., minimum, medium, and maximum values) of these judgment factors. By his making these two or three solutions, the sensitivity of the input factors with respect to controlling the final solution answer will be disclosed. Such ranges of answers are desirable for the decision maker, because he then has a better knowledge of the force of the factors and he may be able to exercise a better judgment in his final decision. It is easily found that in the benefit/cost ratio method a solution that comes out to, say, 1.2 benefit/cost ratio could result in a ratio of less than 1.0 if the discount rate used in the analysis had been increased from 4 percent to 8 percent or some other specific change had been made in the input factors. For further discussion on sensitivity see Grant and Oglesby (*5-4*, *5-5*) and Winfrey (*5-11*, Chap. 5).

THE NULL AND DO-NOTHING ALTERNATIVES

Two of the principles in economic analysis of public investments are as follows: (1) consider all alternatives, and (2) consider all consequences to whomsoever they may accrue. The following discussion is more concerned with discussing all alternatives than it is all consequences. On the other hand, in considering all possible alternatives, their consequences often determine which ones to examine in depth and which ones may be dispensed with without detailed examination. Decision is first required that a facility recommended to be improved is worth keeping, before studying the economy of its improvement.

Fundamental Alternatives

In certain types of considerations, all alternatives are composed of three categories: (1) to do something, (2) to do nothing (i.e., maintain the status quo), and (3) to abandon the service or facility that exists.

With respect to public highways, the ordinary situation is a proposal to do something to improve the quality of transportation being offered, either as a system, as a route, or as a specific section of a given route. With respect to this alternative of doing something it is proper to consider doing something to relieve congestion or otherwise improve the service on this route by improving an alternative routing. This alternative routing may be improving an existing highway or it may be constructing a highway on completely new rights-of-way. In either case the objective is to better the service by improving an existing facility, or building a new facility that will relieve and improve the service on existing facilities.

The category of doing nothing or maintaining the status quo is usually examined more or less automatically by the analyst for the engineering economy of a proposed improvement when he compares an alternative to improve the highway facility with the highway facility that exists. In this way, if the proposed improvement offers possibility of a good return on the investment and makes a contribution to the quality of transportation, the existing situation is automatically compared with doing something and is a proper consideration of the alternative of doing nothing.

Should a comparison of the different alternatives of doing something result in benefit/cost ratios of less than 1.0 or rates of return less than the minimum attractive rate of return, the normal conclusion would be that the existing situation is preferable to those alternatives of doing something that were considered. In this examination, consideration should be given to other objectives of improving highways not included in the engineering analysis of doing something to improve the flow of traffic or the cost of operating vehicles in the traffic stream. These other alternatives include improvements to the aesthetics, the general environment, and to the social and over-all economic welfare of the area affected by the highway improvement. It is concluded that rarely is the alternative of doing nothing not given proper consideration by highway departments.

The third alternative is to abandon the present service facility should one exist and it is being considered for betterment. This alternative is generally not recognized in the normal practice in the examination of the economy of proposed highway improvements. On the other hand, as the first step in the analysis it is important that consideration be given to abandoning what exists. If an existing highway service or highway facility is not rendering a useful service, there is no particular reason why it should be improved even though an improvement to it could render existing services at less cost or at a greater benefit in proportion to the cost than presently exists. There is no need of adding good dollars to bad dollars.

Evaluating the Null Alternative

In most of the improvements proposed for bettering highway facilities it is generally obvious that the existing service, or existing facility, is necessary to the proper functioning of society and economic and social activity within the areas affected. This conclusion can be reached by simply observing that this particular facility is necessary to the movement of traffic and that the movement of traffic judged by its volume and character is a service the public demands and is considered to be useful in the eyes of those familiar with the situation and who are responsible for the highway service in that particular system. There are cases, however, in less-populated areas of the country where a public highway may exist and the question of improving it may come up. In this situation it would be advisable to consider abandoning the highway and the service on the basis that it does not perform a useful service. However, in this situation the facility may be considered for abandonment, but the alternative would be to provide an entirely different routing for the traffic. But rerouting the traffic would not abandon the service but would be moving it to a different location. This is not the kind of an abandonment or null situation that is being considered, because one of the alternatives of improving the situation would be to build a new route (or to improve an alternative route) and abandon the existing route, or facility. Thus, the abandonment is tied directly to providing an alternative service. This would be a normal alternative to be considered in the list of all possible alternatives.

In considering the improvement of lightly traveled highways, roads, or streets, particularly when the traffic volume is so low as to raise the question of whether the service is worthwhile, the answer is often found in the fact that the highway is rendering access to the land. To deprive the landowner of access to bringing goods in and taking products out would not be in the interests of society and, particularly, of the landowner. In this case, the highway gets its value as a highway and is entitled to the expenditure of public funds thereon by the fact that it gives access to the land. Access to land is a tradition in the United States and generally cannot be abandoned except by the public's buying up the access rights from the owners of the land. The buying of access rights is another case of considering all alternatives. In other words, rather than improve the highway to offer better access, the answer may be to buy the access rights and then abandon the highway; here again the alternative of buying the access would be a natural one to consider.

Normally, it is rare in the United States to find a situation wherein a public highway could be abandoned without in any way supplying an alternative service or an alternative facility. Nevertheless, a consideration of the abandonment or null alternative is proper in connection with every proposal to improve a highway facility. The value of the existing facility can often be readily established by considering what would be the consequences of abandoning it.

For instance, improvement of a culvert carrying drainage water across a given roadway has been proposed. The question "Is the culvert necessary?" should be answered before considering improving the existing culvert. The analysis of this question lies in the "with" and "without" consideration. Abandon the culvert and what happens? The consequences could be the flooding of adjacent land or the flooding of the highway, or both. Flooding of either might or might not be a serious affair, depending on two factors: (1) the magnitude of the flood and its duration, and (2) whether the flooding of the land would cause damage or extra cost to the landowner. Likewise, would the flood over the highway damage the highway severely and would it interfere with traffic? These consequences without the culvert need to be evaluated as to their seriousness and compared with the cost of maintaining the culvert as it now exists. In the normal course of the events, comparison of the improvement of the culvert would bring out the alternative of doing nothing. On the other hand, doing nothing (i.e., maintaining the existing drainage facilities) is not considered to be abandoning what is there. The null alternative should always bring up the question of abandoning anything that is existing.

In evaluating the null alternative, difficulties often arise in finding a measure of the magnitude and value of the consequences or services provided by the facility. As already stated, the services rendered can be determined; but placing a value on them may often be difficult. This situation is unlike that involving sales of services or sales of commodities wherein the sales automatically become a measure of value or a measure of benefit of the services or products rendered. This defines value as being *at least* what the consumer is willing to pay.[1] In the case of highway facilities the use of the highway is a measure of the value of the facilities. The contribution that the highway facility makes toward the enjoyment and satisfaction of people is a measure of the value or worthwhileness of the facility. On the other hand, these kinds of services and satisfactions often defy quantitative measurement and, likewise, often defy their pricing on a dollar basis. Thus, a decision that the services rendered are desirable and need to be continued, as opposed to abandonment, may need to be based

[1] The value may be much greater than the price actually paid, however. One means of discovering this full value is by discriminatory pricing, where the price is raised until the consumer stops buying. At that point, price begins to exceed the value to the consumer and full value in money terms is revealed. Value, converted to dollar terms, is how much the consumer would give up rather than do without the object of his desires.

on logic and reasoning and public demand rather than on financial values or measurements of social and economic effects on a quantitative basis.

Role of the Designer and Economic Analyst

The role of the engineer of design or engineer in charge and the analyst for economy needs some discussion related to examining all of the alternatives, including the null alternative.

Often, in highway transportation a decision is made at top level anywhere from Congress down to state legislative bodies and by the officials of special authorities that provide for a specific highway improvement. It is expected that the operating engineers and others engaged in highway construction and operations would be obligated to carry out the mandates of such legislative or executive body. On the other hand, the engineer and others at the working level do have an obligation to make sure that the legislative body was fully informed of the economic, social, and engineering consequences of their decision to construct a public work before they made the decision. If it does appear that factors were overlooked and the decision might not have been founded on solid information, the responsible designers and analysts are obligated to pass upward the results of their findings such that the original decision can be considered for review.

In passing upward the findings of the designers and analysts, it would be proper to include a discussion of the analysis of the null alternative, pointing out what would be the consequences, social and economic, if the facility were abandoned or if the proposed improvements were not carried out and the status quo were continued.

SOLUTION FOR ECONOMY WHEN LEVEL OF SERVICE DIFFERS AMONG MUTUALLY EXCLUSIVE ALTERNATIVES

In general, the methods of analysis for the economy of proposed public works improvements are used when two or more mutually exclusive alternatives are being considered; that is, of the alternatives of doing something, only one of the group will actually be adopted, because essentially they perform the same service and reach the same objectives. However, there are situations when the levels of service or objectives of mutually exclusive alternatives differ sufficiently to require that the normal procedure of the methods of analysis be altered in order to be applied to the particular situation at hand. When one is comparing independent alternatives (i.e., each of the independent alternatives being considered might be constructed) the situation is somewhat different. Here all that is necessary is to have a basis of ranking these independent projects in such a way that their relative economy can be determined; that is, the benefit/cost ratio or the rate of return is determinable for each of the separate projects independently. This section discusses how to handle mutually exclusive alternatives when the level of service, or the average daily traffic, is unequal between the multi-alternatives and is of such character that the methods of analysis need modification in the procedure to make them applicable.

The Situation

The general assumption that applies to most analyses for the economy of proposed improvements in highway facilities is that mutually exclusive alternatives render substantially the same level of service. This situation always exists with respect to any highway improvement involving traffic when the traffic volume on the alternatives may be considered to be substantially equal. The situation also prevails when a type of construction material is being selected, such as a concrete bridge versus a steel bridge, or a high-level bridge versus a low-level bridge, or in analyzing for the economy of culvert diameter with respect to drainage.

The situation, however, is not one of substantial equality of service rendered by the facility when certain urban freeways are being considered with respect to their specific routing. Often the routes of the alternative facilities attract considerably different volumes of traffic and may require consideration of four, six, or eight lanes as between the different alternatives. The situation also exists in the location of interchanges, or the selection of the design of an interchange at particular locations, because these factors contribute to the traffic volume that will use the facility. Whenever the traffic volume is substantially different as between mutually exclusive alternatives, the level of service is not equal, and, therefore, it is necessary to devise a special procedure of analysis for the economy of these alternatives so that the most desirable one may be identified.

Factors of Design that Contribute to Unequal Level of Service Between Mutually Exclusive Alternatives

The factors that most often may differ as between mutually exclusive alternatives and the factors on which the relative economy of the alternatives may depend include such items as the travel distance; the traffic volume that will use the facility; the mix of vehicles as between passenger cars and commercial vehicles; the effects of the particular location, or alternative, on the total network system of highways that may be affected by the facility; and the resulting adverse distance between the mutually exclusive alternatives. It is possible, of course, that the travel distance will vary upward or downward from one alternative to the others that may be higher in highway initial cost, but the adverse distance may result in attracting a greater traffic volume. Ordinarily the analysis procedure will array the mutually exclusive alternatives in ascending order of their initial capital investment. In this way they can be compared in a series of pairs starting with the lowest-cost alternative, often an existing travel situation, and ending with the proposed facility having the greatest total investment cost.

Although the investment cost will increase in the array, it could be that the ADT is such that the total road-user cost will increase between adjacent pairs of alternatives. In such a situation the difference in construction cost may be a positive increase and the change in road-user cost may be also a positive increase in cost; that is, the challenger alternative has a higher road-user cost than the defender alternative. In this situation, of course, considering the total motor vehicle user cost, there would be no road-user benefits. This is one of the situations that makes it necessary to devise the special procedures discussed herein.

Applicability of the Different Methods of Analysis to Alternatives of Different Levels of Service

The equivalent uniform annual cost and the present worth of cost methods are not applicable in mutually exclusive considerations when the differences in costs are the result of serving different objectives, such as serving materially different traffic volumes or land areas. In these situations the total transportation cost (i.e., the highway cost plus the road-user cost) is generally proportional to the number of vehicles using the facility, and, therefore, the higher the traffic volume the higher the total transportation cost.

The benefit/cost ratio and rate of return methods may be used, however, in different levels of service when, as the investment cost increases, it is still possible to show positive gains to the traveling vehicles; that is, the highway-user costs are reduced in total with respect to the increase in the highway cost in spite of an increase in ADT.

In this discussion of mutually exclusive projects that do not render a comparable level of service, it is essential to keep in mind that the analysis to determine the *economic evaluation of a proposed facility* is not the same economic analysis that may be used for project formulation (i.e., to determine the details of design for a *mutually exclusive set of alternatives*). In the analysis for the economic evaluation of proposed improvements it is essential to determine the total net benefits that would be the normal consequence of the improvement. This means that some base of comparison must exist from which to measure the gains to the highway users. Ordinarily, the cost of moving traffic over the existing facility would be the base; but, when the net facility attracts a higher total volume of traffic composed of (1) existing traffic, (2) traffic diverted from other highway improvements, (3) traffic transferred from other modes of transportation, and (4) generated traffic, it is most difficult to determine the particular gains to each of these classes of traffic. Perhaps only the existing traffic may have a predetermined known base of operating cost from which to figure any reductions in motor vehicle running cost (i.e., gains and benefits).

Solution for Economy Under Conditions of Unequal Levels of Service

As with all analyses to determine the economy of proposed highway improvements, the basic approach is one of comparing the differences in alternatives. Comparing alternatives by differences requires comparing the alternatives by pairs, regardless of what methods are used in the analysis.

It is a fairly easy step to find the differences in highway costs and the differences in road-user costs from which to make an analysis of the economy of the lowest-cost proposed facility with the existing situation. In this comparison, it is usual that the proposed additional construction cost as compared to the usually zero construction cost for the existing situation and the reduction in road-user cost will be material. When this first analysis is completed and when the economy is indicated as being favorable, the proposed facility, or some proposed facility, is economically justified and the step of economic evalaution is completed.

Although the basic approach is one of measuring the differences in costs and the differences in gains, it is essential that proper consideration be given to the method of measuring the gains by the traffic on the improved highway as compared to the existing highway or the existing modes or transportation used by traffic that will shift to the improved highway once it is opened to traffic.

The second step in the analysis is to measure the relative economy of the different mutually exclusive proposals for improvement to the facility above the one having the lowest investment cost and that was used in the first step of the analysis in determining the over-all economic evaluation of doing something as opposed to maintaining the status quo. Among these additional proposals for improvement it is common, particularly in urban expressway or urban freeway considerations, to find that they have comparatively small differences in highway construction costs and in details of design affecting the running cost of the vehicle, but they may have large differences in the ADT estimated to use the facilities. For instance, in considering a fully access-controlled highway for moving traffic to the other side of an urban area, one alternative route might be to the north of the central business district, a second route might go fairly close to the CBD, and a third route could be at the southern edge of the urban area such that, although it would serve some intra-urban trips, it would serve through traffic primarily. Under these alternatives it is likely that the north route would have the middle level of traffic volume, the route close to the CBD would have the highest volume of traffic, and the route to the south edge of the city would have the least ADT. It is then necessary to calculate the gains for each segment of traffic as provided by the differences in the alternatives by using either the unit cost per vehicle-mile of traffic movement or figuring the total vehicular running cost for equal ADT's for each pair of alternatives.

Specific Procedure for Analysis of Mutually Exclusive Alternatives of Unequal Traffic Service

The ideal type of analysis for the economy of mutually exclusive alternatives designed for entirely different levels of traffic service, as measured by the ADT, is to break the traffic into its sources. These sources would be: (1) the traffic considered to be existing on the current facility, (2) the traffic diverted from other existing facilities, (3) the transferred traffic coming from other modes of transportation, and (4) the generated traffic—the traffic that did not exist before the new facility was opened. The general normal growth traffic and the traffic developed because of local changes in land use can be considered to be the equivalent to the existing travel, or to diverted traffic when there is no existing traffic to consider.

With the traffic broken into these categories, the travel costs for each source can be estimated and used as the base from which to measure the gains such traffic might realize by using the new facility under study for its economy. This type of analysis would be conducted in each case on the basis of pairs of alternatives, exactly the same as is handled in the differential analysis of the benefit/cost ratio or rate of return methods previously discussed.

In the analysis, it would be important to consider the distance of travel in each case, because some trips would actually suffer an adverse distance of travel not only to get to the new facility in the first place, but because one alternative may be longer in distance than another, yet be strictly a mutually exclusive alternative. By considering any adverse distance, the net economy is measured, which is the economy being sought.

Another important element to consider is the effect of each mutually exclusive alternative on the traffic within the total geographic area affected by the new facility. This effect is basically of three categories:

1. Congestion may be created on certain streets near the approaches to the new facility where congestion did not exist before the new facility was built.
2. The traffic remaining on nearby streets and parallel arterials that did not divert to the new facility may be greatly benefitted. After the new facility is in use, this remaining traffic has a greater freedom of movement and probably travels at a faster speed and with fewer speed changes. Thus, the remaining traffic benefits by reduced travel time as well as by reduced running cost.
3. There may be a general shifting of traffic throughout the area for various reasons. This shifting of traffic is most difficult to determine, but nevertheless it is a consequence that should be investigated and explained even though it cannot be specifically and accurately evaluated.

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CHAPTER SIX

HIGHWAY-USER COSTS AND GAINS

The consequences of highway improvements may be divided into two broad categories: (1) those costs and gains directly related to the vehicle and its driver and passengers, and (2) those costs and gains related to the nonuser of highways and the community. This chapter is devoted only to the highway-user costs and gains. The objective is to give an over-all view of the highway-user costs and gains that result from highway improvements, with particular reference to the features of highway design (such as travel distance, vertical alignment, horizontal alignment, and traffic controls) that affect the running cost, running time, and accidents of vehicles. Because the details of running costs and full explanations are available, this chapter is a condensation of the subject.[1] The effect is primarily to provide a background of the relationship of highway design and traffic use of the highway to the highway-user costs and net benefits.

THEORY AND CONCEPT OF ANALYSIS OF ENGINEERING ECONOMY OF HIGHWAYS

The analysis for the engineering economy of highway improvements (highway-user economy) is based primarily on the fact that highway design (including highway location and traffic control systems) affects the cost of operating motor vehicles on the highway; therefore, vehicle operation and highway design need to be studied together to learn what combinations of the two factors in the long run will produce the greatest economy in highway transportation.

If motor fuel consumption, tire consumption, oil consumption, and vehicle maintenance expenses can be reduced, such actions would result in a lower unit cost of motor vehicle operation. When these motor vehicle cost reductions are greater than the increased cost of highway construction and maintenance to achieve the motor vehicle cost reductions, the net result would be a favorable economy. Thus, the analysis of the engineering economy of highway improvements is directed toward comparing the highway design as it affects the cost of motor vehicle use.

General Procedure

This analysis follows the usual concept, techniques, procedures, and methods outlined in Chapter Five with reference to engineering economy. In this particular analysis the nonuser factors are neglected; they are treated separately in Chapters Three, Eight, and Nine and in Appendix B. The social effects, general economic effects, and community effects of highway design and highway use should be given proper consideration. The highway, and its special facilities, should be the most economical from the standpoint of motor vehicle use, but the lowest motor vehicle cost plus highway cost may not be the best choice when considered in combination with the general economic, social, and community effects. What is sought is that highway design that contributes most to the well-being and satisfaction of the highway users and nonusers considered together.

In the analysis of the economy resulting from proposed highway improvements the normal procedure is to take each of the factors of highway design and calculate the effects of these factors on the total running cost of the motor vehicle and on traffic accident costs. Such an analysis is made for each of the alternatives of design being examined, with the purpose of determining which one of the alternative designs produces the lowest cost of motor vehicle operation consistent with the level of traffic service desired. The level of traffic service may be measured by the travel time factor of speed and speed changes and by the potential of traffic accidents. These two items are also considered to be factors of the running cost of motor vehicles that are affected by highway design and traffic regulations. There is one other highway-user factor involved but usually not put into the analysis for economy because it is an irreducible, or nonpriceable, item. This item is called the personal preference factors, including comfort and convenience, as desired by the highway user. These personal preference items are not items of economy generally but they are items of economic influence and items for which the highway user may be willing to pay.

Vehicle Running Cost Factors Related to Highway Design

Primarily, the cost of motor vehicle operation as affected by highway design is concerned with:

1. The running costs of the vehicle when on the highway, consisting of fuel, oil, tires, maintenance, and depreciation.
2. Traffic accident costs and accident rates.
3. Travel time.
4. Comfort and convenience and driving strains on the driver and passengers.

These motor vehicle running cost items are discussed individually as they relate to the geometrics of highway design and traffic control. The highway design factors of primary concern are:

1. Travel distance.
2. Plus grades.
3. Minus grades.
4. Horizontal curves.
5. Operating speed.
6. Changes in the speed of the motor vehicle.
7. The type of roadway surface.

Highway cost factors are:

1. Construction cost.
2. Highway maintenance expense.
3. Traffic operations expense.
4. Administration.
5. Highway patrol (police).

The gains to be expected from the improvement of highways lie principally in the area of the reduction in running costs of the vehicle, the reduction in accident costs, and the reduction in travel time. In addition, there is the factor of the reduction in driving strains, inconveniences, and discomforts. In other words, the priceable gains to the highway users from improved highways lie in reductions of costs. The base of measuring these gains is principally some given condition (the existing situation) or assumed condition. This particular device for identifying and measuring road-user gains is an enforced one because, for highways, the benefits cannot be measured in terms of a

[1] In accordance with the revised objectives of Project 2-11, this chapter does not include the detail in motor vehicle running-costs, traffic accidents, travel time, and vehicle performance that is now available from Winfrey (*6-28*), who gives a complete series of working tables for cost-benefit analysis. Because the final reports from Projects 5, 5A, and 7 were not available at the time this report was written, such data are not included.

sales income as is true with entrepreneur and other business types of ventures. The gain (benefit) is, therefore, the increment in satisfactions and favorable factors, or the decrement (decrease) in costs and unfavorable factors.

Vehicle Operating Cost Factors Not Affected by Highway Design

In the economy studies for economic evaluation of proposed highway works or for the project formulation of the design factors certain costs can be omitted in the analysis (license fee, insurance premium, parking fees, toll fees, rental on garage, and an interest charge, or vestcharge, on the investment in the vehicle). For commercial vehicles, the driver's wage, terminal facility expense, and management overhead are also involved.

These items can be omitted in economic analysis because they are not controlled by highway design or traffic conditions. Further, they generally will be the same for all improvement alternatives, and, therefore, they may be omitted because they do not affect the relative choice from alternatives being considered because of their equality between alternatives. To give some impression of what these items might amount to, Table 3 gives typical results that might be achieved from passenger car operation. If one were to develop the over-all cost of highway transportation to compare with the cost of other modes of transportation or for its usc alone, it would be necessary to include these nonmileage items and nonhighway-design-affected items in the calculations.

HIGHWAY-USER COST AND BENEFIT FACTORS RELATED TO ECONOMY ANALYSIS

The factors of highway-user costs and benefits as related to highway design, highway use, and the analysis of highway-user economy are discussed in the following. Each vehicle cost factor and each user benefit factor is discussed in terms of its measurement and pricing. The analysis for highway-user economy cannot be fully understood, nor can the results of the analysis be wisely applied, until the basic relations of the highway, the vehicle, and the vehicle driver are understood.

Vehicle Fuel Consumption

The fuel consumption of an internal combustion engine is affected by many factors, including atmospheric pressure, air humidity, air temperature, vehicle speed, power required, vehicle weight, and engine design. In terms of the highway, vehicle fuel consumption is affected by six factors—distance, vertical grade, horizontal curve, vehicle speed, changes in speed, and roadway surface. Distance, of course, bears a direct relationship to total fuel consumption. The vertical grades affect fuel consumption by increasing the horsepower required in going upgrade and decreasing the fuel required in descending grades. Horizontal curves increase fuel consumption as compared to tangents because of the increased air and tractive resistance offered by the continuous changing in direction of the motor vehicle that is necessary when traveling a curved path.

Fuel consumption is affected by speed and speed changes because of three basic factors: (1) the characteristic of the internal combustion engine is affected by both the speed at which the engine revolves and the load that the engine has to carry, (2) both rolling resistance and air resistance increase with road speed, and (3) the engine thermal efficiency varies with changing the throttle opening. The roadway surface affects fuel consumption principally by the change in rolling resistance offered by the contact between the tires and the roadway surface. A pressure-yielding type of surface or a rough surface will increase rolling resistance over that of a rigid smooth surface.

Speed changes (i.e., slowdowns, speedups, and stops) affect fuel consumption primarily in the changing of the rate of fuel consumption due to the carburetor construction and the use of richer fuels in accelerating than need be used in maintaining a constant speed. Also, more fuel is burned in accelerating a vehicle to a given speed than fuel is saved in coasting from this speed down to the initial speed.

As the speed of the vehicle increases up to about 30 or 35 mph for passenger cars there is an increase in gallons per mile of fuel consumed. As the speed of the vehicle is increased, three basic elements operate to require more fuel: (1) internal resistances of the power train increase, (2) rolling resistance on the pavement increases, and (3) air resistance to forward movement of the vehicle increases, somewhat as the square of the speed, whereas the horsepower varies as the cube of the speed. Therefore, at 70 mph, as compared to 90 mph, a passenger car requires seven times as much over-all horsepower to overcome these three resistances. One way to reduce the power train resistance at high speed is to put in an overdrive to reduce the revolutions per minute of the engine with reference to the road speed of the vehicle.

Highway improvements often reduce fuel consumption by shortening distance, using less steep vertical grades, reducing horizontal curvature, and reducing the number of speed changes through grade separations and routing the highway outside of urban areas to where speed zoning traffic signs and signals are fewer. Thus, the increase in fuel efficiency (i.e., an increase in the miles per gallon of fuel) is achieved primarily through a combination of reductions in distance, grades, horizontal curves, and speed changes.

In highway engineering economy studies related to highway design it is necessary to know the fuel consumption for specific vehicles as related to level tangent distances, vertical plus grades, vertical minus grades, horizontal curves, changes in speed, and effect of roadway surface. For each of these highway design factors it is necessary to know the fuel consumption at specific speeds from as low as 10 mph to as high as 80 mph for passenger cars. In addition, it is necessary to know the effect on fuel consumption of slowdowns and stops.

Figure 9 shows fuel consumption rates for typical vehicles operating at uniform speed on level tangents. Figure 10 shows the fuel consumption of a passenger car operating at uniform speed on plus and minus grades. Figure 11 shows fuel consumption on horizontal curves in excess of the consumption when driving level tangents.

TABLE 3

ESTIMATED COST OF OPERATING AN AUTOMOBILE (TOTAL COSTS IN DOLLARS, COST PER MILE IN CENTS)

ITEM	FIRST YEAR (14,500 miles)		SECOND YEAR (13,000 miles)		THIRD YEAR (11,500 miles)		FOURTH YEAR (10,000 miles)		FIFTH YEAR (9,900 miles)	
	TOTAL COST	COST PER MILE	TOTAL COST	COST PER MILE	TOTAL COST	COST PER MILE	TOTAL COST	COST PER MILE	TOTAL COST	COST PER MILE
Costs Excluding Taxes:										
Depreciation	842.00	5.81	589.00	4.53	420.00	3.65	280.00	2.80	230.00	2.32
Repairs & Maintenance	58.10	.40	120.50	.93	165.10	1.43	190.00	1.90	274.63	2.77
Replacement Tires & Tubes	-	-	-	-	26.96	.23	23.45	.23	26.64	.27
Accessories	24.51	.17	17.14	.13	12.22	.11	8.15	.08	6.69	.06
Gasoline	216.99	1.50	194.55	1.50	172.10	1.50	149.65	1.50	148.15	1.50
Oil	32.99	.23	29.48	.23	26.44	.23	22.70	.23	22.47	.23
Insurance	181.00	1.25	170.00	1.31	170.00	1.48	157.00	1.56	157.00	1.59
Garaging, Parking, Tolls, etc.	207.73	1.43	198.65	1.53	189.57	1.65	180.50	1.81	179.90	1.82
Total	1,563.32	10.79	1,319.32	10.16	1,182.39	10.28	1,011.45	10.11	1,045.48	10.56
Taxes and Fees:										
State:										
Gasoline	65.91	.45	59.09	.45	52.27	.45	45.45	.45	45.00	.46
Registration	10.00	.07	10.00	.08	10.00	.09	10.00	.10	10.00	.10
Titling	85.68	.59	-	-	-	-	-	-	-	-
Property	5.00	.04	5.00	.04	5.00	.04	5.00	.05	5.00	.05
Subtotal	166.59	1.15	74.09	.57	67.27	.58	60.45	.60	60.00	.61
Federal:										
Gasoline	40.56	.28	36.36	.28	32.17	.28	27.97	.28	27.69	.28
Oil	.85	-	.76	-	.68	.01	.58	.01	.58	.01
Auto, Tires, Tubes, etc. 2/	50.49	.34	35.32	.27	28.52	.25	19.69	.19	17.07	.17
Subtotal	91.90	.62	72.44	.55	61.37	.54	48.24	.48	45.34	.46
Total Taxes	258.49	1.77	146.53	1.12	128.64	1.12	108.69	1.08	105.34	1.07
Total of All Costs	1,821.81	12.56	1,465.85	11.28	1,311.03	11.40	1,120.14	11.19	1,150.82	11.63

ITEM	SIXTH YEAR (9,900 miles)		SEVENTH YEAR (9,500 miles)		EIGHTH YEAR (8,500 miles)		NINTH YEAR (7,500 miles)		TENTH YEAR (5,700 miles)		TOTALS AND AVERAGES FOR TEN YEARS (100,000 miles)	
	TOTAL COST	COST PER MILE	TOTAL COST	COST PER MILE	TOTAL COST	COST PER MILE	TOTAL COST	COST PER MILE	TOTAL COST	COST PER MILE	TOTAL COST	COST PER MILE
Costs Excluding Taxes:												
Depreciation	170.00	1.72	100.00	1.05	75.00	.88	60.00	.80	40.00	.70	2,806.00	2.81
Repairs & Maintenance	223.96	2.26	281.33	2.96	218.81	2.57	173.03	2.31	82.85	1.45	1,788.31	1.79
Replacement Tires & Tubes	30.95	.31	29.70	.31	34.18	.40	34.22	.46	26.00	.46	232.10	.23
Accessories	4.95	.05	2.91	.03	2.18	.03	1.75	.02	1.17	.02	81.67	.08
Gasoline	148.15	1.50	142.17	1.50	127.20	1.50	112.24	1.50	85.30	1.50	1,496.50	1.50
Oil	22.46	.23	21.53	.23	19.19	.23	17.08	.23	12.87	.23	227.21	.23
Insurance	116.00	1.17	116.00	1.22	116.00	1.37	116.00	1.54	116.00	2.03	1,415.00	1.41
Garaging, Parking, Tolls, etc.	179.89	1.81	177.48	1.87	171.42	2.01	165.38	2.20	154.48	2.71	1,805.00	1.80
Total	896.36	9.05	871.12	9.17	763.98	8.99	679.70	9.06	518.67	9.10	9,851.79	9.85
Taxes and Fees:												
State:												
Gasoline	45.00	.46	43.18	.45	38.64	.45	34.10	.45	25.91	.45	454.55	.45
Registration	10.00	.10	10.00	.11	10.00	.12	10.00	.13	10.00	.18	100.00	.10
Titling	-	-	-	-	-	-	-	-	-	-	85.68	.09
Property	5.00	.05	5.00	.05	5.00	.06	5.00	.07	5.00	.09	50.00	.05
Subtotal	60.00	.61	58.18	.61	53.64	.63	49.10	.65	40.91	.72	690.23	.69
Federal:												
Gasoline	27.69	.28	26.57	.28	23.78	.28	20.98	.28	15.95	.28	279.72	.28
Oil	.57	.01	.55	.01	.49	.01	.44	.01	.33	.01	5.83	.01
Auto, Tires, Tubes, etc. 2/	14.01	.14	9.65	.10	8.70	.10	7.81	.10	5.62	.10	196.88	.19
Subtotal	42.27	.43	36.77	.39	32.97	.39	29.23	.39	21.90	.39	482.43	.48
Total Taxes	102.27	1.04	94.95	1.00	86.61	1.02	78.33	1.04	62.81	1.11	1,172.66	1.17
Total of All Costs	998.63	10.09	966.07	10.17	850.59	10.01	758.03	10.10	581.48	10.21	11,024.45	11.02

1/ This estimate covers the total costs of a medium priced 4-door sedan purchased for $2,806 ($2,965, if the Federal excise tax of $159 is included), operated 100,000 miles over a 10-year period, then scrapped. Baltimore prices, considered to be in the middle range, were used.

2/ Includes $159 Federal Manufacturers Excise Tax.

NOTE: This table omits the cost item of (1) interest charge on the investment of the vehicle, (2) automobile club membership, accident costs above the insurance premium, and driver's license.

Source: Bureau of Public Roads, Office of Planning, Highway Statistics Division (Jan. 1968).

Engine Oil Consumption

Although engine oil accounts for only a small percentage of the over-all cost of operating a motor vehicle, it is one element of cost that can be measured, but not without some difficulty. Because engine oil can be easily quantified and easily priced, it is a logical item to keep separate in any itemization of the running cost of vehicles as related to highway design.

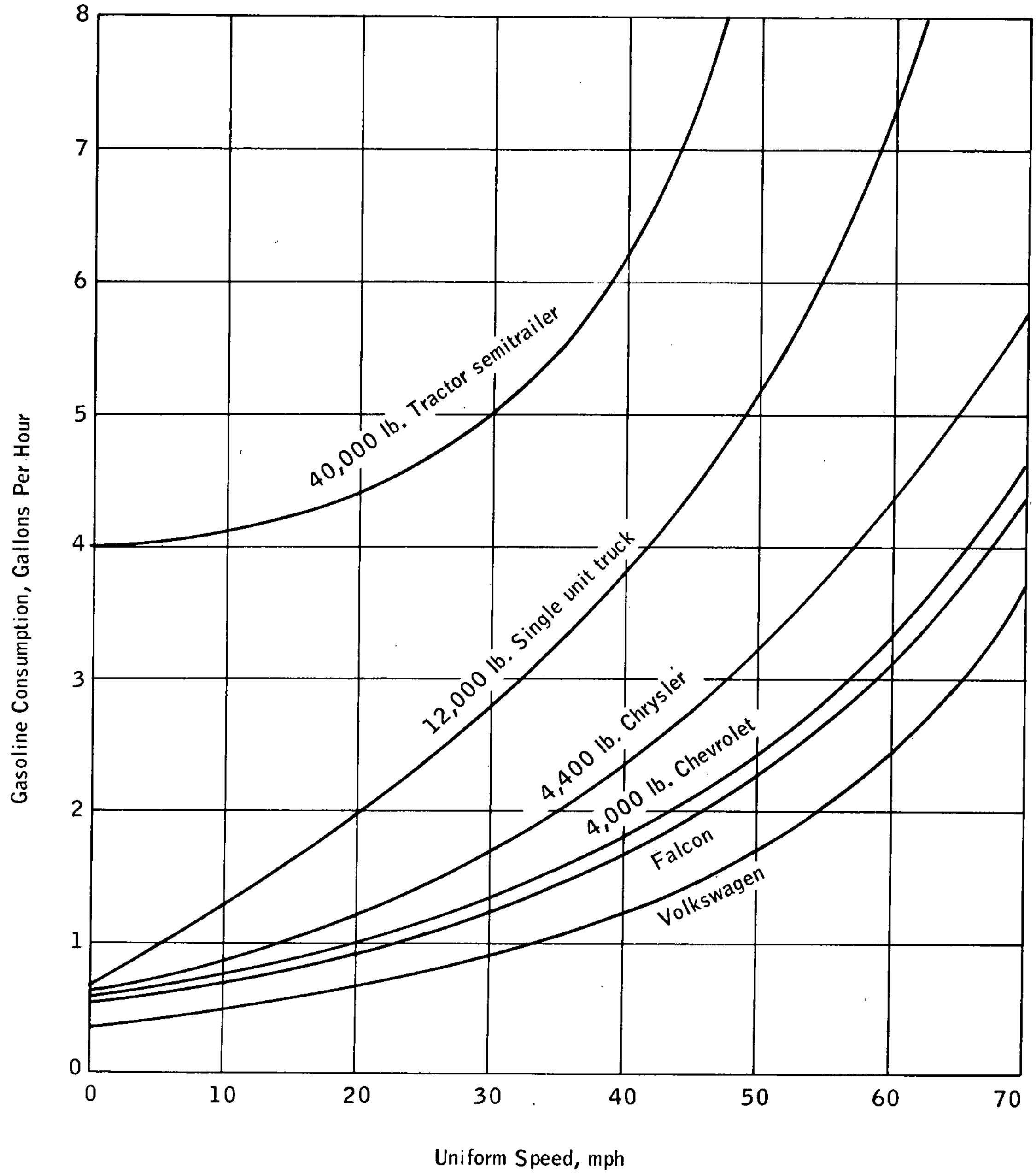

Figure 9. Gallons per hour fuel consumption rates for specific vehicles driven at uniform speed on high-type pavements in good condition. Source: (6-28, 6-29, 6-30).

Oil consumption is primarily a factor of engine temperature, engine speed, and vehicle speed changes. Engine oil is consumed by three direct actions: (1) there is the oil that passes by the piston rings to the combustion chamber and is either consumed or passed through the exhaust mechanism to the outside atmosphere; (2) some oil is vaporized in the crankcase and exhausted through the ventilation system; and (3) in addition to the actual consumption of fuel oil, there is the fuel oil that is drained from the crankcase and discarded. The crankcase drainings account for the largest total gallonage of oil consumption, but it is a type of oil consumption that is difficult to measure with respect to highway design.

In fact, oil consumption is not so closely related to the design of a highway as it is related to the travel speed, temperature of the engine, and care of the engine. Oil consumption is also a factor of the speed change insofar as speed changes cause increased dilution of the crankcase oil through the bypassing of raw gasoline. One of the factors of roadway design that does affect fuel consumption through crankcase drainage (or, at least, it certainly should) is the dustiness or dirtiness of the roadway surface. In the days before oil filters, much of the engine wear and piston ring wear was attributed directly to the intake of abrasive materials in the form of dust particles in the air. Even

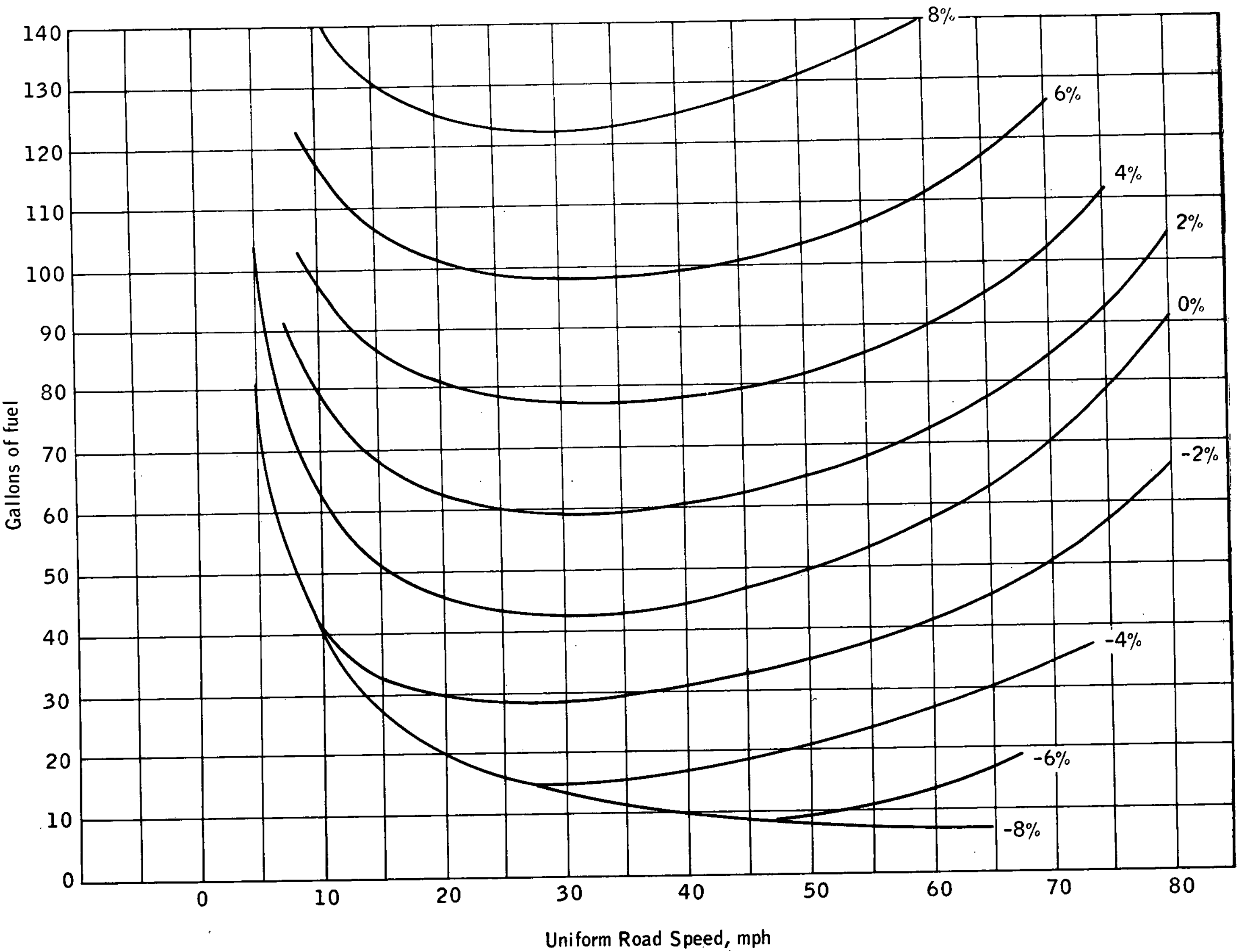

Figure 10. Gallons fuel consumption per 1,000 vehicle-miles for a 4,000-lb passenger car driven on vertical grades at uniform speed on high-type pavements in good condition. Source: curves plotted from data obtained from Winfrey (6-28, *App. A*).

today, with oil filters, this source of wear in the piston rings and cylinders prevails.

Added oil consumption will be experienced on vertical grades, horizontal curves, and other conditions of increased demand for horsepower without any change in speed, probably because of the change in engine pressures. This oil consumption probably is somewhat proportional to the increase in fuel consumption and may be theoretically computed on this basis when there is a lack of actual field measurements of oil consumption.

In all situations, engine oil consumption is related to the revolutions per minute of the engine and the resulting feet of piston travel per minute. Thus, in low-gear operations the consumption of engine oil increases per mile of travel because of the increase in piston travel per mile of highway travel.

Tire Tread Consumption and Carcass Wear

Tire tread consumption and carcass wear and, therefore, tire costs, may be related to two functions of the tires: (1) tire tread as the friction factor through which the engine power is applied to the pavement to drive the vehicle forward or backward, and (2) the carcass compression to afford the cushioning effects of vertical deceleration and acceleration of the vehicle.

Tire tread is worn off in two ways. First, in driving the vehicle forward there is the rolling friction between the tires and the roadway surface that gradually grinds off the tire tread. Second, the tire tread wear results from power applied to the wheels. On the power wheels, usually on the rear axle, the rate of tread wear is greater than it is on the front or driving wheels because of the power applied to move the car forward or backward. On the other hand, when the vehicle is decelerated, particularly by brake

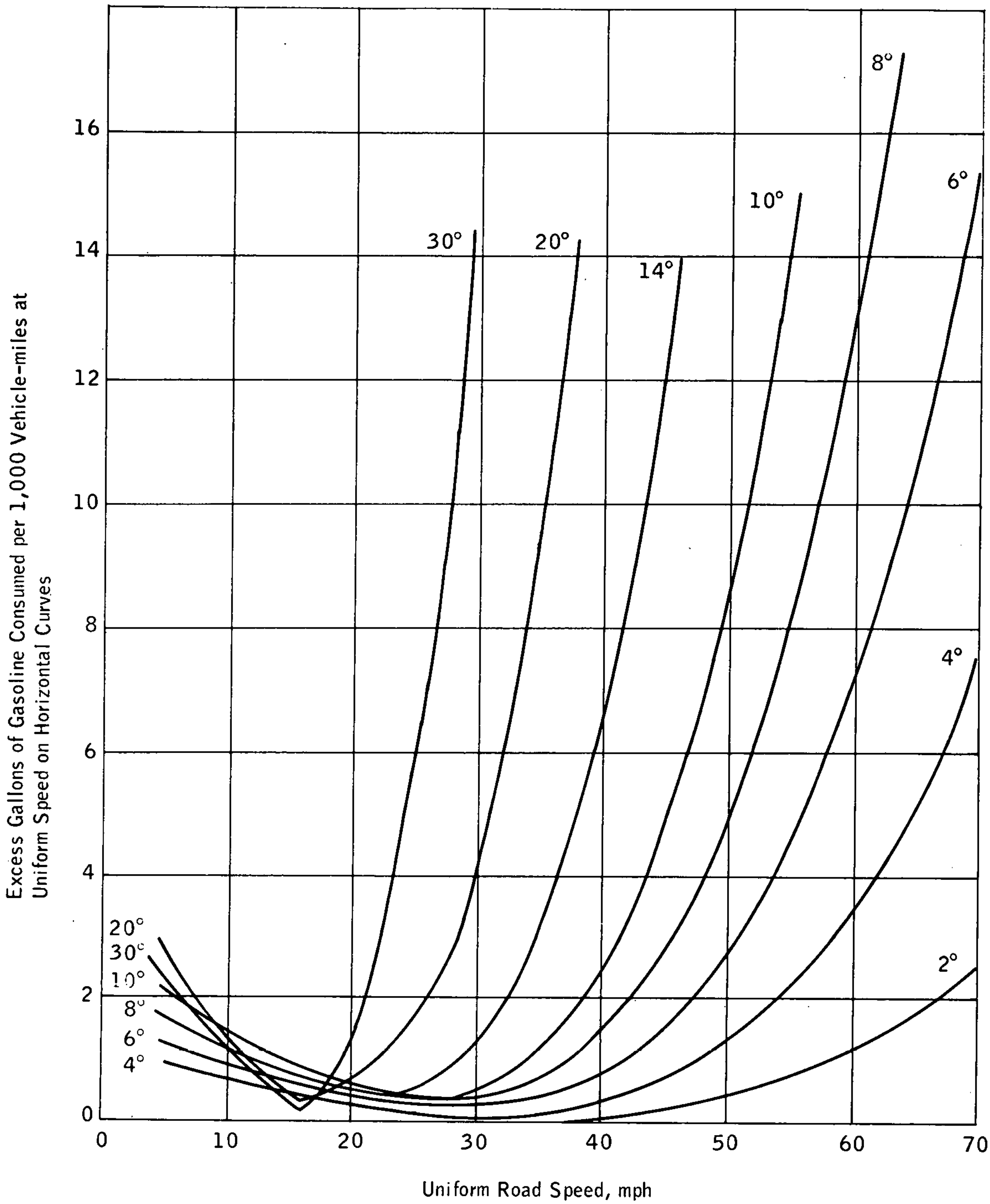

Figure 11. Gallons of gasoline consumed per 1,000 vehicle-miles at uniform speeds on horizontal curves—excess consumption above driving on level tangents. Source: curves plotted from data obtained from Winfrey (6-28, *App. A*).

action, there is wear on both front and rear tires as result of the decelerating force necessary to reduce the vehicle speed.

Another factor in tire tread wear is that of steering around horizontal curves where additional force must be developed to change the motion of the vehicle from that on a tangent to that on a curve. This additional force, supplied by an increase in the coefficient of friction, actually used in changing the direction of travel, requires more horsepower, and, therefore, more tread wear.

The second factor of tire wear is that caused by the continuous compression of the tire and release of the compression at the contact of the tire on the roadway as the tire revolves. The flat part of the tire at the contact area means that the sidewalls of the tire have to flex. They continue to flex and reflex as the car wheels turn around. This action takes energy that is transformed into heat and thus creates as much as 140° or more tire temperature. In time, the tire sidewalls become weak and the tread may become loose. The result may be a carcass failure of the tire.

A third element of tire wear consists of punctures and mechanical injury to the carcass of the tire. Fortunately, these sources of damage are gradually disappearing as tire quality is improved and as the puncturing foreign material on the highways becomes less.

The tire tread wear is proportional to highway distance when other factors are constant—particularly speed and character of the roadway surface. The vertical grades operate to increase tire wear when they are plus, and they will decrease tire wear when the grade is minus as long as the brakes are not applied to keep the car from going too fast downhill.

The horizontal curves increase tire wear as already explained by the fact that the cornering action of the tire is used to increase the coefficient of friction to offer the force to keep the car on a curved path as opposed to a tangent. The tire wear due to speed changes is caused by the changing of speed through acceleration and deceleration, thus adding more horsepower to be consumed than is true with constant-speed driving.

The roadway surface is an important factor in tread wear and also in carcass life because of the abrasive character of the roadway surface and because rough surfaces, such as gravel or crushed stone, cause much greater flexing of the sidewalls of the tire than is experienced on hard smooth surfaces. In this kind of driving, the rough surface often produces a carcass failure before the tire tread is worn to its bottom.

For economy studies it is necessary to know the rate of tire wear and, therefore, the cost of tires at different speeds as affected by distance, vertical plus and minus grades, horizontal curves of different degrees of curvature, the number and extent of speed changes, and the character of the roadway surface.

Figure 12 shows rates of excess cost of tires on horizontal curves.

Table 4 gives the total cost of speed changes for a 5,000-lb commercial delivery vehicle. These costs are based on decreasing the speed from an initial speed, then accelerating back to the initial speed. Winfrey (*6-28*) gives a similar table showing the excess time consumption due to the speed change above the time consumption when continuing at the initial speed.

Vehicle Maintenance and Repair Expense

The expense of maintaining and repairing a motor vehicle to keep it in a safe and satisfactory condition for operation may be divided into two broad categories: (1) the maintenance of the running and wearing parts of the motor vehicle that receive wear and damage as a direct result of highway mileage, and (2) the maintenance features of the vehicle that result from other than mileage use of the vehicle, such as taking on and putting off passengers and cargo, opening and closing doors, and other factors of use not directly related to vehicle mileage. The action of time and weather on the deterioration of certain parts of the vehicle is also not a factor of mileage use. Highway engineering economy studies are concerned only with the factors of vehicle maintenance that can be attributed to the features of highway design and the conditions of the use of the vehicle as it moves on the highway.

General Factors of Vehicle Maintenance

Table 5 gives the factors of cost that are involved in the use and ownership of motor vehicles. In this listing some

TABLE 4

DOLLAR EXCESS COST OF SPEED CHANGE CYCLES—
EXCESS COST ABOVE CONTINUING AT INITIAL SPEED[a, b]

VEHICLE: 5-KIP COMMERCIAL DELIVERY
UNIT: DOLLARS PER 1,000 CYCLES

ROADWAY SURFACE: HIGH-TYPE PAVEMENT IN GOOD CONDITION

INITIAL SPEED (MPH)	SPEED REDUCED TO AND RETURNED FROM (MPH)													
	STOP	5	10	15	20	25	30	35	40	45	50	55	60	65
5	1.00													
10	2.17	1.11												
15	3.70	2.58	1.39											
20	5.64	4.42	3.17	1.71										
25	8.00	6.71	5.38	3.86	2.09									
30	10.86	9.49	8.10	6.51	4.68	2.52								
35	14.33	12.89	11.43	9.77	7.87	5.68	3.07							
40	18.55	17.02	15.51	13.78	11.80	9.52	6.85	3.74						
45	23.62	22.01	20.40	18.60	16.55	14.20	11.48	8.29	4.50					
50	29.67	27.98	26.29	24.39	22.27	19.83	17.04	13.76	9.90	5.37				
55	36.80	35.01	33.23	31.23	29.02	26.50	23.58	20.25	16.32	11.69	6.30			
60	45.19	43.29	41.41	39.32	36.99	34.34	31.33	27.89	23.86	19.18	13.69	7.38		
65	55.00	53.02	51.05	48.82	46.38	43.64	40.50	36.94	32.78	27.98	22.41	15.94	8.58	
70	66.40	64.30	62.19	59.83	57.27	54.39	51.08	47.41	43.11	38.23	32.50	25.96	18.41	11.02

[a] Cost includes fuel, tires, engine oil, maintenance, and depreciation. A speed-change cycle is reducing speed from and returning to an initial speed.
[b] Source: (*6-28*, p. 692).

TABLE 5

CLASSIFICATION OF MOTOR VEHICLE OPERATING COST ITEMS[a]

A. Mileage Items

1. *Body*
   - Bumpers
   - Doors
   - Fenders, body dents
   - Glass
   - Heater
   - Instruments
   - Interior
   - Keys, locks
   - Paint
   - Rattles
   - Wash, polish
   - Windshield wiper
2. *Brakes*
   - Adjustments
   - Cylinders
   - Drums
   - Fluid
   - Inspection
   - Lining
   - Shoes
3. *Chassis*
   - Frame
   - Front end
   - Gas line and tank
   - Grease fittings
   - Hub caps
   - Muffler, tail pipe
   - Shock absorbers
   - Steering
   - Suspension system
   - Tire rims
   - Wheel and axles
4. *Electrical*
   - Battery and cables
   - Generator and belt
   - Lamps and bulbs
   - Regulator
   - Starter motor
   - Turn signal
   - Wiring
5. *Engine*
   - Air cleaner
   - Antifreeze
   - Bug screen
   - Carburetor
   - Distributor
   - Fuel pump
   - Fan and belt
   - Internal work
   - Oil filter
   - Radiator
   - Spark plugs
   - Steam clean
   - Tune-ups and parts
   - Water pump
6. *Engine Oil*
7. *Engine Fuel*
8. *Greasing and Lubricants*
   - Chassis
   - Differential
   - Front wheels
   - Transmission
   - Universals
9. *Power Train*
   - Clutch
   - Differential
   - Drive shaft
   - Transmission
   - Transmission fluid
   - Universals
10. *Tires*
    - Balance
    - Chains
    - Flats
    - Rotate
    - Snow tires
11. *Other*
    - Radio
    - Safety inspections
    - Small tools
    - Tow-in

B. Time Items

12. *Accidents* (also a mileage item)
13. *Depreciation* (also a mileage item)
14. *Insurance*
15. *Licenses*
16. *Parking*
17. *Tolls*

C. Ownership Items

18. *Auto Club Membership*
19. *Garage*
20. *Personal Property Tax*
21. *Vestcharge*

D. Commercial Items

22. *Driver's Wage, Fringe Benefits, and Subsistence*
23. *Overheads*
24. *Special Road User Taxes and Fees*

[a] Source: (*6-28*, pp. 302-03).

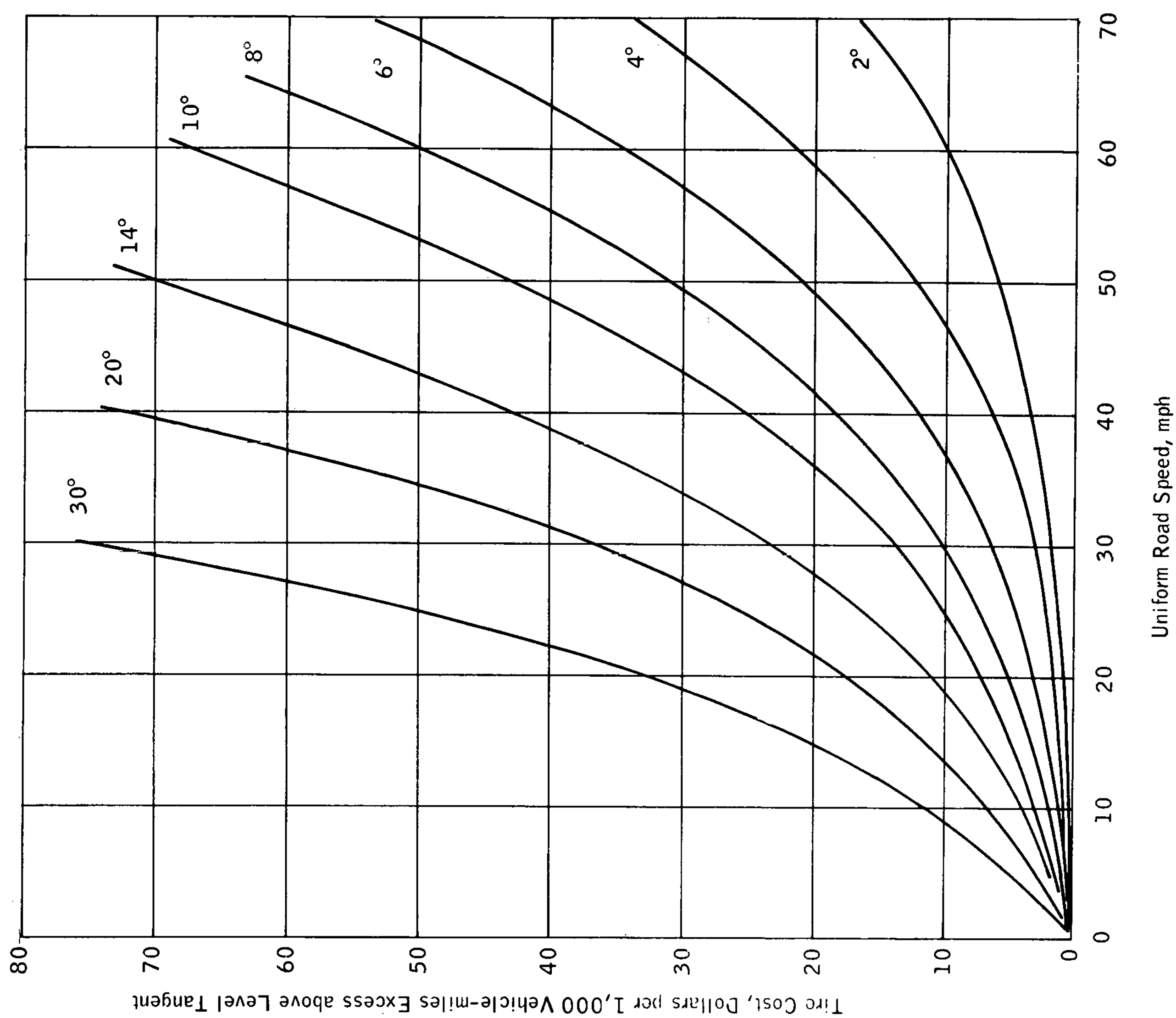

Figure 12. Excess dollar cost of tire wear on horizontal curves above cost of driving on level tangent; 4,000-lb passenger car. Source: curves plotted from data obtained from Winfrey (6-28, App. A).

of the maintenance items are grouped to illustrate the many factors involved in the over-all maintenance and repair of motor vehicles.

Because the maintenance expenses of a vehicle and the actual wear of parts is so difficult to trace to the specific features of highway design, such as distance, vertical grades, horizontal curves, and speed changes, it has not yet been possible to measure by field testing the maintenance expense of the vehicle over-all with respect to these particular features of highway design. Some measurements, however, have been made with reference to the wear of brake bands and brake drums, with particular reference to the roadway surfaces (*6-15*) and numbers of stops and slowdowns per mile. It is well known that the engine ignition system needs to be checked and tuned up periodically to keep it working at reasonable efficiency. In addition, the transmission system and clutch, if any, in the power train, are subject to considerable wear, depending on speed and speed changes. Vehicles used in urban delivery services, including taxicabs, have a high rate of wear on the clutch and the braking system because of the large number of speed changes and idling of motors that occur in this vehicle use.

Maintenance expense of the motor vehicle is highly proportional to the owner's maintenance policy. Some owners take vehicle maintenance seriously and have their vehicle inspected, repaired, serviced, and adjusted at regular intervals. Other owners give the vehicle no preventive maintenance whatsoever; it goes to the shop for service or repair only in case of a breakdown. Engines and the entire vehicle can be either severely abused or properly taken care of, depending on the owner's attitude. Thus, the development of reliable records of the over-all cost of maintaining vehicles requires the assembly of a large number of such records from a variety of types of driving and owners.

But even though motor vehicle operating costs with respect to maintenance expenses could be developed, they still would not relate to the specific conditions of use, features of highway design, and traffic conditions. Usable maintenance costs for economy studies must be obtained by making theoretical allocations of over-all expense to features of highway design and highway use. Nevertheless, the maintenance expenses of the vehicle is appreciable and there is no doubt that such expense in the long run depends on the highway design, speeds driven, and other conditions of highway use. Maintenance is the one large item of motor vehicle operating expense that is most difficult to allocate to highway design, whereas fuel is perhaps the easiest to allocate.

Allocating Maintenance Expense to Features of Highway Design

In the absence of any extensive and reliable observations of the relationship of the maintenance of the many parts of the motor vehicle to its conditions of the use and to the type of highway driven over, it is necessary to resort to the calculation of maintenance expense by theoretical and logical approaches. Several maintenance items can be related fairly closely to horsepower-hours of output, to pressures and speeds, and to fuel consumption required or existing at the time of the output of horsepower. For instance, the electrical ignition system of the internal combustion engine using gasoline as a fuel is subjected to a high rate of wear at high speed on long-distance driving, such as on the Interstate type of highway. The braking system receives excessive wear and tear in urban driving, whereas on the modern freeway it is possible to drive a long distance (100 miles or so) without using the braking system.

It is theoretically correct to conclude that the wear and strain on the chassis and certain other parts of the body are somewhat related to speed changes and the over-all pressures and forces that the vehicle must withstand in connection with changes of speed and at high-speed driving.

With respect to engineering economy analyses, the maintenance expense of a vehicle is an important item. It is affected by distance, vertical plus and minus grades, horizontal curves, speed changes, and roadway surface. In general, vertical grades affect the maintenance cost of a vehicle by changing the horsepower requirements and greater use of the braking system on downhill grades as compared to not using the brakes on plus grades or when driving level tangents, except when traffic or horizontal design necessitates changing the speed by application of brakes.

Horizontal curves will affect vehicle wear and tear, principally by changing the internal resistances and forces applied to the car from those that might be considered to be longitudinal and vertical to those that become tangential or centrifugal. Speed changes affect the vehicle similarly. In particular, fast starting and fast stopping place considerable stress on the vehicle. A dirty, dusty roadway surface has a marked influence on the maintenance cost of the body, the power train, and the braking system. Rough surfaces have considerable influence on cost of maintaining the front end alignment and the suspension systems. Shock absorbers need far more frequent replacement as a result of driving rough and dirty roads than they do in driving smooth, hard-surface roadway pavements.

Depreciation Expense of Vehicles as Related to Highway Use

The total depreciation expense of a motor vehicle is defined for the purpose of highway engineering economy studies as the difference in the vehicle's cost new and its scrap value when it is removed from highway use. Like vehicle maintenance, vehicle depreciation can be broken into two major components: (1) the effect of road use and its resultant wear and tear on the vehicle that, in the end, reduces the vehicle to a condition unacceptable for further highway use; and (2) the effect of time and weathering on the physical condition of the vehicle that may serve as an index as to its desirability of continued highway use. In connection with time, a second item affects the date that a vehicle is scrapped. Particularly in the case of passenger cars, the vehicle's obsolescence with reference to newer models causes people to discard a vehicle sooner and buy a newer one to obtain satisfaction from the newer features of automotive design and the prestige of owning the latest style.

Only the factors of depreciation in item 1 should be charged to the vehicle use on the highway. The other factors can be recorded as strictly time and weather factors; they are absorbed by the owner without reference to highway mileage services.

Depreciation Related to Highway Use

There is little guidance in the literature pointing first to the proportion of total depreciation that might be chargeable to mileage use of the vehicle and the remaining portion of depreciation that could be charged to time or simply ownership of the vehicle. Secondly, there is still less evidence of the mileage portion of the total depreciation that should be charged to the factors of highway design and highway use, such as distance, vertical grades, horizontal curves, speed, speed changes, and roadway surface.

Depreciation expense, however, may be allocated to certain features of highway design and highway use by a conceptual analysis of the factors involved. For instance: a vehicle continuously driven at high speed probably will be driven a larger total of miles during its lifetime than will a vehicle driven mostly at slow speeds. This conclusion is reached because by high-speed driving a large annual mileage can be driven while the vehicle is relatively new and relatively modern in design. The annual mileage of vehicles is less and less per year as they get older and older (*6-3*). Therefore, less desirable from the standpoint of ownership, old vehicles will be relegated to the graveyard at a much lesser total life mileage after having been driven at low speeds than will vehicles that are driven continuously at high speed. Therefore, high-speed driving may be concluded to cost less in depreciation measured in cents per driven mile than does slow-speed driving. Likewise, high-speed driving should absorb a smaller proportion of the over-all depreciation cost of a passenger car than would slow-speed driving because a lesser amount of its obsolescence would be attributable to styling or modernity than would be the case of a vehicle driven at slow speeds or low annual mileage.

In considering the depreciation expense of a motor vehicle that is assignable to or directly caused by highway use, the market value of the vehicle is an irrelevant factor, except, of course, for the final scrap value. In highway engineering economy studies the vehicles using the highway for their full lifetime must be considered. Therefore, the market value of a used vehicle year to year is not a factor entering into estimating the depreciation expense on a per mile basis as affected by highway design.

TRAFFIC ACCIDENTS AND THEIR COST

The economic cost of traffic accidents is high; in fact, roughly it approaches year by year about the same amount that is spent on highway construction and maintenance ($11 billion for accidents and $13 billion for highways). Many of the currently active projects to improve highways are devised with accident cost reduction as a major objective. In analyses of highway improvements, generally, or in the analysis of specific highway projects, traffic accidents can be an important factor in magnitude that may control the ultimate answer of economic value of the proposal.

TRAFFIC ACCIDENT DATA FOR ECONOMIC ANALYSES

Generally, traffic accidents may be classified into three groups: (1) property-damage-only accidents, (2) nonfatal personal injury accidents, and (3) fatal accidents. The number of accidents in each of these three categories decreases in the order named, but the cost per accident increases in the order named. Table 6 gives some indication of the relative magnitudes of the numbers of accidents in relation to total travel and also as to the cost per accident and total costs. Traffic accidents have not yet been studied widely and deeply enough to produce the information necessary to prepare the ideal arrangement of traffic accident data—basically, cost and relative frequency or expectancy of accidents, that would apply to the features of highway design and highway use necessary to good analyses of the economy of highway improvements. In the meantime, the factor of traffic accidents should be included in all analyses to the degree it is possible to estimate the relative accident cost between the alternatives being compared.

Research and data gathering and analysis still fall short of indicating, with a reasonable degree of correctness, the role of highway design and traffic regulations on the severity, number, and cost of traffic accidents. As this work progresses, however, the analyst of the economy of proposed highway improvements will have much better input data at his disposal.

A good source of the probable rate of reduction in accidents is Jorgensen (*6-12*). That report lists specific accident reduction potentials of specific types of roadway improvements, particularly of the so-called spot improvement variety. The Cornell Aeronautical Laboratory (*6-6*) is a good source for over-all general reduction of accidents based on the vehicle-mile.

Traffic Accidents and Highway Design

Highway distance affects the rate of traffic accidents proportionally to the distances involved when other factors are equal.

Little information is available to determine the effect of vertical grades on traffic accidents. Plus grades may induce traffic accidents because of slower-moving vehicles that are overtaken and passed by faster-moving vehicles. In such a case, the additional maneuvering and lane changing may set up accident-producing situations. In addition, uphill grades at crests tend to produce accidents because of inadequate sight distance, the changing of speeds, and the tendency of passenger cars to pass trucks before the beginning of a downgrade.

On minus grades the accident-producing situations arise primarily from the fact that many vehicles do not compensate downhill speed for the effects of gravity, and, thus, their stopping distance is materially increased when going downgrade. A bad combination is a sharp horizontal curve on a downgrade where the sight distance is materially restricted and the vehicle, to stay in its lane around a curve,

TABLE 6

NUMBER OF AND DIRECT COST PER ACCIDENT OF URBAN AND RURAL TRAFFIC ACCIDENTS CLASSIFIED BY TYPE OF HIGHWAY AND SEVERITY; ACCIDENTS IN ILLINOIS INVOLVING VEHICLES OF ILLINOIS REGISTRY—1958 [a, b]

Type of Highway	Passenger Car Accidents								Truck Accidents							
	Fatal Injury		Nonfatal Injury		Property Damage Only		Total		Fatal Injury		Nonfatal Injury		Property Damage Only		Total	
	No.	$/Ac	No.	$/Ac	No.	$/Ac	No.	$/Ac	No.	$/Ac	No.	$/Ac	No.	$/Ac	No.	$/Ac
Urban Accidents																
Intersection	217	7,678	49,934	1,724	242,416	180	292,567	486	30	4,336	3,645	417	45,225	89	48,900	124
Nonintersection																
One-way streets with --																
One traffic lane	---	---	157	680	5,414	124	5,571	139	---	---	6	*	34	*	40	*
Two traffic lanes	9	7,017	163	743	17,543	77	17,715	86	---	---	17	25	1,390	23	1,407	23
Three or more traffic lanes	---	---	309	913	9,183	132	9,492	157	---	---	414	16	1,589	43	2,003	30
Undivided highways (two-way) with --																
Two traffic lanes	115	6,210	22,873	996	219,927	144	242,915	227	35	5,006	1,424	699	24,128	74	25,587	116
Three traffic lanes	2	540	218	830	4,093	114	4,313	150	---	---	17	59	271	*	288	3
Four or more traffic lanes	81	7,283	7,381	1,341	76,842	234	84,304	338	11	5,248	546	426	10,379	87	10,936	109
Divided highways with --																
Four traffic lanes	24	6,788	2,182	2,454	10,234	129	12,440	549	---	---	118	1,841	1,713	116	1,831	227
Six or more traffic lanes	10	6,251	2,773	1,572	3,295	603	6,078	1,055	1	540	36	36	997	127	1,034	124
Not specified	---	---	28	2,615	38,767	73	38,795	93	1	9,600	268	86	3,370	95	3,639	97
Total	458	7,118	86,018	1,503	627,714	183	714,190	346	78	5,007	6,491	416	89,096	84	95,665	117
Rural Accidents																
Intersection	145	9,828	5,947	1,539	18,257	284	24,349	647	46	7,760	683	1,059	5,163	150	5,892	348
Nonintersection:																
Undivided highways (two-way) with --																
Two traffic lanes	508	9,021	9,850	2,658	85,023	265	95,381	558	79	7,592	1,920	2,095	15,038	242	17,037	485
Three traffic lanes	9	5,039	27	76	3,963	106	3,999	117	1	972	---	---	---	---	1	972
Four or more traffic lanes	45	12,020	1,001	3,017	7,515	109	8,561	511	9	12,603	133	1,293	719	150	861	458
Divided highways with --																
Four traffic lanes	4	3,995	381	2,077	260	575	645	1,493	6	11,160	42	2,609	300	1,340	348	1,662
Six or more traffic lanes	---	---	82	5,830	---	---	82	5,830	1	4,164	---	---	17	478	18	740
Not specified	---	---	---	---	13,139	70	13,139	70	---	---	4	361	1,895	35	1,899	44
Total	711	9,297	17,288	2,292	128,157	234	146,156	522	142	8,053	2,782	1,807	23,132	225	26,056	437

* No costs of less than $5.00 per involvement were incurred.

[a] Source: (*6-11* and *6-28*, pp. 388-89).
[b] Cost updated from 1958 to 1966 by a factor of 1.25.

has a tendency to skid outward into the other lane, or even overturn.

Horizontal curves are accident-producing, primarily when sight distances are restricted and when the curve is taken too fast, so that centrifugal force throws the vehicle outward. Again, in bad weather, because the horizontal curve requires the development of a considerable side friction coefficient to keep the vehicle on the curved path, there is a tendency to outward skidding. Generally, the speeds on curves are not excessive enough to cause the rear of the vehicle to track outside the lane or outside the front wheel track. But, when this happens, there is danger because of the reduction in the normal distance between the opposing traffic streams.

As Prisk (*6-16*) shows, it is the differential in speeds of vehicles, rather than the speed itself, that contributes to accidents. Therefore, speed changes in the traffic stream produce accidents. These accidents are caused by vehicles not allowing enough headway to avoid collision when the forward vehicle makes a quick slowdown or stop. Also, the change of speed when changing lanes or overtaking and passing, rather than speed itself, is the accident-producing factor.

The roadway surface has a direct effect on traffic accidents, primarily from two sources: (1) pavements that are slippery, and thus have a low coefficient of friction, are accident producing, particularly in wet weather; and (2) rough types of pavements, particularly the loose surfaces of gravel and crushed stone, tend to cause accidents when cars are changing directions, even when going straight ahead, because of the development of side coefficients of frictions that allow the vehicle to skid or roll over the loose material.

The over-all accident-producing qualities of the geometrics of highways are found primarily in such factors as sight distance, lane width, horizontal curvature, and particularly the intersections of different highways at grade. A four-lane divided access-controlled type of highway has a remarkable ability to maintain a low rate of traffic accidents, primarily because it eliminates the potential contact of vehicle with vehicle by eliminating at-grade intersections and eliminating the interference of vehicles of opposing directions when traveling in adjacent lanes.

The four-lane divided type of highway eliminates accidents by reducing the number of speed changes required. That is, there is little need to slow down for other traffic, for urban areas, or for access to a highway from residences, commercial establishments, and farm driveways.

Figures 13, 14, and 15 show accident rates for two classes of highways, expressed in accidents per 0.3-mile section.

TRAVEL TIME AND ITS VALUE

The clock time required to travel from an origin to a destination of a specific trip is usually an important factor to drivers and passengers of motor vehicles. In fact, travel time is often the basis of electing the routing of a certain trip, and is used in many trip allocation studies in forecasting the use of proposed highway facilities.

Travel time has psychological attributes that give it, perhaps, an importance in the minds of drivers and travelers far beyond its real monetary value to them. Principally, people do not like to be delayed. Observation of drivers shows that they are more satisfied if they keep moving while in their vehicle, and they are dissatisfied when the car is stopped. Some of these objections are psychological, for if drivers can be kept in motion at any reasonable speed they are not particularly dissatisfied with the trip, even preferring it to a trip that requires less time but involves more stops.

The travel time required for a specific trip is usually a function of two elements of the highway: (1) the normal design speed or legal speed for a given routing, and (2) the impediments to traveling uniformly at the design or legal speed. Traffic conditions, horizontal curves, grades, corners, traffic interferences, and changing of legal speeds are the factors that produce driving at nonuniform speeds. Whenever the speed of the vehicle must be reduced below design speed or legal speed, additional travel time is involved in that particular trip. Consequently, the ideal type of highway is one that can be driven at uniform speed. This ideal is approached on toll highways and the Interstate system where the speed changes, either slowdowns or stops, are comparatively few. When speed changes do occur, they generally are brought about by some traffic interference up to the point of congestion and by the failures of drivers to use the off-ramps and on-ramps in the most efficient manner.

Dollar Value of Travel Time

It long has been the custom in highway economy studies to price travel time in dollars so that the figures could be used in the economy analysis along with the factors of motor vehicle running cost. In general, each analyst has used his own particular value of time, arrived at by a study of wage rates or by studying the literature. The literature, on the other hand, usually has given the value of time as that given in prior literature, no author having determined the value in a scientific manner.

In the earlier days, some values of time were determined by comparing what people paid to use a toll bridge rather than a toll ferry or to use a toll bridge in preference to a longer toll-free route. The modern version of this attempt to value highway travel time was the work of Claffey and St. Clair (*6-5, 6-27*) done in connection with the cost allocation study published in 1960-61 (*6-27*). The Claffey study involved driving toll highways and parallel free roads in many parts of the U.S. By mathematical manipulations it was then possible to arrive at a value of time based on the toll rate paid and the differential in travel time between the toll highway and the nontoll, or free highway. This work resulted in a value of $1.42 an hour for a passenger car and its occupants in driving intercity trips. Urban driving was not evaluated.

Two more recent studies are those by Thomas (*6-25*) and Lisco (*6-13*). The Thomas study involved the same driver-choice environment as was used by Claffey, but it was applied solely to urban commuter travel at peak hours and with a much improved mathematical model. The Lisco study was done in the Chicago area and used the rail rapid transit from the Skokie Swift area into the Chicago Loop.

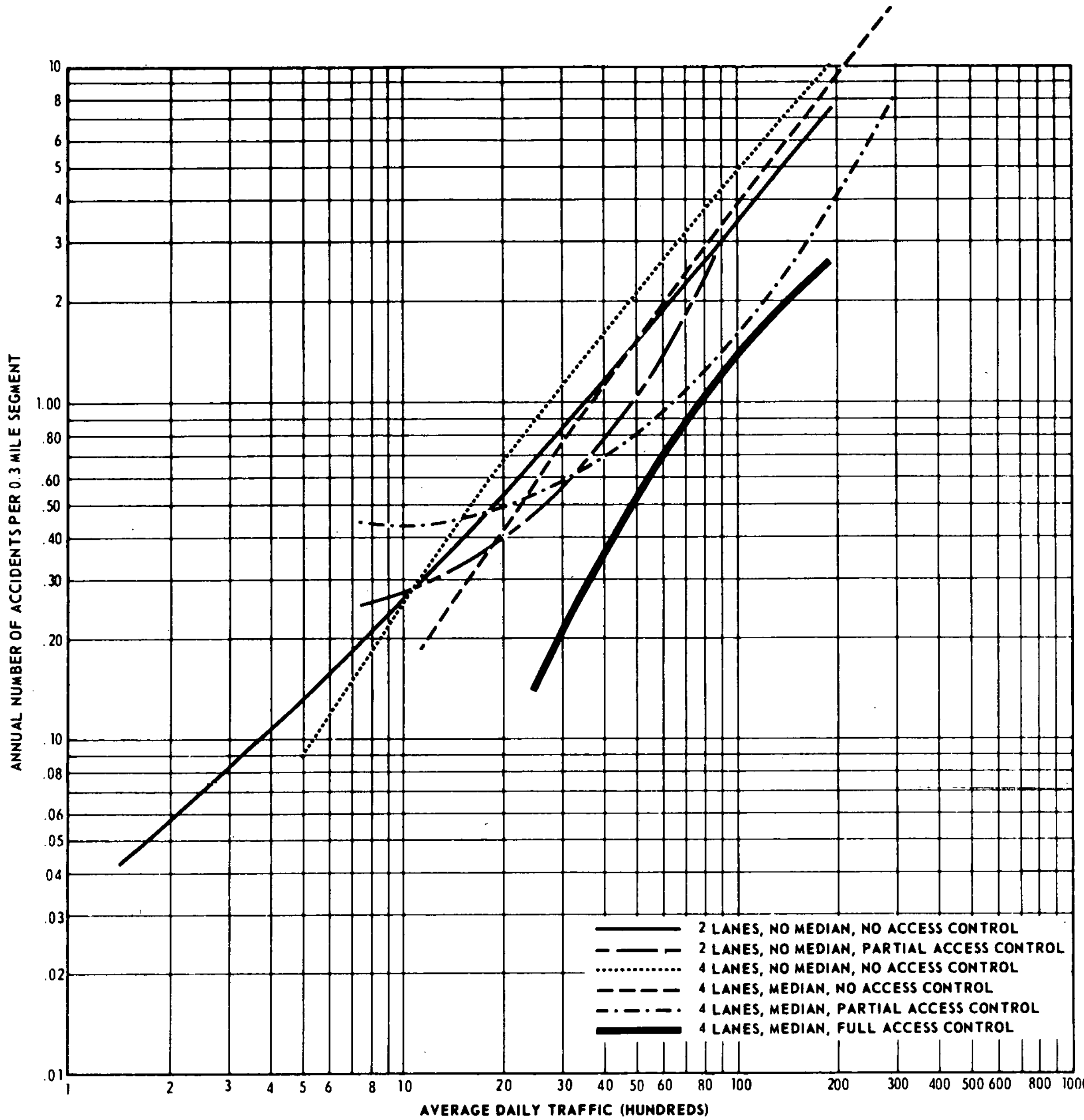

Figure 13. Average total accident rates, Ohio. Source: (6-6).

The Lisco study compared driving one's personal automobile into the Loop, as compared to riding the rail rapid transit. The Thomas study came out with a value of about $2.80 per person-hour and the Lisco study arrived at about $2.50 a person-hour. It must be realized that these two values in dollars per hour of travel time represent highly selected conditions; first, the rates apply solely to urban peak-hour driving and solely to employed persons on their home-to-work or work-to-home trip. They also refer only to commutation trips of middle- to upper-middle-class suburbanites. These values, determined in 1966 and 1967, respectively, are perhaps the highest values that highway travelers ordinarily place on highway travel time. There is a need to extend the work to urban off-peak travel, including night travel, and to make a similar determination on intercity travel. The mathematical technique used by Thomas is superior to that used in the Claffey study and overcomes some of the technical difficulties involved. The Lisco study uses almost the identical mathematical solution as was used in the Thomas study.

The Texas Transportation Institute (*6-1*) undertook to evaluate the travel time of commercial vehicles.

Travel time is greatly and distinctly affected by highway design and traffic conditions, and is directly proportional to distance traveled under constant speed. It is affected by vertical grades, especially so for the travel of heavy trucks. Similarly, the minus grades affect travel time because of a necessity of slowing down for reasons of safety, even though the vehicle power would be adequate.

Table 7 gives the total values of travel time of com-

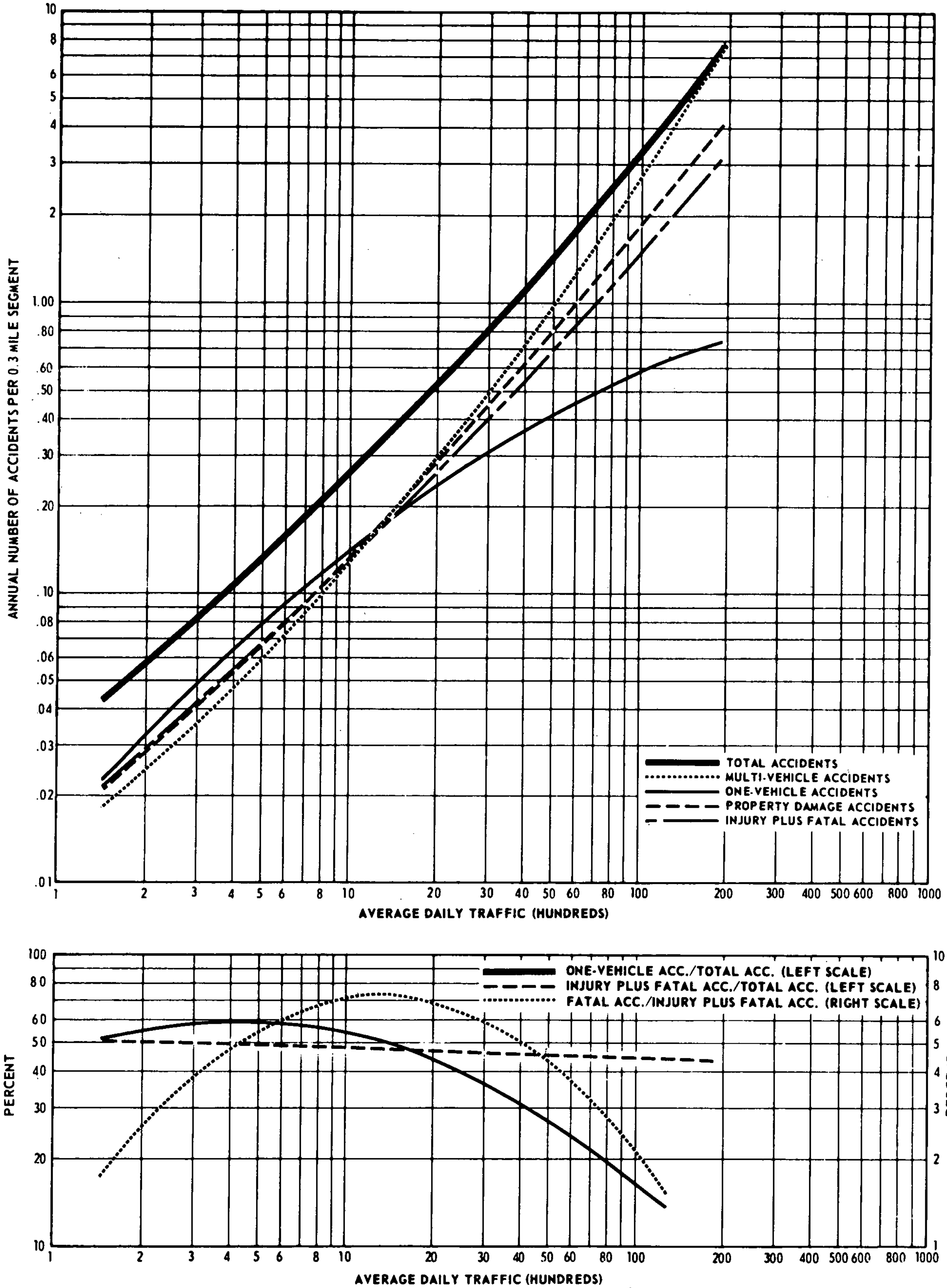

Figure 14. Average accident and severity rates, by ADT; Ohio, 2-N-N, all segments. Source: (6-6).

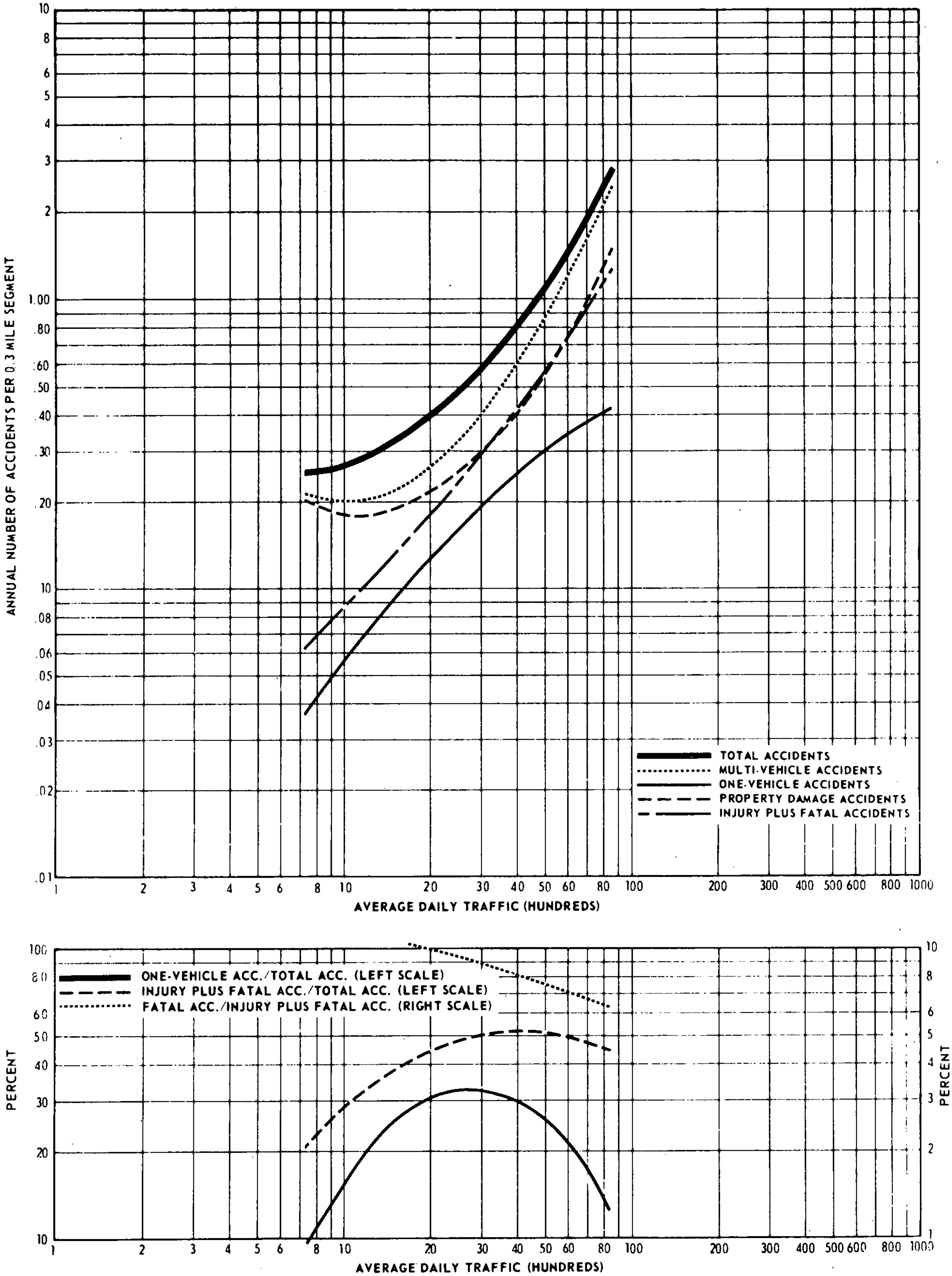

Figure 15. Average accident and severity rates, by ADT; Ohio, 2-N-P, all segments. Source: (6-6).

TABLE 7

SUMMARY OF VALUE OF TRAVEL TIME OF INTERCITY CARGO VEHICLES, BY TYPE, BY ICC REGION (1962 DATA UPDATED TO 1965)

VEHICLE TYPE [a]	VALUE OF TIME SAVINGS ($/HR) SOUTHERN	NEW ENGLAND	MIDDLE ATLANTIC	CENTRAL	NORTHWESTERN	MIDWESTERN	SOUTHWESTERN	ROCKY MOUNTAIN	PACIFIC
Composite cargo vehicle	5.45	4.86	5.16	5.39	6.11	5.62	6.56	5.16	5.75
S.U. 2-axle gasoline, van	4.16	3.95	3.99	4.23	4.43	4.20	4.28	3.86	4.11
S.U. 2-axle diesel, van	4.30	4.06	4.11	4.34	4.62	4.34	4.46	3.97	4.23
S.U. 3-axle gasoline, van	4.66	4.37	4.42	4.65	5.14	4.73	4.94	4.26	4.55
S.U. 3-axle diesel, tank	5.41	5.00	5.07	5.29	6.22	5.53	5.94	4.89	5.22
2-S1 gasoline, light, van [e]	5.03	4.46	4.57	4.67	5.47	5.04	5.53	4.77	5.07
2-S1 gasoline, light, tank	5.35	4.73	4.84	4.94	5.93	5.37	5.95	5.03	5.36
2-S2 gasoline, heavy, van	5.71	5.04	5.16	5.26	6.41	5.75	6.40	5.34	5.70
2-S2 diesel, light, van	5.82	5.13	5.25	5.35	6.56	5.87	6.54	5.43	5.79
2-S2 gasoline, heavy, tank	6.04	5.31	5.44	5.53	6.87	6.10	6.83	5.61	5.98
2-S2 diesel, light, tank	6.14	5.40	5.53	5.62	7.02	6.21	6.97	5.70	6.08
3-S2 gasoline, van	5.84	5.20	5.27	5.37	6.57	5.89	6.56	5.46	5.82
3-S2 diesel, light, van	6.38	5.58	5.67	5.76	7.22	6.37	7.16	5.83	6.22
3-S2 gasoline, tank	6.17	5.47	5.55	5.65	7.03	6.22	6.99	5.72	6.10
3-S2 diesel, light, tank	6.71	5.85	5.94	6.04	7.68	6.71	7.59	6.10	6.50
3-2 diesel, light, van	—	—	—	—	—	—	—	5.79	6.18
3-2 diesel, light, tank	—	—	—	—	—	—	—	5.96	6.36
2-S1-2 diesel, heavy, van	—	—	—	—	—	—	—	6.58	7.02
3-S2-4 diesel, heavy, van	—	—	—	—	—	—	—	7.78	8.29

[a] See Table C-2 (*6-1*) for equipment descriptions.
Source: (*6-1*, p. 32).

merical vehicles by ICC regions; Table 8 gives the breakdown of the total value by subitems for the Midwestern Region.

Highway Design Factors and Travel Time

The passenger car, except for the lightly powered foreign models, is not affected materially by plus grades below

TABLE 8

VALUE OF TRAVEL TIME COMPONENTS FOR CARGO VEHICLES BY AXLE, ENGINE, AND BODY TYPES, MIDWESTERN REGION (1962 DATA UPDATED TO 1965)

VEHICLE TYPE [a]	VALUE OF TIME SAVINGS ($/HR) INTEREST,[b] S_1'	DEPRECIATION,[b] S_2'	PROPERTY TAX,[b] S_3'	DRIVERS' WAGES,[c] S_4'	DRIVERS' WELFARE,[c] S_5'	WORKMEN'S COMPENSATION,[c] S_6'	SOCIAL SECURITY,[c] S_7'	TOTAL, V'
Composite cargo vehicle	0.2064	1.0012	0.0651	3.9196	0.2712	0.0407	0.1129	5.6171
S.U. 2-axle gasoline, van	0.0739	0.3585	0.0233	3.3652	0.2329	0.0349	0.1129	4.2016
S.U. 2-axle diesel, van	0.0971	0.4710	0.0306	3.3652	0.2329	0.0349	0.1129	4.3446
S.U. 3-axle gasoline, van	0.1593	0.7726	0.0502	3.3652	0.2329	0.0349	0.1129	4.7280
S.U. 3-axle diesel, tank	0.2901	1.4072	0.0915	3.3652	0.2329	0.0349	0.1129	5.5347
2-S1 gasoline, light, van [e]	0.1294	0.6278	0.0408	3.8208	0.2643	0.0397	0.1129	5.0357
2-S1 gasoline, light, tank	0.1844	0.8946	0.0582	3.8208	0.2643	0.0397	0.1129	5.3747
2-S2 gasoline, heavy, van	0.2285	1.1090	0.0722	3.9196	0.2712	0.0407	0.1129	5.7541
2-S2 diesel, light, van	0.2466	1.1969	0.0778	3.9196	0.2712	0.0407	0.1129	5.8657
2-S2 gasoline, heavy, tank	0.2844	1.3797	0.0898	3.9196	0.2712	0.0407	0.1129	6.0983
2-S2 diesel, light, tank	0.3025	1.4676	0.0954	3.9196	0.2712	0.0407	0.1129	6.2099
3-S2 gasoline, van	0.2415	1.1715	0.0763	3.9689	0.2746	0.0412	0.1129	5.8869
3-S2 diesel, light, van	0.3195	1.5500	0.1008	3.9689	0.2746	0.0412	0.1129	6.3679
3-S2 gasoline, tank	0.2851	1.4422	0.0939	3.9689	0.2746	0.0412	0.1129	6.2188
3-S2 diesel, light, tank	0.3753	1.8207	0.1184	3.9689	0.2746	0.0412	0.1129	6.7120

[a] See Table C-2 (*6-1*) for equipment descriptions.
[b] Based on 1962 replacement costs of equipment.
[c] From 1962 ICC data updated to 1965 using the multipliers shown in Table 22 (*6-1*).
Source: (*6-1*, p. 35).

4 percent, because the car usually has enough reserve power to maintain the ordinary road speed below a plus 4 percent grade. However, many people will not drive as fast up the grade as they do on the level, so there is some sacrifice in travel time for passenger cars on plus grades.

The horizontal curves usually cause vehicles to slow down, except on the flat curves of 3° and less. Normally, a vehicle will slow down to take a curve even though the curve may be superelevated for the normal speed at which the traffic is traveling. There are psychological factors involved in driving curves at the same speed as one drives tangents on the same route.

One of the heaviest consumptions of travel time is the changing of vehicle speed. Every time a vehicle is required to slow down or to stop there is consumption of travel time over continuing at the initial speed. These time consumptions by speed changes are particularly noticeable in urban driving where slowdowns and stops are often required because of traffic interference, stop signs, yield signs, intersections, traffic signals, turning corners, etc.

The roadway surface affects speed and, therefore, travel time, primarily by its degree of roughness. The loosely bound roadway surfaces of gravel and crushed stone do not permit driving much in excess of 40 mph. The driver also will drive slower on a rough paved surface than he would on a hard, smooth surface.

Lane width and roadside obstructions affect the speed of traffic. Narrow lanes, narrow shoulders, roadside objects, and narrow bridges result in speed changes and, therefore, reductions in speed and increases in travel time.

Role of Travel Time in Economy Studies

In engineering economy studies of highway improvements there is a serious question as to what weight to give passenger car travel time on highways. It is general practice, however, to treat travel time as a cost of travel priced out at the selected value per vehicle-hour, or selected value per person-hour, in the same way as factors of running costs of the vehicle, such as fuel, oil, and tires.

In these analyses, time is customarily priced for all travel time, regardless of the reasons for changes in speed and amount of travel time reduction. In general, reductions of travel times by such fractions of a minute as 5, 10, 15, or 20 sec are questioned as to whether they have economic value to the drivers. There is some evidence in Thomas (*6-25*) that commuters do not value travel time reductions of less than 5 min per trip. There is great uncertainty, however, as to what time is worth to travelers when related to the purposes of trips, the amount of travel time reduction possible through highway improvement, the time of day, and other factors involved.

Travel time has another distinguishing characteristic when compared with fuel, oil, tires, and maintenance factors of motor vehicles. A reduction in fuel, oil, or tire consumption results in a bona fide saving of commodities and, therefore, a real reduction in money outlay for a given trip or given vehicle use. Passenger car travel time, to the contrary, does not result in the saving of any commodities or even in the "saving" of time; the only difference is that travel may take less time and, therefore, that time not used in travel is available for some other activity. If it can be assumed that the time not used in travel can be put to productive use, particularly to a use that will earn a cash income, it would be readily apparent what the money value of that time would be, and, therefore, the economy effected by highway improvements would be a real economy. On the other hand, travel time reductions that are not used to gain monetary income must be looked at from a different viewpoint. This viewpoint is one of a transfer of one's activity as between travel and such other activity as leisure time, work time, sleep, or whatever one chooses to do with the time he did not spend in travel.

If all passenger car travel time reductions are priced out at some price per hour and used in the analysis for economy, the effect of this practice should be understood. In a money sense, this travel time reduction is not true economy, but it certainly is an economic factor that needs to be given proper consideration and that most travelers recognize as an important feature of their travel. On the other hand, there is not money left unspent as there is when one does not buy fuel, oil, or tires, but time is made available for other purposes. The highway, therefore, in this particular case of travel time reductions would have to be financed by the highway users spending less money on other activities and purchases as opposed to paying for the highway from the money they did not spend for the consumption of commodities.

It is advisable to treat travel time as a separate item in economy studies in order that the decision maker can see readily the amount of over-all gains that are priced out on the basis of the dollar value of time and those gains that are actual bona fide reductions in expenditures for travel.

For the commercial vehicle, however, the value of travel time can be used as a straightforward value in the same way that the nonconsumption of fuel, oil, and tires is used as a direct gain. Commercial vehicles are operated to make a profit, and, because they are operated for commercial reasons, they are usually carrying paid drivers. If the new facility permits the driver to cover greater distances or to make more trips per day, there is a definite reduction in the cost of doing business. This same conclusion may apply to the passenger car when used for professioal purposes, such as by the medical profession, salesmen, and in service work.

The value of passenger car travel time is especially important in economic evaluation. Many types of projects can be justified economically solely on the basis of the travel time reductions when this travel time reduction is priced at a reasonably high value in dollars per vehicle-hour. On the other hand, in project formulation (i.e., as an aid in deciding between alternative features of highway design) the economic analysis may not be so sensitive to the price per hour applied to passenger car travel time as it is in economic evaluation. This does not mean, however, that due precautions should not be taken in the pricing of time for project formulation. It is probable that the differences in travel time may not be material between mutually exclusive alternatives, and, therefore, with respect to the features of highway design, whereas, in comparing a proposed highway or proposed highway improvement with an existing situation, the differences in travel time expressed in hours or in dollars may be great.

DRIVING STRAINS AND PERSONAL PREFERENCES

One of the benefits of most types of highway improvements is the reduction of mental and physical driving strains for the driver and passengers of both cars and trucks. The words "comfort" and "convenience" are often used to imply the same factors that produce driver strains or relieve the driver from such strains. Another expression used for this purpose is "personal preference."

Character of Personal Preferences

The factors of driver strains and personal preferences are evaluated by each individual separately, and what he is willing to pay for the elimination of strains or the increase in comfort and convenience really is a personal matter. Throughout our society there are many illustrations of payment for comfort and convenience inside and outside of transportation (e.g., the air-conditioning of automobiles is a good illustration of what many individuals are willing to pay for a more comfortable ride). One pays for mechanical and electrical equipment to save muscular strain, and hires taxicabs and drives cars for short trips to eliminate walking—probably a combination of comfort and convenience.

One of the considerations with particular reference to economic evaluation of proposed highway improvements is that even though people will pay good prices to eliminate driving strains and to acquire more personal preference satisfactions, in the long run these items of themselves do not contribute monetary savings in the same sense as do reductions in consumption of fuel, oil, and tires. Therefore, highway construction undertaken to produce additional comforts and conveniences to the highway traffic has to be undertaken with the realization that the payment for the highways cannot be made out of savings to the highway user, but the users or other people must pay for the added values and these personal preference benefits through a reduction in expenditures or the gaining of more income in other activities. The result is a transfer of consumer spending from one choice to another. These personal preference items are somewhat similar to time, although the personal preference items, with one possible exception, do not give the opportunity to convert the benefit into a monetary form as is possible with many of the reductions in travel times.

It is reasonable to assume that the reduction in mental and physical strains on the drivers and passengers of motor vehicles could result in a reduction of the accident rate, but, if this is true, the reduction in accident rate would be measured in the economy analysis not through reduction in driver strains but in terms of accident reduction as an input quantity into the analysis. On the other hand, a person who travels a comfortable and convenient highway may reach his destination in a good mental and physical condition with more energy than he would have otherwise. Therefore, he may be more productive in his daily occupation than he otherwise would be. In this case there is a direct economic contribution of the reduction of driver strains resulting from improved highways.

Personal Preference and Economic Analysis

To price comfort and convenience items on a dollar basis and to include these prices in the analysis may be a form of double counting. The reduction in driver strains or the increase in comfort and convenience of driving highways is largely a result of highway design and traffic control which in themselves eliminate the factors that produce discomfort and inconvenience. These are primarily those that cause a good deal of turning and changing of directions and speed of the vehicle. To the extent that these two factors of design do produce economy in driving by reducing the consumption of fuel, oil, and tires they would be evaluated at this point directly, and the added benefits of reduced driver strains could be regarded as a by-product. To evaluate both driver strains and any reduction in vehicle running cost as related to speed changes and then to include them both in the analysis for economy would be double counting.

These factors that produce the unwanted mental and physical strains for drivers and passengers in highway transportation have not been quantified. The work by Claffey (*6-5*) in his toll road-free road driving, wherein he endeavored to find a value of travel time, also included the factor of measuring speed changes as an index to comfort and convenience of driving. The statistical analysis used by Claffey in this respect resulted in a cents-per-mile value of a speed change, but the statistical tests of the results indicated that the work was not statistically sound. Therefore, his dollar price of a speed change is not a reliable index. Thomas also attempted to measure the discomfort and inconvenience associated with driving in congested traffic. He formulated a number of different variables to measure congestion and found that none would significantly improve the degree to which he could explain route choices. Until further research gives a better scientific analysis of the specific factors that produce driver strain, comfort, convenience, and other factors of personal preferences, it perhaps is a better procedure to omit such factors from the analysis for economy.

In spite of the widespread recognition of the role of driver strains and personal preference factors in highway use, the factors that produce strains, comfort, and convenience have not been quantified; neither have they been priced directly. Including them in an analysis for the economy of proposed highway improvements or the economy of alternative designs on mutually exclusive projects has to be done mostly on a total assumption basis. Therefore, it is not recommended that these factors be specifically included in the analysis for economy of proposed improvements. This does not imply that the decision maker should not evaluate these personal preference factors and give them the proper consideration in his ultimate decision, but it does mean that the analysis for economy in itself ends up with a more meaningful figure when the personal preference items are omitted.

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CHAPTER SEVEN

ENGINEERING FACTORS RELATED TO SOCIAL AND ECONOMIC CONSEQUENCES

HIGHWAYS IN SOCIETY

Each community, local or national, has certain goals. The accomplishment of these goals usually involves transportation of goods and people by several modes. It is fundamental to society that transportation facilities and transportation itself exist not only for the sake of transportation, but also as a necessary factor in achieving the objectives of society. Therefore, the objective of travel of people and the transport of goods is to make possible the achievement of economic and social objectives.

The highway engineer, rightly or wrongly, in recent years has been accused of designing and operating highways for the pure sake of transportation rather than to aid in accomplishing the over-all objectives of society (such as the preservation or change of social customs, historical sites, and natural beauty). The criterion by which the success of highway transportation should be measured is the extent to which a specific highway and the highway system as a whole accomplish the objectives of society in an efficient and acceptable manner. One factor in this measurement is the extent to which the transportation itself is performed at the lowest over-all and long-run economic cost consistent with providing the satisfactions included in the community's objectives and standards.

Therefore, in the economic analysis of proposed highway improvements it is natural to consider two separate sets of factors: (1) the direct highway-user economy of transportation and the economy, and (2) the economic and social effects involved in the community consequences of highway transportation, or simply, the nonuser and the user effects. Another logical reason for this division is that generally the social and community economic consequences of highways cannot be priced on a market basis, so that their costs and benefits cannot be directly compared with the measurable dollar costs and benefits of the road user, considering both the highway and the vehicle.

The management decision process involves: (1) whether to improve the highway, and (2) what specific location and design to adopt if the decision is to construct the proposed new facility. In reaching both of these decisions, the decision maker should consider all of the factors in each main division—that is, the nonuser factors in terms of the objectives of society and the road-user factors in terms of economical, efficient transportation desirable as a means of promoting the objectives of society.

PROCEDURE OF ECONOMIC ANALYSIS

The decision maker who must decide whether to construct a highway facility (and, if so, to what specific engineering design) needs many types of aids or guides in arriving at his decision. The relative economy of the road-user costs and benefits is one type of decision aid available. Another and equally important decision aid is the analysis of the social and economic costs and benefits. These social and economic factors ordinarily are not wholly reducible to a dollar basis, but, where the costs are not so reducible, the beneficial and adverse consequences may be qualitatively and quantitatively described through the process of cost-effectiveness analysis discussed in Chapter Three.

The building up of statistical, analytical, and descriptive aids useful in reaching a decision can start with either the engineering factors or the social and economic factors. In either case, the analyst, whether an engineer, a sociologist, or an economist, needs to have some knowledge of the total picture and of the interrelationships of the complex of factors. These relationships are highly involved and somewhat subjective in measurement and classification. The next section lists the highway factors and the economic and social consequence factors, and attempts to show their

TABLE 9

HIGHWAY ENGINEERING FACTORS THAT HAVE NONUSER CONSEQUENCES

GROUP AND FACTORS
I. Planning, Predesign, and Preconstruction Activities
1. Coordination with other transportation facilities.
2. Coordination with land-use plans, projections, and zoning.
3. Degree of support of community objectives and goals.
4. Length of time involved from conception to award of construction contract.
II. Rights-of-Way and Route Location
5. Corridor location.
6. Center-line location.
7. Landscape of right-of-way.
III. Highway Design
8. Degree of control of access.
9. Basic geometric design.
10. Steepness of gradient.
11. Elevation of grade line relative to adjacent land.
12. Horizontal curves.
13. Intersections and interchanges.
14. Traffic safety factors.
IV. Structural Design and Materials
15. Geometric shape.
16. Physical size.
17. Aesthetics of construction materials.
V. Construction Operations
18. Period of duration.
19. Equipment necessary.
20. Handling of traffic during construction.
VI. Traffic Control and Traffic Service
21. Driveway openings.
22. Highway lighting.
23. One-way and reversible traffic flow.
24. Speed changes.

TABLE 10

DEGREE OF EFFECT OF ENGINEERING FACTORS ON SPECIFIC SOCIAL AND ECONOMIC CONSEQUENCES

H - Heavy
M - Medium
S - Slight
-- - None
X - Not applicable

Social and Economic Consequential Factor	Highway Design Element and Degree It Affects The Consequences																													
	GROUP I. Planning, Predesign, and Preconstruction Activities	1. Coordination with other transportation facilities	2. Coordination with land use plans, projections, and zoning	3. Degree of support of community objectives and goals	4. Length of time involved from conception to award of construction contract	GROUP II. Rights-of-way and Route Location	5. Corridor location	6. Centerline location	7. Landscape of right-of-way	GROUP III. Highway Design	8. Degree of control of access	9. Basic geometric design	10. Steepness of gradient	11. Elevation of grade line relative to adjacent land	12. Horizontal curves	13. Intersections and interchanges	14. Traffic safety factors	GROUP IV. Structural Design and Materials	15. Geometric shape	16. Physical size	17. Aesthetics of constructional materials	GROUP V. Construction Operations	18. Period or duration	19. Equipment necessary	20. Handling of traffic during construction	GROUP VI. Traffic Control and Traffic Service	21. Driveway openings	22. Highway lighting	23. One-way and reversible traffic flow	24. Speed changes
1. Aesthetics																														
a. The view from the road		--	S	M	--		M	H	H		H	H	S	H	M	M	--		H	H	M		H	--	H		--	--	--	--
b. The view of the road		--	M	M	--		M	H	H		H	H	S	M	M	M	--		H	H	M		H	--	H		--	--	--	--
c. Highway-mode induced aesthetic effects		--	M	M	--		M	M	M		H	H	S	M	M	H	S		H	H	M		H	--	H		--	--	--	--
2. Agriculture																														
a. Access to improved road		--	M	M	--		--	M	--		H	S	S	H	--	H	--		--	--	--		H	--	H		H	--	M	--
b. Economic units (size of farm unit)		--	S	--	--		S	M	--		H	S	S	M	S	S	--		--	--	--		--	--	--		M	--	--	--
c. Productivity		--	M	--	--		--	--	M		--	--	--	--	--	--	--		--	--	--		--	--	M		--	--	--	--
d. Dislocation		--	--	--	--		S	H	--		S	--	--	--	--	--	--		--	--	--		--	--	--		--	--	--	--
3. Commercial																														
a. Commercial sales receipts and incomes		--	M	M	M		H	H	S		M	M	S	M	--	H	S		S	M	--		M	S	H		H	S	M	S
(a) Change due to dislocation and relocation		--	--	M	M		S	H	--		X	X	X	X	X	X	X		X	X	X		X	X	X		X	X	X	X
(b) Change due to barrier		--	M	M	--		S	H	--		X	X	X	X	X	X	X		X	X	X		X	X	X		X	X	X	X
(c) Change due to population change		--	M	M	M		S	S	S		X	X	X	X	X	X	X		X	X	X		X	X	X		X	X	X	X
(d) Change due to income group change		--	M	M	M		S	S	M		X	X	X	X	X	X	X		X	X	X		X	X	X		X	X	X	X
(e) Change due to traffic volume change (bypass effect)		--	M	M	--		M	M	M		X	X	X	X	X	X	X		X	X	X		X	X	X		X	X	X	X
(f) Change due to accessibility change (trade area)		--	M	M	--		M	M	H		X	X	X	X	X	X	X		X	X	X		X	X	X		X	X	X	X
(g) Change due to community price change (resulting from transportation)		--	--	--	--		S	M	--		X	X	X	X	X	X	X		X	X	X		X	X	X		X	X	X	X
b. Rental property receipts		--	M	--	M		S	H	S		S	S	M	H	--	S	--		--	--	--		H	M	H		S	S	S	--
c. Employment		--	M	M	S		S	H	--		M	S	--	--	--	S	--		--	--	--		M	M	M		S	S	S	--
d. Land use		--	H	M	S		S	H	M		M	S	S	H	S	M	--		--	--	--		S	S	S		M	S	S	--
e. Land value		--	H	M	S		S	H	M		M	S	S	M	S	M	--		--	--	--		S	S	S		M	S	S	--
f. Effects on public transportation		H	M	M	S		M	H	--		M	H	--	--	--	M	--		--	--	--		H	M	H		--	--	S	--
g. Parking		M	M	M	--		M	H	--		H	H	--	--	--	S	S		--	--	--		H	S	H		--	--	M	--
4. Government																														
a. Community services and facilities		M	M	M	S		M	H	S		S	H	--	--	--	M	--		--	--	--		M	--	M		--	S	S	--
b. Park, recreation, and open space		--	H	M	--		M	H	H		S	M	--	--	--	M	--		--	--	--		--	--	H		--	S	--	--
c. Non-highway government revenues and expenditure changes		M	S	S	S		S	H	--		M	--	--	--	--	M	--		--	--	--		S	--	M		--	--	--	--
d. Public policy and laws		S	S	M	--		--	--	M		--	--	--	--	--	--	--		--	--	--		--	--	--		--	--	--	--
e. Community goals		H	H	H	--		M	M	H		S	--	--	--	--	S	--		--	--	--		--	--	--		--	--	--	--
5. Construction																														
a. Community social and economic effects during construction		--	--	--	--		S	H	--		S	M	--	M	--	M	--		--	--	--		H	S	H		--	--	--	--
b. Immediate effects on highway construction industry		--	--	--	--		--	--	--		X	X	X	X	X	X	X		X	X	X		M	X	X		X	X	X	X
c. Long run effects on non-highway construction industry		--	--	--	--		--	--	--		M	S	--	--	--	M	--		--	--	--		--	--	--		--	--	--	--
6. Employment																														
a. Employment change due to new land use development		--	S	S	--		S	M	S		--	M	--	--	--	--	--		--	--	--		--	--	--		--	--	--	--
b. Employment change due to dislocation and relocation		--	S	S	--		S	H	--		--	--	--	--	--	--	--		--	--	--		--	--	--		--	--	--	--

interrelationships. It is thought that a highway department, a highway design engineer, or a design team representing different disciplines can be aided by the classification and description that follows.

ENGINEERING FACTORS

The engineering factors of highway design, including the center-line location of a highway, lead to certain social and economic consequences, both favorable and unfavorable. Although every engineering factor of highway design affects the road user, many individuals have not considered that these same factors have general social and economic consequences on the environment and the community.

Table 9 gives 15 groups of engineering factors. These factors are chosen and grouped with specific references to their application in connection with their consequences on the social and economic environment.

These engineering factors have both a direct and an indirect, or a primary and secondary, effect on the social and economic values and activities within the community. The highway is designed to provide for mobility of people and goods, but such mobility results in direct and primary effects on transportation considered solely as transportation. But because these engineering factors, in achieving their transportation function, also affect the value and use of land, and the location of commerce and social activities, they have pronounced consequences on the objectives of society, the achievement of which requires transportation facilities.

TABLE 10 (*continued*)

H - Heavy
M - Medium
S - Slight
-- - None
X - Not applicable

Social and Economic Consequential Factor	Highway Design Element and Degree It Affects The Consequences																											
	GROUP I. Planning, Predesign, and Preconstruction Activities	1. Coordination with other transportation facilities	2. Coordination with land use plans, projections, and zoning	3. Degree of support of community objectives and goals	4. Length of time involved from conception to award of construction contract	GROUP III Rights-of-way and Route Location	5. Corridor location	6. Centerline location	7. Landscape of right-of-way	GROUP III. Highway Design	8. Degree of control of access	9. Basic geometric design	10. Steepness of gradient	11. Elevation of grade line relative to adjacent land	12. Horizontal curves	13. Intersections and interchanges	14. Traffic safety factors	GROUP IV. Structural Design and Materials	15. Geometric shape	16. Physical size	17. Aesthetics of constructional materials	GROUP V. Construction Operations	18. Period or duration	19. Equipment necessary	20. Handling of traffic during construction	GROUP VI. Traffic Control and Traffic Service	21. Driveway openings	22. Highway lighting	23. One-way and reversible traffic flow	24. Speed changes
7. Environment																												
a. Noise		--	--	M	--		S	H	H		--	S	M	--	--	S	--		--	--	--		H	H	H		--	--	--	M
b. Air pollution		--	--	M	--		--	S	S		--	S	M	-	--	S	--		--	--	--		H	M	H		--	--	--	M
c. Virbration		--	--	M	--		--	M	S		--	-		-	--	S	--		--	--	--		--	H	M		--	--	--	--
d. Drainage patterns		--	--	M	--		S	H	M		S	S	M	M	--	S	--		S	S	--		--	--	--		--	--	--	--
8. Industrial																												
a. Industrial development		--	M	M	S		S	M	--		M	S	S	M	--	M	--		--	--	--		--	--	--		M	S	S	--
b. Industrial dislocation		--	--	--	--		S	H	--		--	S	--	--	--	M	--		--	--	--		--	--	--		--	--	--	--
c. Industrial relocation		--	M	M	S		M	H	--		M	S	S	M	--	M	--		--	--	--		--	--	--		M	S	--	--
d. Industrial land use		--	M	M	S		M	H	S		M	S	S	M	--	M	--		--	--	--		--	--	--		M	M	S	--
e. Industrial land value		--	M	M	S		M	H	S		M	S	S	M	--	M	--		--	--	--		--	--	--		M	M	S	--
9. Institutions																												
a. Institutional dislocation and relocation		--	M	M	S		S	H	--		S	--	S	S	--	S	--		S	S	--		--	--	--		M	M	S	--
b. Institutional accessibility and patronage change		--	M	M	S		S	H	--		S	--	--	--	--	S	--		S	S	--		--	--	--		M	M	S	--
10. Population																												
a. Population growth		S	M	M	S		S	H	S		S	S	S	S	--	M	--		--	--	--		--	--	--		--	--	--	--
b. Population density		M	M	M	S		S	H	--		M	S	S	S	--	H	--		--	--	--		--	--	--		--	--	--	--
c. Population geographic shifts		M	M	M	S		S	H	S		S	S	S	S	--	S	--		--	--	--		--	--	--		--	--	--	--
d. Population distribution		M	M	M	S		M	H	--		H	M	--	M	--	H	S		--	S	S		S	--	S		--	--	S	--
11. Public utilities																												
a. Utility joint-use of right-of-way		M	--	--	--		S	M	S		M	M	S	S	--	S	M		M	K	--		--	--	--		S	S	--	--
b. Utility dislocations and relocations		S	--	--	--		S	H	--		H	M	S	S	--	--	--		M	M	--		--	--	--		--	--	--	--
c. Utility patterns and costs		S	--	--	--		S	M	S		M	M	S	S	--	S	--		M	M	--		M	--	M		S	--	--	--
12. Residential neighborhoods																												
a. Rents, costs, and prices of replacement housing		--	--	--	S		M	M	S		--	--	--	--	--	--	--		--	--	--		--	--	--		--	--	--	--
b. Residential relocation costs		--	--	--	S		M	M	--		--	--	--	--	--	--	--		--	--	--		--	--	--		--	--	--	--
c. Social and economic relationships of dislocatees		--	--	S	S		S	H	S		S	--	--	--	--	S	--		--	--	--		--	--	--		--	--	--	--
d. Quality of neighborhood life		S	S	M	M		S	M	H		S	S	S	S	--	M	--		--	S	S		--	--	--		--	S	--	--
e. Property values in right-of-way before taking		--	--	--	M		--	--	--		--	--	--	--	--	--	--		--	--	--		--	--	--		--	--	--	--
f. Neighborhood and community stability		M	M	M	M		M	H	M		S	S	--	--	--	M	--		--	--	S		--	--	--		--	S	--	--
g. Neighborhood and community linkage patterns		M	M	M	M		M	H	M		H	M	S	S	--	M	--		M	M	S		M	--	M		--	--	S	--
h. Residential land development		S	M	M	S		M	H	H		S	S	S	M	--	M	--		S	S	--		--	--	--		S	--	--	--
i. Residential property values		S	M	M	S		M	H	H		S	S	S	M	--	M	--		S	S	S		--	--	--		S	--	--	--
j. Neighborhood and community patterns		H	M	M	S		M	H	M		M	S	S	S	--	M	--		--	S	S		S	--	S		--	S	S	--
k. Social life and social patterns		S	M	M	S		M	H	S		M	S	S	M	--	M	--		--	S	S		S	--	S		--	S	S	--
13. Road-user																												
a. Accident and safety		--	--	--	--		--	S	S		H	M	S	S	S	M	H		M	M	--		S	--	S		M	M	M	M
b. Running costs -- distance related		--	--	--	--		M	H	--		H	--	--	--	--	H	M		M	M	--		M	--	M		M	--	S	S
c. Running costs -- land and population density and intensity related		--	--	--	--		M	M	M		M	--	--	--	--	M	--		S	S	--		--	--	--		--	--	--	--
14. Spatial and geographic changes																												
a. Local		M	M	M	S		M	H	H		H	--	--	S	--	M	--		--	--	--		S	--	S		--	--	--	--
b. Metropolitan		M	M	M	--		M	S	M		M	--	--	S	--	S	--		--	--	--		--	--	--		--	--	--	--
c. Regional		S	M	S	--		M	S	S		S	--	--	S	--	S	--		--	--	--		--	--	--		--	--	--	--
15. Urban form and development																												
a. Land use inventory		S	S	M	--		M	M	M		S	S	--	--	--	M	--		S	S	--		--	--	--		--	--	--	--
b. Land values; general		--	--	M	S		M	M	M		S	S	S	S	--	M	--		S	S	--		--	--	--		--	--	--	--
c. Central business district		H	M	M	--		M	H	--		S	S	--	--	--	S	--		--	--	--		--	--	--		--	--	--	--
d. Urban form and development patterns		H	M	H	--		H	H	M		M	S	S	S	--	M	--		--	--	--		--	--	--		--	--	--	--
e. Real property and land taken for right-of-way; Use and Value		X	X	X	X		X	X	X		X	X	X	X	X	X	X		X	X	X		X	X	X		X	X	X	X

The engineering factors of highway design and the improvement of the highway itself may be for the purpose of (1) reducing traffic congestion, (2) providing greater traffic capacity, (3) speeding up the movement of traffic, (4) reducing travel distance, (5) reducing motor vehicle running costs, and (6) reducing traffic accidents. But in the achievement of these direct and sought-after goals, the social and economic consequences come into being. These favorable and unfavorable consequences vary in magnitude, in intensity, and in degree of desirability or undesirability. The local situation and goals of the people within the community and the viewpoint applied (i.e., whether individual or collective) determine largely whether, and to what extent, the consequences are favorable or unfavorable. From the standpoint of achieving the goals of society at the minimum cost and disruption of normal activities, it is highly desirable that the highway designer and the highway department agency responsible give attention to the factors of transportation that are highway-motor-vehicle and highway-user oriented and equal attention to the social and economic factors that are affected by the transportation factors.

THE RELATIONSHIP OF ENGINEERING FACTORS TO SOCIAL AND ECONOMIC FACTORS

In the final analysis, good highway administration calls for considering all factors involving the user and the nonuser. Table 10 serves as an aid to better appreciation of what is involved in reaching an acceptable compromise between the ideal highway from the standpoint of transportation efficiency and the ideal highway for the purpose of serving the social and economic goals of society. Table 10 attempts to interrelate the social and economic factors affected by highway improvement with the engineering factors of Table 9. In Table 10 the engineering factors of Table 9 are indicated as to whether they have heavy, moderate, or slight influence on the consequential social and economic factors. Any of the engineering factors not indicated by a reference number to Table 9 are thought not to influence that particular social or economic consequence. Although this table is a result of considerable subjective evaluation it nevertheless should be helpful in developing an improved understanding of the relationship of highway engineering to the community social and economic factors.

As a further index of the relationship between engineering and nonroad-user consequences, Table 10 indicates whether the highway designer or the highway agency can control the consequence, whether he may control it partially, or whether he has no control whatsoever.

It should be obvious that a highway department cannot control the market value of private land adjacent to the highway, or its use. On the other hand, the value of adjacent land is influenced by highway location and design. This effect on the value of land is considered to be an indirect consequence of the highway improvement. The highway may have been built to improve transportation efficiency. The change in land value may be a result of the increased efficiency of the highway, but such change in land value and land use was not an objective of the highway department.

Because the highway department determines what land is to be taken for highway purposes and where access to the highway is to be provided, it also determines what particular people and establishments may be forced to relocate, or will be otherwise affected by the highway. Table 10 is presented without any recognition of whether the effects of engineering on the social and economic factors are favorable or unfavorable and whether the effects would be frequent or infrequent, temporary, or long lasting. A good understanding of Table 10 and its supporting concepts affords a better understanding of the desirability of considering the engineering factors of transportation together with the community social and economic factors in the final decisions as to highway improvements, including highway location and all design elements.

Four basic considerations are involved: (1) How does the highway affect the social and economic factors? (2) To what extent does it do this? (3) From what viewpoint will the ultimate decision be made? and (4) Will greater weight be given the road user or the nonuser, and to what sectors within the nonuser factors? It is recognized, particularly in the case of urban highway improvements, that locating urban expressways and freeways determines just what particular land will be acquired for the highway. Almost without question, certain individuals will have to suffer somewhat in order for the community to gain the advantages of improved transportation. Generally, the objections to any highway location come from the few people in the community who will be directly adversely affected. The larger percentage of the people in the community will not be directly affected and will suffer no social or economic cost or disruption, but they will gain whatever benefits they choose to use from the new highway facility.

The foregoing can be illustrated by referring to the design of a freeway system for an urban community as opposed to the designing of a particular segment of the freeway system. In laying out a freeway system, there may be little opposition, because specific properties and specific disruptions of the community life are not pinpointed. However, in the design of a particular segment of the freeway system, specific lands and individuals are pinpointed. It is often from this source that the objections and opposition arise. Therefore, it is important that the highway department be aided by reliable knowledge of how engineering decisions will affect the social and economic forces in the community and to what extent these disruptions and unfavorable consequences can be minimized while still gaining the efficiencies in transportation that were the original goals. The devices, procedures, and designs by which these conflicting goals can be compromised call for teamwork between the highway engineer and the sociologist, the economist, the psychologist, the political scientist, the urban planner, and local citizens.

CHAPTER EIGHT

ECONOMIC THEORY RELATED TO USER AND NONUSER CONSEQUENCES

Public investment in transportation facilities in a developed economy (as distinct from an undeveloped or underdeveloped one) takes place mainly to improve efficiency of portions or the whole of an already established transportation system.

To prove that the transportation efficiency gains exceed the costs incurred to obtain them is the task of the engineering economy analysis described in the preceding chapters. The achievement of the expected efficiency gains results in a change—usually a lowering—of the cost of tripmaking in one or more of its dimensions: vehicle operating costs, travel time, risk, comfort and convenience. The change in cost becomes the *independent variable* to which some other economic and social variables respond. These responses are some of the so-called "nonuser" consequences of highway improvement. Although there are other consequences of highway improvement, intended and unintended, the efficiency effects are usually foremost in that they result from the improvement's prime objective.

Determining the amount of the change in cost of transportation is the job of engineering economy. Tracing out the effects of the change in transportation is the task of systems analysis. Predicting and understanding the nature of the effects is the role of economic analysis. To perform total economic analysis, it is necessary to have some background in economic theory, or at least so much of it as may be useful in explaining how economic nonuser consequences result from the act of highway improvement.

The purpose of this chapter is not to offer a reading in classical economic theory but rather to describe the origin of the nonuser consequences of highway improvements in terms of economic theory and, as a result, of the interaction between economic behavior and transportation use. It is hoped that this will show how highways affect the social and economic activities of a community and result in an understanding of how the nonuser benefits and adversities come about. This understanding is requisite to the understanding of how the net benefits are evaluated and the reason why this class of consequences from highways often cannot be priced in terms of the marketplace.

ENGINEERING ECONOMY VERSUS ECONOMIC ANALYSIS

Although nonuser consequences have long been proposed as additions to the analysis for selection of highway route location and design, their incorporation has been held up, partly by lack of techniques for their analysis and partly by their imprecise and unpredictable nature.

Highway improvements have three possible types of outcomes:

1. Indeterminate.—In this case, nothing is known concerning the possible outcomes of the highway improvement. Forecasting what consequences will accrue is subject only to guesswork. Succeeding events are uncertain and their occurrence may or may not have a necessary connection with the act of improving the highway.

2. Probabilistic.—In this case, there is a necessary connection between present and future states discoverable by observing the future state when it arrives and tracing the connection or examining the present state of similar systems that have been subjected to similar changes in the past. Future states vary, even where similarities exist, being influenced by a variety of forces having different magnitudes, constraints, and weights, and actors having varying degrees of knowledge, rationality, willingness, and ability to react to the changes induced by the highway improvement. Most nonuser consequences fall in this category. Certain sets of outcomes appear likely based on past performances of similar systems under similar circumstances. However, the outcomes represent a range of possible events rather than a single event, and vary in the probability of their occurrence matching a particular point in the range.

3. Determinate.—In this case, there is a necessary connection between the highway improvement and its consequences. There is both a single deducible outcome based on the nature of the improvement and a set of definable relationships between the improvement and the consequences that follow it. This means that it is possible to construct a theory, model, or mathematical expression that specifies the independent variables that define the nature of the improvement and their relationship to the set of dependent variables they affect. The values of the dependent variables may be found by inserting values for the independent variables and solving the equation. This is a case of mechanical causation. The study for engineering economy is of this sort. It relies on the similar mechanical properties and functioning of all motor vehicles of the same type under similar conditions to produce a set of values that define the user costs that react to the proposed improvement. Many of the phenomena dealt with by engineers obey physical and other laws. Relationships can be defined by a formula. Consequences may thus be predicted within a range so narrow that single values often are used and small margins of error are assumed.

This procedure has led many highway engineers to desire and unrealistically to expect that there were discoverable formulae by which nonuser consequences might similarly be computed. They desired single numerical values of nonuser costs and benefits to insert into one grand cost-benefit analysis. This result is incapable of achievement because user costs and benefits are largely determinate, whereas nonuser ones are largely probabilistic and, in some cases, indeterminate.

Nonuser consequences must be handled in part quantitatively, in part descriptively, and predicted on the basis of the range of observed outcomes of similar highway improvements under similar circumstances.

Although there is no guarantee that the predicted consequences will happen, there is also some indication of what might happen; in some cases, what probably will happen; and in others, perhaps most important, what will not happen. Prediction is aided both by empirical evidence of what often does happen and by understanding theoretical reasons why it happens. The empirical evidence appears in Chapter Nine and Appendix B; the theoretical reasons are the subject of this chapter. Both are essential to a full understanding of highway consequences.

ECONOMICS AND TRANSPORTATION

Economics

Economics is basically the study of the arrangements whereby scarce resources are allocated, produced into goods and services according to demand based on human needs and wants, and distributed among the population for consumption. Consumption fulfills human wants and needs and produces utilities and satisfactions for the consumer. Highways play an important role in resource allocation, and the production and distribution of goods and services (*8-7*, p. 5).

Scarcity is a central fact of existence. There are insufficient means to totally gratify all needs and wants. Economics does not form value judgments about what needs and desires should be satisfied, or what goods and services should be demanded or supplied in preference to others. Economics may, however, demonstrate the consequences of fulfilling certain preferences or demands. The main task of economics is to demonstrate what mix of allocations appears to return the most total product or satisfaction from the available resources based on revealed preferences of people. In terms of highways, it is desirable for highway agencies to look beyond the physical highway to: (1) the social and economic needs that are fulfilled as the result of a highway improvement, (2) how the highway changes resource allocation, and (3) the processes of production, distribution, and consumption and the location of economic units, enterprises, and households engaged therein.

Fulfillment of economic needs requires the provision of access to basic resources that go into the production of economic goods and services—the development effect of highways. Access must also be provided between the places of production (factories), distribution (commercial enterprises), and consumption (households) in the chain from resource extraction to consumption. Social needs must also be recognized and means of personal contact and intercommunication must be provided for the carrying on of the social, political, and cultural life of the society and community. Defense is another important need entering into highway decisions.

Highways compete for economic resources with such other public works as schools, sanitation systems, public housing, libraries, and hospitals. Resources allocated to highway improvements might otherwise be used for such other purposes. These are the "opportunity costs" of highway investment and form the initial social and economic impact of highways.

In that points of production, distribution, and consumption are usually separated spatially, transportation costs enter into economic processes. Hence, transportation prices or costs will influence both the delivered price of goods and services and the location of operations engaged in their production, distribution, and consumption, especially where transportation costs form a significant share of total costs. These effects may be termed distributional—both in the sense of bringing about geographic location changes, and, also, securing redistribution of wealth among regions, areas, communities, and socio-economic groups.

Transportation Economics

Transportation is not an end in itself, desired for its own sake as an object of final demand. Transportation is a service made essential by the differential placement of supply and demand in space. The process of bringing supply and demand together requires transportation of people and goods. A transportation system, in turn, requires ways, vehicles, energy, control, storage, maintenance and administration, user services, and terminals. From these inputs arise the costs of transportation in terms of resource expenditure.

The costs of transportation are pervasive. They attach to practically every economic good and service consumed and to most personal contacts with others and with the environment. These costs make the economizing of transportation desirable in order to lessen the total cost of attaining the objects of final demand and to achieve certain socio-economic goals and objectives.

Transportation "demand" is therefore a "derived" demand, stemming from the desire for objects or contacts with persons spatially separated from the demander. If the demander is to fulfill his desires either he or the objects or other persons must be transported. The final cost of the object or contact will be increased by the transportation costs incurred in the process. In paying these costs, the consumer pays for place utility: the utility of having what he wants, where and when he wants it.

Because governmental agencies control many of the inputs, especially those that influence the amount of additional inputs required, governmental policy, taxation, and investment are major influencing factors in determining highway transportation supply, prices, and demand. By design, government agencies influence the rate of consumption of resources used in producing highway transportation services. By location, they influence the geographic distribution of the supply of and demand for land for various purposes—hence, land use and value, intensity of activities and population densities, access to resources and factors of production—in short, the economic, social, and political geography of the nation, regions, states, cities, and towns. Highway planning and investment in highways are thus strategic elements in the fulfillment of both individual and community goals and objectives.

Economic Analysis

Economic analysis is relevant to the costs and consequences of highway investment and policy planning of transportation. Highway transportation uses scarce resources (land, labor, construction materials, fuel, vehicles) to provide services and their utility—the timely movement of persons and goods through space to accomplish desired objectives.

The objective of the economic analysis of highways is to find the means of supplying that quality and quantity of highway transportation services desired by the public at the least total cost. The total cost includes both economic costs—resources consumed and paid for by highway suppliers and users, and social costs—the unassignable costs borne by all (e.g., noise, air pollution, aesthetic effects). There is a high degree of interaction between economic and social costs in producing the desired level of highway quantity and quality, with trade-offs and compromises often necessary.

In terms of economic or resource costs, the concern is with economizing the total cost of producing highway transportation services. Economic analysis of highways can be accomplished with the tools of classical supply-demand equilibrium economics and engineering economy.

In terms of social costs, the concern is with analyzing the consequences, or impacts, of transportation investments and the use of transportation systems on the community. This concern recognizes that, in addition to its own internal costs, transportation normally generates many side effects of "externalities," costs and benefits incident on others than the suppliers or users of the highway.

In addition, transportation has been shown to have a dynamic impact on the economic development of a community or a nation. Although, so far, no adequate model has been developed by which to trace the total effects of investment in highways, there is a need to evaluate the socio-economic impacts to whatever extent possible to aid in the selection and evaluation of transportation improvements. Required are estimates of economic and social costs and benefits, and identification of their incidence geographically and among various segments of the population. In the formation of such estimates, the techniques of general equilibrium economic analysis and economic location analysis are probably the most useful.

Consequently, the demand-supply analysis involved in the production of highway transportation services is discussed first, followed by general equilibrium and location theory used as analytical techniques for determining community consequences.

HIGHWAY TRANSPORTATION DEMAND

Being a "derived" demand, the demand for transportation can best be explained as a function of the demand for goods and services and people trips requiring transportation to fulfill various purposes. Tracing demand to its source via consumer demand theory aids in understanding changing levels of demand for highway transportation services. Most economic concepts and theories stem from observed regularities in the behavior of individuals. Theoretical concepts are introduced here to show how individual reactions to changes in highway transportation services create the demands and some of the problems to which highway administrations respond. Viewed as a function of a variety of independent variables such as population and incomes, prices and costs of goods and services, costs of transportation, production technologies, and cultural patterns all interacting in a spatial framework, demand becomes more easily analyzable and predictable.

Indifference Curves and the Budget Line

The theoretical explanation of consumer choice is embodied in the concept of indifference curves and the budget line.

Concept of Indifference Curves

An indifference curve (see curves I_1, I_2, and I_3 in Fig. 16) defines a locus of points on a graph representing possible different combinations of quantities of two goods or services, G and H, from which combinations the consumer derives equal amounts of utility or satisfaction. The consumer is therefore "indifferent" to which combination he receives (*8-14*, p. 68 ff).

The indifference curves shown in Figure 16 demonstrate their theoretical typical shape: convex to the origin. As more of Commodity G is gained, units of Commodity H are given up. Due to "diminishing returns" in utility or satisfaction from additional units of a commodity, an increasing number of units of G must be received to induce giving up each additional unit of H, as it becomes scarce to the consumer relative to G, to preserve the same level of satisfaction.

A "family" of indifference curves always represents a specific combination of goods as viewed by an individual or a homogeneous group of individuals. A single curve throughout its length represents a constant level of utility or satisfaction. Curves higher from the origin represent

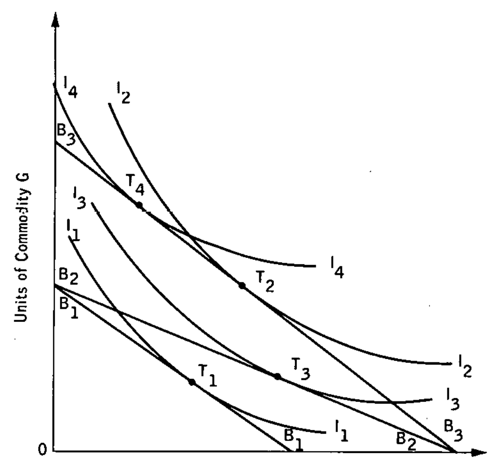

Figure 16. Indifference curves and budget lines. Drawn as straight lines, the budget lines reflect economic convention and assume a uniform price per unit at all volumes. In real-world situations quantity discounts are often obtainable and the ends of budget lines would be curved in such cases.

higher levels of utility or satisfaction; lower curves, lower satisfactions. Theoretically the "family" of indifference curves is unlimited in number for an individual, each curve representing his preferences under the different conditions of tastes, needs, income, and choices that might exist at various times.

The Budget Line

The absolute and the relative price or cost of Commodities G and H and the total amount of money available for purchase of the two commodities are important factors in establishing a choice. It may be assumed that the budget line B_1 in Figure 16 represents the various combinations of units of Commodities G and H that could be purchased with a specific budget. Point T_1 on this curve represents the point of tangency of the budget line with the indifference curve I_1. At this point, the individual would presumably get the greatest satisfaction from the combination of the two commodities that he can afford, given their relative prices, his budget, and his tastes or preference represented by the indifference curve.

Line B_2 of Figure 16 represents the same general situation as for B_1 but for a higher budget or a set of lower prices for one or both commodities. With the shift in the budget line, the point of tangency moves up to indifference curve I_2, occurring at T_2. Whether the budget is raised or prices are lowered, the result is to increase the number of units of G and H purchased and a gain in total satisfaction.

This analysis assumes an unlimited supply of both commodities so that, within the budget limitation, the consumer is able to make a choice.

Indifference Curves as Applied to Highway Travel

The concept of indifference curves and the budget line can be applied to highway trips as well, helping to explain the demand for trips and the gains and consequences stemming from highway improvement based on consumer choice. Although there is little demand for highway trips as such, there is demand for the goods, services, and contacts obtained by highway travel. The delivered cost of such objects of demand is increased by the cost of transportation necessary to obtain them. The effect is to influence choice of objects demanded, the route and, possibly, time of travel, the travel mode, and location where the demand is fulfilled.

Indifference curves and budget lines can be used to illustrate the effect of three variables on consumer choice and demand: income, price, and taste.

Income Effect

If the delivered prices of Commodities G and H are affected by highway transportation costs, an improvement of the highway over which they move that produces user cost savings will lower their delivered price. More of both commodities can then be purchased at no increase in total expenditure. The lowered cost of highway travel furnishes the same number of trips or miles of travel to obtain G and H at a saving. The saved dollars when translated into market price add to the "real income" or purchasing power of the household. This saving can be used to buy more transportation or more commodities. Travel demand probably will increase in either case. This is the "income effect" of a highway improvement.

The highway improvement's effect on the budget line may be depicted by reference to Figure 16. Under the influence of highway-improvement-induced lower delivered prices for G and H the budget line shifts upward from B_1 to B_2, indicating more of G and H can be obtained from the budget. B_2 becomes tangent to a higher indifference curve, at T_2. Being higher than T_1, T_2 indicates that more utility or satisfaction has been gained.

Although not highway-improvement-induced, demand may be similarly increased by other real income gains such as wage and salary increases or by lower prices of other goods and services. When income increases, more can be spent on transportation absolutely without increasing its relative share of the budget.

Substitution Effect

When a highway improvement causes the cost of highway travel to fall on a certain route, the supply and demand functions carried out over that route are affected. Prices of goods, services, and trips for various purposes obtained by using the route fall relative to prices of goods moving over other routes or by other means.

The consumer can improve his standard of living by substituting the lower-cost goods, services, and highway trips for their now higher-priced alternatives. The enterprises and locations from which the lower-priced commodities are supplied benefit from the substitution in the form of increased sales, rents, and land values.

Budget line B_2 in Figure 16 illustrates the case in which the price of Commodity H has fallen due to a cost-reducing highway improvement. In this case, Commodity G is unaffected by the improvement, being obtained over an unimproved route. At the lower delivered price, more of H can be obtained with the same dollars while leaving the quantity of G unchanged.

Budget line B_2 reflects the change in their relative prices. The new combination of G and H chosen is reflected by the point of tangency with indifference curve I_3 at T_3. This shows more of Commodity H being taken at its lower price while the quantity of G remains unchanged. The fact that a higher indifference curve has been reached indicates that, as before, an increase in utility or satisfaction has resulted.

To capture the benefits of the relatively lower price of trips, goods, and services obtained over the improved route, consumers may substitute routes (diversion), modes (modal split), shopping, residential and/or work locations (house, shopping centers, jobs), or means of communication (personal visits replacing mail or phone calls). Commercial and industrial firms may make similar substitutions to gain the advantages of lower cost of operation or greater access to their market provided by the improvement.

Routes, modes, locations, goods, and services made to appear relatively less expensive by the cost-reducing highway improvement thus gain competitive advantage. Demand for them increases while demand falls for their more expensive substitutes. Spatial reorganization of activities and traffic flows and shifts in supply and demand of certain goods and services, including transportation by other modes, occur. Shifts of various economic units, households, and firms occur in an attempt to capture the advantages produced by the improvement in the form of increased utility or satisfactions, higher sales, or lower costs of production. These community consequences reflect the accommodations and adjustments made to the new schedule of highway transportation "prices" and the new pattern of relative accessibilities produced by the improvement.

Change in Tastes

Tastes determine the shape of the indifference curves—what commodities or services or mix thereof are preferred to others when confronted with choices. Choices may be between commodities or between the range of styles, colors, and qualities in which a single commodity is available. Education, experience, age, family condition, values, advertising, and psychological, cultural, and "crowd" influences all help determine tastes.

In economic analysis, tastes are usually accepted "as is" and are assumed to remain constant for the period of analysis in order to better examine the income and substitution effects arising from price changes. Tastes do, however, change over time and enter into the problem of estimating travel demand when highway improvements alter the quality as well as the cost of travel.

A highway improvement usually not only reduces the cost of travel but also raises its quality. Comfort and convenience and perhaps aesthetic pleasure are likely to be increased. It is not the old product at a lower cost that the consumer is offered but a qualitatively different product. The consumer easily develops a taste for the improved product, particularly at its "bargain price." He therefore tends to increase his use of the improved highway and to abandon use of the now less-satisfactory alternative routes.

Indifference curve I_4 in Figure 16 represents a shift in tastes and preferences that leaves relative prices, represented by the budget line B_2, unchanged. If Commodity G is presumed to represent trips by automobile over an improved facilty and Commodity H to represent trips by an older alternative route, the improvement-induced change in tastes leads to a redrawing of the indifference curve indicating G is preferred in greater proportion to H. The consumer moves his choice from T_2 to T_4, substituting units of G for units of H—trips by the improved highway for trips over older routes.

Limitations on the Concept

Although useful in explaining how people choose trips by alternative routes (and perhaps modes) and to alternative destinations, the discussion of indifference curves and budget lines would be incomplete without mentioning their limitations. They assume, for instance, a high degree of choice and conscious planning in most consumer expenditures, whereas habit, impulse, and regimentation also frequently influence individual demand. From the supply side, product differentiation, monopolistic activity, and institutional controls are often at work expanding or contracting choices. The concept is nevertheless useful in stating how people do, in general, decide between commodities, or trip routes or destinations, in the absence of the distortion of choice provided by the foregoing factors. When distortion does appear, one of these factors or similar ones can be sought as providing the explanation.

Marginal Utilities and Trip Purposes

Although the concept of indifference curves and the budget line is useful in explaining how consumers allocate choices between two commodities, it is of little use in explaining the observation that people purchase not one or two but a variety of commodities.

The concept of equilibrium of marginal utilities is a useful one in explaining why consumers allocate their incomes over a range of commodities. As more units of a single Commodity G are purchased, each additional unit provides less utility or satisfaction than the previous one (law of diminishing marginal utility). At some point the utility offered by the first unit of some other Commodity H is greater than that offered by the last unit of Commodity G in proportion to their respective prices. It would then increase one's total satisfaction to stop buying G and begin buying H. Such trade-offs go on among all commodities, leading the consumer to demand each commodity up to the point where the ratios between the marginal or added utility and the prices of all commodities are equal. Up to that point some commodities were returning more marginal utility than others and it paid to divert dollars from the ones returning less to the ones returning more (*8-13*, pp. 419-23).

Thus, due to diminishing returns and comparative marginal utilities, more satisfaction or total utility is derived from consuming a variety of commodities rather than only one or a few. The consumer's budget is correspondingly divided among such commodities until a state of equilibrium among ratios of their marginal utility to their price is reached. At that point, the consumer has optimized the total utility available from a given budget or income.

In that transportation is undertaken to procure these varied commodities and services, trip purposes are correspondingly varied. Table 11 gives a typical or average breakdown of household trip purposes by percentage of trips and vehicle-miles devoted to each. The number of vehicle-miles for each purpose is the product of frequency times round-trip distance to the location where the purpose is fulfilled. Distance is, in turn, a function of the household's location relative to activities at various locations with which it has "linkages"—recurrent and significant supply-demand relationships.

The more frequent the need to pursue certain "linkages" by large numbers of the population, the greater the cost of fulfilling that demand or purpose and the greater economy to be realized by improving the transportation facilities serving those particular "linkages." Evidence that such economy is sought is found in the tendency for households to locate either proximate to workplaces or near direct routes to them. According to Table 11, the journey to work involves the highest percentage of trips and vehicle-miles of all trip purposes. Economizing work trips can yield a significant reduction in aggregate and household

TABLE 11

DISTRIBUTION OF PASSENGER-CAR TRIPS AND TRAVEL CLASSIFIED BY MAJOR PURPOSE OF TRAVEL [a]

PURPOSE OF TRAVEL	PERCENTAGE DISTRIBUTION OF: TRIPS	VEHICLE-MILES	AVERAGE TRIP LENGTH (MILES)
Earning a living:			
To and from work	33.6	26.0	6.5
Related business	13.9	17.7	10.7
Total	47.5	43.7	7.8
Family business:			
Medical and dental	1.4	1.9	10.9
Shopping	15.0	6.9	3.9
Other	10.7	8.7	6.8
Total	27.1	17.5	5.4
Educational, civic, and religious	6.1	3.2	4.5
Social and recreational:			
Vacations	0.2	4.8	276.2
Pleasure rides	7.2	12.8	15.0
Other	11.9	18.0	12.7
Total	19.3	35.6	15.6
All purposes	100.0	100.0	8.4

[a] Source: Unpublished motor-vehicle-use studies conducted in 1951-56 in 19 States (*8-28*, p. 26).

transportation costs and lends support to the high priority often given to improving commuter routes.

Summary of Effects of Highway Improvement on Consumer Choice

The effect of improved highways on individual consumer choice is to increase the amount of highway travel, and, in turn, highways demanded. The increase is due to income effects, substitution effects, and taste changes reflected by shifts in budget lines and indifference curves. The consumer views his choice as leading to an increased amount of utility or satisfaction obtainable from his budget. These utilities and satisfactions are the ultimate "benefits" of highway improvement. Only a portion of them are represented by the engineering economy analysis—the income effect stemming from lowering trip cost for present users.

The generated, diverted, and developed traffic represent substitution effects and taste changes that substitute lower priced or more satisfactory routes, modes, goods and services, locations, origins and destinations, for those that appear relatively more expensive or less satisfactory after the improvement.

The community consequences that follow logically from the consumer reaction to highway improvements are:

1. Real income gains for certain users of the improved facility lead to increased demand for goods and services and for the transportation required to obtain them. Increases in commercial sales, industrial productivity, and consumer satisfaction are possible with the expenditure of the user "savings."

2. Competitive advantage is given to those locations, enterprises, modes, goods, and services to which are attached the lowered transportation costs or added satisfactions afforded by the improved highway. Increased land values, revenues, sales, development, and investment could result. The locations, enterprises, modes, goods, and services placed at a competitive disadvantage would feel an opposite set of effects from the substitutions that occur. Trade activity may move from one locality to the locality favored by the improved transportation.

3. Changes in taste bring about increased demand for travel by highway modes—automobile, bus, truck. The extent, pattern, and form of the community and its economic and social life will reflect the changes required to accommodate the operating characteristics and system configuration of the predominant mode. The mode may aid in the indulgence or development of other tastes such as those for low-density housing, drive-in movies, and dining out.

4. Due to diminishing marginal utilities, a variety of commodities are chosen to fulfill needs and wants. This leads to the variety of trip purposes and frequency of trips by purpose related to the division of the consumer budget and the necessity for work trips to produce income. Those routes serving the trips most frequently made, especially those made with diurnal regularity, are usually the ones most likely to carry high volumes and to be congested periodically. They are also the ones on which efficiency gains from highway improvement are usually largest.

Market Demand

Market demand is the sum of the demands of all individuals in the market. The market demand curve represents the horizontal summation of all individual demands, the total quantity demanded at each unit price level.

A demand curve (Fig. 17) is formed by aggregating the maximum utility points (where budget line is tangent to indifference curve) for all consumers of a given product. At various delivered prices the budget lines will shift and lie tangent to various curves in the family of indifference curves of all consumers. The resulting demand curve shows the quantities of a specific good that will be bought at various prices holding all other prices, and income and tastes (indifference curves), fixed. The demand curve reflects the greater quantities demanded at lower prices as a result of (1) substitution of cheaper goods for dearer, (2) increase in "real income," the amount of goods or services actually obtainable from available money, and (3) interception of budget lines with indifference curves of lower income groups that previously had no point of tangency.

The response of quantity demanded to price changes is given by the concept of elasticity of demand. Elasticity of demand is the ratio of the percentage change in quantity demanded given a percentage change in price. Elasticity is represented by the following (*8-14*, p. 33):

$$\text{Elasticity} = \frac{\text{relative change in quantity}}{\text{corresponding relative change in price}} = \frac{\Delta Q}{\Delta P} \times \frac{P}{Q} \qquad (7)$$

in which

$Q =$ quantity;
$P =$ price;
$\Delta Q =$ change in quantity; and
$\Delta P =$ change in price.

A 20 percent decrease in price that caused a 20 percent increase in quantity demanded, for example, produces an elasticity of one and is said to be unitary. A price change that produces a proportionally greater percentage change in demand is "demand elastic." A price change that produces a proportionally lesser percentage increase or decrease in demand demonstrates "inelasticity" of demand. The elasticity of supply in relation to a price change may be measured by the same process (*8-13*, pp. 363-65).

Demand curves apply primarily to competitive conditions in which the supply of or demand for a commodity is responsive to changing price. They relate primarily to choices between "private goods"—those with divisibility, excludability, and few external effects. To the price of such goods, transportation costs are additive. Influencing the delivered price, such costs affect the demand for private goods, especially those goods that are demand elastic, and the number and length of trips made to obtain them.

Highway demand, being thus derived from final demand for commodities subject to those conditions, has a similar demand curve. The use of demand curves can be used to illustrate demand for trips over certain links or to certain destinations (i.e., to highway *use*). This analysis is also useful in demonstrating how trip demand and highway location and design interact to produce trip costs (*8-14*, pp. 43-65).

PRICE AND DEMAND RELATIONSHIPS

The foregoing theoretical discussion of indifference curves, budget lines, and demand curves leads to consideration of the effects of a change in the price or cost of transportation on the temporal and spatial demand pattern of the travelers and vice versa.

It is also possible to gauge the effect of two current trends on the transportation demands of consumers and of highway use: (1) the trend toward lowering the cost of highway services through investment in highway improvements to secure greater efficiency, and (2) the rising level of incomes (relative to the cost of living) in the United States since World War II.

Price-Demand Curves for Highway Trips

The improvement of highway facilities and the volumes of trips over them change both the cost of vehicular trips and the quality of trips. Therefore, travelers increase their transportation demand accordingly and trade off other commodities or services for more highway travel or for the substitute commodities or services that have become relatively less expensive due to highway improvement.

These changes are shown by the price-demand curve in Figure 17. As cost of a highway trip decreases without a change in income or trip quality, consumers will buy more trips, assuming demand elasticity. For example, starting with a price of P_0 the demand would be Q_0. Lowering the price to P_1 would increase the demand (quantity) to Q_1.

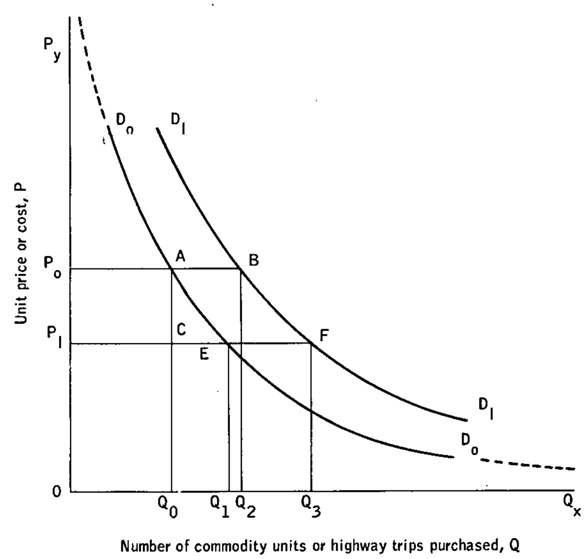

Figure 17. Price-demand curve for a commodity and for highway trips.

The time period indicated is zero or so short a lapse of time that there may be no change in the over-all factors or personal circumstances that would affect the demand.

This discussion of price-demand curves is on the basis that the good or service in question is demand elastic (i.e., the quantity consumed reacts directly with any change in its price, the quantity purchased decreasing with increasing price and increasing with decreasing price). In concept it is assumed that consumers fully perceive the unit price (or the unit cost) they pay.

It is known, however, that a change in the quality of a product results in a different product and a different price-demand curve will result. When highway facilities are improved to increase the quality of comfort and convenience of the ride, such highway improvement may cause the demand for highway travel to increase even with or without a change in cost.

In Figure 17, D_0 represents the price-demand curve before the highway facility was improved. D_1 is the price-demand curve after improvement. The trip cost was P_0 before improvement and P_1 after the improvement. The number of trips over the facility increased from Q_0 to Q_3 as a result of improving the highway. In this particular instance two variables are changed in establishing the second or D_1 demand curve: the cost per trip and the quality of the trip.

Further, the qualitative change and decreased cost of highway travel alter the public attitudes and preferences. The substitutions of highway travel for alternative modes may cause them to discontinue operation due to losses resulting from competitive disadvantage and declining patronage. The demand for highway services may then increase due to lack of alternatives, even if the specific highway facilities or the cost of using them remain unchanged. The price-demand curve D_1 would then represent the increased demand due to a monopoly condition. In this case demand would become highly inelastic and the demand curve would become more nearly vertical, representing the insensitivity of trip volumes to price changes.

In Figure 17, the curve D_0 can also represent the demand curve at a given level of income. At that income level the demand is for the quantity of trips Q_0 at price P_0. Assuming that incomes rise over time, demand curve D_1 would then prevail. Had this occurred in the absence of a highway improvement, at the new income level the quantity purchased would be Q_2 at the old price of P_0. If, however, an improvement lowers the price to P_1, the consumers then buy quantity Q_3 at this new income level. The quantity Q_3 probably would be slightly greater in that the lower unit price induces an increase in real income to accompany the increase in dollar income.

As highway facilities are improved to better the conditions of highway travel, it is usual that the unit cost of travel is reduced and the satisfactions in travel are increased through a trip of better quality. Thus, the price-demand curve and the economic theory of price and demand are useful tools to understanding why when an improved highway replaces an obsolete or inadequate one the ADT usually increases beyond the usual projections of traffic demand.

Summary of Demand Factors

The same demand curves and economic concepts are also useful in tracing the effect of other factors influencing demand for highway travel. In addition to cost and qualitative changes, highway transportation demand reflects secular trends in demography and the economy that set the over-all level of potential demand. This potential for a system, a community, or a traffic zone can be estimated and projected on the basis of examining the following variables. Indications of their precise relationship to demand levels is contained in the references.

1. Population.—Demand rises with population. More licensed drivers, registered vehicles, origins, and destinations drive up trip generation potential (*8-19*, pp. 52, 71).
2. Age.—More middle aged, fewer of the young (under 20) and old (over 60) are licensed. Demand will be greater where the middle-age group predominates in the population; less where younger or older age groups are in the majority (*8-19*, pp. 22-23).
3. Sex.—More men than women are licensed to drive. Again, where the more heavily licensed group predominates (men) there will be a greater demand for highway travel (*8-19*, pp. 22-23).
4. Income.—Demand is related to car ownership which increases with income. The number of auto trips made for all purposes except work (which is fairly constant for all income groups) and miles driven per annum also increase with income (*8-17*, p. 12; *8-20*, pp. 12, 23). Increasing auto-for-transit substitution takes place at progressively higher incomes (*8-17*, p. 12).
5. Taste.—Auto popularity increases with improvement in vehicle and highway, and with reductions in travel time and money costs (*8-9*, pp. 2, 15).
6. Residential density.—Demand for auto travel increases at low-density population; declines at high density where other modes are more efficient, convenient, or available (*8-17*, p. 8).
7. Size of household.—The number of automobiles owned and trips made increase with size of household (*8-17*, p. 20).
8. Characteristics and availability of alternative modes. —Demand for auto travel increases where there is more auto ownership, densities are too low to support transit, transit does not exist at all or lacks competitive advantage due to unattractive fares, routes, ride quality, travel times, and scheduling relative to the automobile. Demand for auto travel decreases with the availability of alternative modes and where conditions opposite from those just cited exist (*8-18*, p. 13).
9. State of the economy.—Demand increases during prosperity due both to the effect on employment and incomes and to the increased variety and lower cost of goods resulting from invention and mass production that increase the amount of travel required to produce, distribute, and procure them (*8-19*, p. 18).
10. Price and cost per unit of travel.—Lowering the cost of travel through improving specific links in the highway system has local effects on the geographic distribution of the supply of and demand for land and the relative accessibility of sites to each other. Increased demand occurs over the improved routes and to those locations made to appear more advantageous by the change, in order to capture the gains. Gains include lower costs of travel or of land; the rewards of the qualitative aspects of one or both (scenery, comfort, convenience, space); and/or the favorable location of a site in relation to other locations with which linkages exist (trade areas, markets, resources, utilities, clients, friends or relatives).
11. Land-use intensity.—Highway demand increases relative to the intensity of the land uses that develop or redevelop or merely attract more trips in response to the changes in trip cost or land price induced by the improved facility (*8-17*, p. 16).

It is the level of over-all demand that justifies the provision of highways at a certain level. It is the local demand patterns related to existing and planned development trip generation rates, and the desire lines they produce, that determine the manner and places in which demand will be satisfied. Response to the former demand specifies resource allocation to highways. Response to the latter demand determines route location and design.

SUPPLYING HIGHWAY TRANSPORTATION

The supplying of highway services capable of meeting the travel demands discussed in the previous section relates to the total transportation cost—the highway cost plus the motor vehicle cost. The interaction of the highway and vehicle factors in their different combinations produces a "supply" of highway transportation services and establishes their cost to those who use the highway. The cost may be expressed per vehicle-mile, per trip, or per annum. The production of highway services incorporates the variable factors next discussed.

TABLE 12

HIGHWAY TRANSPORTATION SYSTEM COMPONENTS

COMPONENT	FORM	SUPPLIER	INCIDENCE OF COSTS
Supporting way	Highways, roads, streets	Government highway departments	Government through user and nonuser taxes, user tolls
Traffic controls and services	Signs, traffic controls, snow and ice control, police, etc.	Government highway or other departments	Governments, user and nonuser taxes, user tolls
Vehicle	Automobile, bus, taxi, truck	Auto manufacturers	Highway user or vehicle owner
Control	Driver	Private consumer or employed drivers	Highway user or vehicle owner
Power	Gasoline, diesel, or other fuel or energy	Petroleum corporations, retail service stations, suppliers of electricity	Highway user or vehicle owner
Terminals and storage	Parking lots, garages, streets	Private enterprise, governments, vehicle owners and users	Private enterprise (free parking lots), governments (tax-supported parking and street parking), users (garage and parking on private property).

Incidence of Highway Transportation Costs

The six essential components of a transportation *system*, their form, suppliers, and the incidence of their costs in creating a supply of highway transportation services are given in Table 12.

The costs of supplying transportation services that are incident on the highway automobile *user* are distributed, on the average, in the manner given in Table 13. They represent the costs of owning and operating an automobile, the user's share (other than for commercial vehicles) of the resources consumed in the course of using highway transportation service.

In arriving at total costs of highway transportation, account must also be taken of operators' and, possibly, passengers':

1. Risk—traffic accidents whose financial costs may be partially spread by the use of insurance.
2. Time—the value of time spent en route in terms of both its actual monetary value (truck drivers and salesmen) and imputed monetary value (the opportunity cost of time based on valuation of its alternative uses).
3. Cost of capital—interest charged on money invested in the vehicle and highway and imputed interest based on opportunity cost of capital.
4. Psycho-physical nonmonetary costs—presence or absence of comfort and convenience: physical exertion, frustration, tension, disorientation, decision pressures, odors, vibrations, aesthetic pleasure, directness of travel, and similar items affecting the *quality* of travel. These factors of personal preference and satisfaction are unreliably priced in the market, if priced or priceable at all. However, users' willingness to use toll facilities that are superior in terms of comfort and convenience indicates that users do attach a monetary value to these qualities.

Highway improvements, in economic terms, create a new cost schedule for trips over the route improved and capacity for an enlarged supply of transportation service. The new cost schedule results from engineering the route improved and capacity for an enlarged supply of transportation service. The new cost schedule results from engineering the route location and design in a manner that alters either or both the distance or the rate of consumption of the resources that are priced-out in the cost items per vehicle-mile. Reducing distance or the rate of consumption tends

TABLE 13

COST OF OWNING AND OPERATING AN AUTOMOBILE, PER MILE OF TRAVEL AND PER DOLLAR SPENT[a, b]

ITEM	CENTS PER MILE OF TRAVEL	CENTS PER DOLLAR SPENT
(a) Costs exclusive of taxes		
Depreciation of vehicle cost	2.81	25.5
Repairs and maintenance	1.79	16.2
Gasoline	1.50	13.6
Insurance	1.41	12.8
Garaging, parking, tolls	1.80	16.3
Oil	0.23	2.1
Tire and tube replacement	0.23	2.1
Acccssories	0.08	0.8
Total excluding taxes	9.85	89.4
Taxes (see details below)	1.17	10.6
Total cost, including taxes	11.02	100.0

(b) Taxes

ITEM	CENTS PER MILE OF TRAVEL: STATE	FEDERAL	TOTAL	CENTS PER DOLLAR SPENT: STATE	FEDERAL	TOTAL
Gasoline	0.45	0.28	0.73	4.1	2.5	6.6
Registration	0.10	—	0.10	0.9	—	0.9
Titling	0.09	—	0.09	0.8	—	0.8
Property	0.05	—	0.05	0.5	—	0.5
Oil	—	0.01	0.01	—	0.1	0.1
Excise on auto, parts, tires	—	0.19	0.19	—	1.7	1.7
Total	0.69	0.48	1.17	6.3	4.3	10.6

[a] Estimated average cost, excluding interest, for a medium-priced four-door sedan with a "life span" of 100,000 miles, over a 10-yr period.
[b] Source: *(8-23,* p. 9).

toward economic efficiency—maximization of the productive potential from a given amount of resources used (i.e., producing the same amount of output with lesser quantities of input). Expansion of the supply or capacity both lowers the cost and extends the potential gains to more users.

Government therefore promotes efficiency in highway transportation by manipulating highway route location, capacity, and design and traffic control. An understanding of the ability of a highway department to affect the rates of resource consumption "by highway design" is best gained by examining the "production function," the mix of inputs that supplies the highway transportation service. Chapter Six and Winfrey (*6-28*, Chap. 13) discuss the relationship of motor vehicle operating costs as affected by highway design and traffic conditions.

Cost-Volume Curves

The resultant new trip price schedule can be converted to a price-volume curve analogous to the supply curve usually drawn in demand-supply diagrams. Supply curves indicate the quantity reaching the market in response to demand at various prices that will cover the producer's cost, produce a profit, and, at the same time, clear the market—ensure that all goods will be sold. Figure 18 shows the cost-volume curves of a variety of facilities.

The demand-cost and volume-cost curves are combined in the same diagram in Figure 19 to show how the equilibrium per mile cost of highway travel is arrived at via the interaction of supply and demand. The properties of these curves can be used to analyze a variety of highway traffic phenomena and investment issues.

In Figure 19, the S_1 curve represents the per mile cost of travel over the route in the "before" period. The curve S_2 shows the trip cost at various volumes after a highway improvement. The D_1 curve represents a constant demand schedule in both periods. The supply-demand equilibrium points E_1 and E_2 establish the per vehicle-mile cost of travel before and after the improvement. The area $P_1E_1E_2P_2$ is the difference in travel cost resulting from the improvement—the area usually reckoned as the cost savings in user cost-benefit analysis.

An "improvement," however, as previously pointed out, creates a new product. Improvements of the sort usually analyzed involve the creation of a superior product: a direct, convenient, high-speed, limited-access, landscaped, low-cost, low-accident facility, for instance. The differences are both qualitative and quantitative and do not involve offering the old product at a new price. The new facility therefore fashions its own demand rather than just captures that of the old. If engineering economy has been practiced and a favorable benefit/cost ratio results, the new facility not only gives superior service but also offers it at a lower trip cost.

The improved facility will thus have a higher demand curve for its services, D_2. The new equilibrium point will be at E_3, indicating a volume of Q_3 traveling at a cost of P_3: higher than P_2 but still lower than P_1. The cost savings to users of Q_1 of the former facility are represented by the

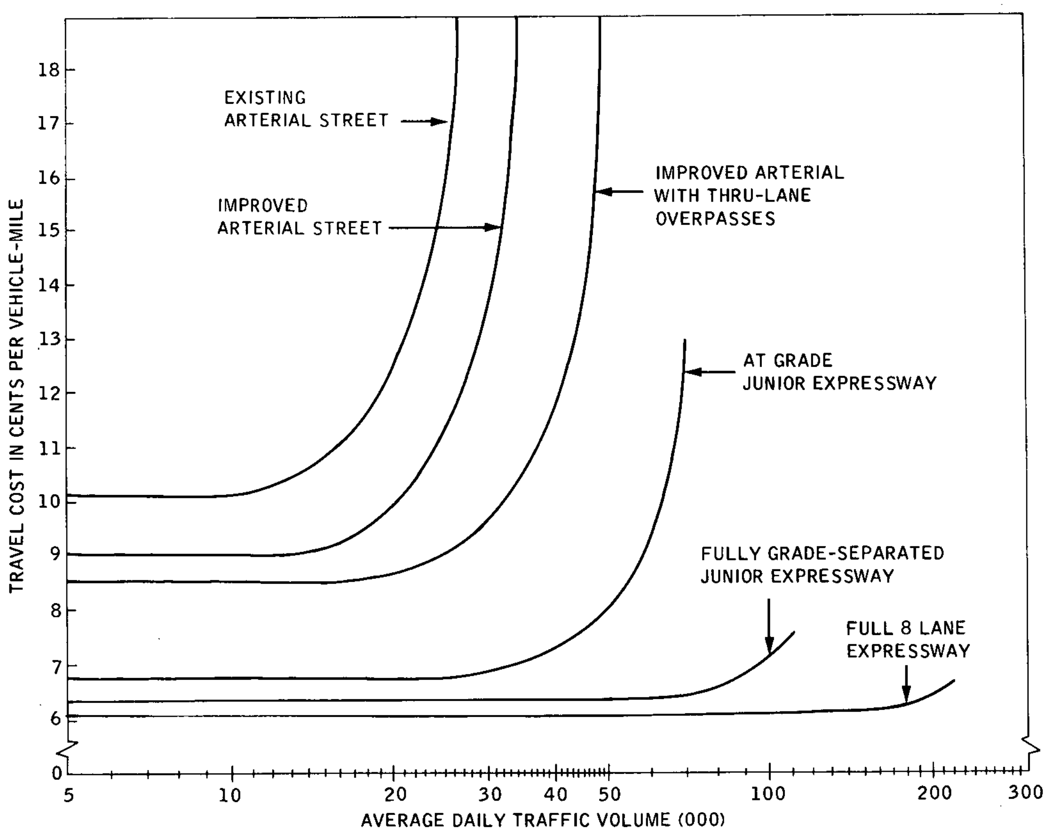

Figure 18. Travel cost-volume functions for alternate traffic facility designs. Source: (8-4, *p. 20*).

rectangle $P_1E_1RP_3$. Herein lies a partial explanation of why new facilities, which substantially add to capacity, become, within a relatively short period of time, as congested as the former facilities they replaced.

The higher quality and lower cost of trips over the improved facility causes a "substitution effect" that diverts demand away from alternative routes, competing modes, and former destinations made to appear relatively more expensive or less comfortable or convenient by the improvement. In addition, the lower travel cost generates trips that were not made at all at the former higher costs.

Over time, development traffic generated by changed land uses exploiting the new accessibilities offered by the improvement join the original, diverted, and generated traffic stream.

The secular growth trends in population, income, and auto registration described previously also add to long-term demand. This long-term rise in demand may move the demand curve up to D_3 and establish a new per-vehicle-mile travel cost at P_4. This, it will be noted, exceeds all former unit travel costs, including those over the former facility. All the cost-savings benefits that formed the basis for the benefit/cost analysis have been eradicated. This is the theoretical explanation of the observed erosion of trip travel times and the raising of trip costs that takes place on many facilities over the long term as congestion builds up.

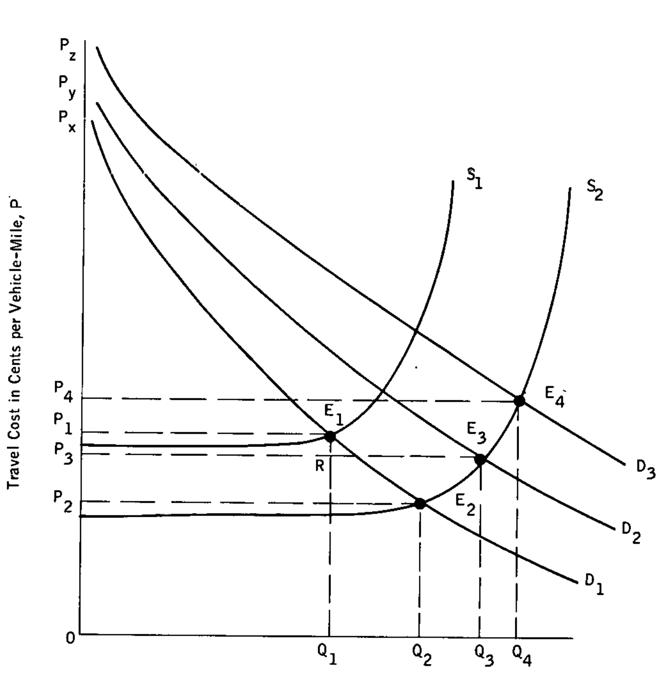

Figure 19. Price-demand and price-volume curves for travel on original (S_1) *and improved* (S_2) *highway.*

Highway Utility and Supply-Demand

Because cost-savings "benefits" have been eradicated does not mean that the investment in a new facility was not justified or that it has ceased to produce economic gains.

Like any other economic good or service, the supplying of highways is justified by the total utility or satisfactions gained from their use. The highway is one of the inputs to the product—highway transportation service. The utility of the highway is measured by the amount of service it provides in response to travel demands. The provision of highways is justified basically not by the "cost savings" they produce but by the trip purposes they fulfill—the value of goods or person movements, land developments, and social or economic exchanges that occur because of the highway and that probably would not have occurred without it or would have occurred at greater cost.

The total "utility" potential in a good or service is represented by the total area under the demand curve. The demand curve represents the quantity that would be bought at each point in the price schedule. The area under the curve represents the cumulated amount that would be paid by all potential consumers if each consumer paid the maximum price he would be willing to pay rather than do without the commodity or service.

Most goods and services are offered at a single price. The volume of the commodity taken at that price identifies one point on the demand curve. Adjusting the price up or down and noting the volume of sales occurring at each new price would identify others. This is frequently impractical in the real world. Market analysts are left to surmise the shape of the demand curve from the limited evidence of current sales, past experience, and the performance of similar products.

DEMAND AND PUBLIC INVESTMENT CRITERIA

Producers of private goods use sales income as evidence of the utility of their product. Although difficult to evaluate precisely, utility (satisfaction, value, usefulness) is evidenced by consumer behavior when faced with choices. The level of utility is presumed to be *at least* equal to what the consumer is willing to pay or "sacrifice" to obtain it. How much more it is worth to him is unknown. The marginal or added utility derived from the chosen good is assumed to be equal to or greater than that obtainable from other goods at similar prices that are not chosen (*8-2*).

The difference between what the consumer would be willing to pay rather than do without the good or service (representing total utility) and what he does pay (the total cost) is known as the "consumer's surplus" (*8-13*, p. 425). In Figure 19 the triangular area $P_1E_1P_x$ represents the consumer's surplus at price P_1. If the price is lowered to P_2, the area $P_2E_2E_1P_1$ represents the added amount of consumer's surplus resulting from the lowering of the price.

The only way to discover total utility would be to auction all goods and note the price at which each person stopped bidding. Where it *is* possible to price on this basis, the entrepreneur is said to practice "discriminatory pricing." He forces the consumer to pay for almost all the utility he receives, leaving little consumer's surplus (*8-2*).

The producer of private goods is unconcerned with measuring the total utility of his product. He is concerned only with that share of the utility for which the consumer pays and that it covers the producer's costs and produces a profit. The decision to produce is based on the producer's judgment concerning the relationship of potential costs, prices, demand volumes, and profits arrived at by

$$P \times V = GR \quad \text{and} \tag{8}$$

$$GR - C = NR = P \tag{9}$$

in which

$P =$ price;
V $=$ volume of goods sold;
$GR =$ gross revenues;
$C =$ costs of production and distribution;
$NR =$ net revenues; and
$P =$ profits.

Contrariwise, highway administrators have no similar sales income by which to judge the minimum amount of utility provided by their product and on the basis of which to regulate costs. Although the previously discussed demand curves can be used to analyze the demand for "private goods" and trips, the same curves cannot be applied to "public goods" such as schools, parks, and highways. Public goods are usually indivisible, additions to supply coming as "lumpy" investments. They usually lack excludability and transferability and often generate numerous external effects. It is therefore desirable to evaluate the total utility of a public good to justify investment in it. Hence, the importance of the concept of consumer's surplus in highway investment. Frequently, in fact, highways appear "free" (all consumer's surplus) to their users.

Private entrepreneurs seek to promote their own interests in competition with others. Their products have few redistributional or external effects. The highway agency, however, in common with other governmental entities, is constrained to pursue the public interest, not that of a particular segment of the population. Particularly in transportation, the redistributional and external effects are usually significant. Highway agencies therefore wish to count all costs and benefits "to whomsoever they may accrue." These considerations mark some of the distinctions between private and public investment criteria.

Without a sales income, the highway investment analyst is constrained to attempt to evaluate the total utility of a highway improvement in order to justify the cost to construct or to improve it. Dealing with a public good, the analyst must also recognize public interest factors, development, distributional and external effects, and the relation these bear to community goals and values.

Demand estimates used as investment criteria must therefore rely on a variety of indicators of the total utility and desirability of a highway improvement. Such indicators are discussed in the following sections and include:

1. Trip cost—transportation efficiency gains identified via cost-benefit analysis.
2. Trip volumes—purpose, origin and destination, present and projected desire lines analyzed by traffic and land-use surveys.
3. Socio-economic or community consequences—identified by economic, location, cost-effectiveness, and system analysis. Linear programming and input-output models are some of the additional techniques being developed to analyze the nonuser effects of highway transportation.

Trip Costs or Prices as Indicators of Utility

Prices set relative values on the variety of commodities produced. They thus aid in the allocation of resources and the rationing of supply among demanders where scarcity prevails. Producers of private goods use prices as guidelines to arrive at the amount of their product required to service demand.

Ideally, the cost of trips, aggregated, would show *at least* that portion of the highway's total utility, social and economic benefits, that is priced and paid for in the market. The actual total utility is greater, but one can be aware of only that portion of utility for which people pay. Total utility is a subjective valuation of a good chosen in preference to others similarly priced because its usefulness appears to be greater. In opportunity cost terms it represents the alternative choices foregone in order to have the good.

When a good or service is offered on the market at a single price, the consumer pays an amount of money (representing optional utility foregone) that represents some share of the utility or satisfaction he expects to obtain from using the good. His evaluation of the total utility of the good or service determines his willingness to pay a given amount for it. Income and available resources determine his ability to pay. To consummate a purchase, the consumer must posses both willingness and ability. Buying at the price set is the behavioral act that informs the economist-observer how the consumer evaluates the utility of a commodity. He does not know how much more the object might have been worth to the consumer but he knows the object was worth *at least* the amount paid for it. This forms a conservative estimate of the object's utility.

Trip costs of present users of a corridor and the volume of traffic willing to travel at that cost or "price" offer some indication of the utility of the present services. The fact that consumers of highway transportation services are willing to incur these costs is evidence that some consumer's surplus is present that could be increased by lowering the trip cost via a highway improvement. Users who do not enjoy the "cost savings" addition to consumer's surplus gain the added utility represented by the higher demand curve. The utility for them includes both their trip cost and some consumer surplus—otherwise they would not make the trip.

Even where the cost of using a segment of highway can be computed, as it is in cost-benefit analysis, there are practical and theoretical difficulties in using it as an indicator of the consumer's willingness to pay and therefore of his demand for highways or a particular highway. Problems of pricing highway services for investment analysis are covered in the following section.

Lack of Good Estimates of Consumer's Surplus

From the foregoing analysis it would appear that the usual cost-benefit analysis that counts user savings as the benefit to justify the cost of improvements may be underestimating the true value resulting from the improvement. The total utility, meaning the total area under the demand curve, is the appropriate one against which to measure costs.

There are both theoretical and practical difficulties with estimating the consumer's surplus under any specific condition. The practical ones include lack of data concerning the demand function: the effect on volumes demanded at various trips cost-prices due to the extreme variability of trip cost-prices.

Highway transportation is distinguished from other modes by the ability of the individual consumer to set the cost-price of his trips or highway transportation services over all. This is because the consumer of automotive transportation is also, in part, its producer. From a range of variously priced inputs he chooses that combination that suits his budget and tastes. This is in contradication to other modes (sea, air, and rail transit) where a single-price fare is paid to a transportation producer for a given quality of service with only a few qualitative options (e.g., tourist and first class, parlor car and Pullman). The producer, not the consumer, chooses the inputs—vehicles, control, energy, paths, and terminals—on a least-cost basis.

The producer-consumer of highway transportation, in effect, sets his price of travel. Each car on the highway travels at a different price per mile, extending over a wide range. Capital or fixed costs include the vehicle price, which can vary from $50 for a used car to more than $10,000 for a luxury model. Operating costs include gasoline, which has a range of prices by location and grade and is consumed at rates that can vary from, say, 6 to 36 miles per gallon.

Costs of other inputs and their rates of consumption are similarly varied. Some costs, such as time, comfort, risk, and convenience, are extremely subjective, with the possibility of values ranging from zero to hundreds of dollars imputed to them. Variations may be due to circumstances, trip purpose, and socio-economic status of the traveler. Consider, for example, the "value of time" differences represented by a pleasure driver and a "life or death" occupant of an ambulance.

Drivers can adjust their trip costs by other means. If congestion causes a higher cost of highway transportation to occur at certain hours or over certain routes, drivers can choose another route or schedule travel at an hour when there is less congestion. The per-person trip cost can be reduced by car pooling. Thus, it seems unlikely that marginal price changes in highway transportation would have significant effect on demand—especially when drivers can set trip cost in the ways described.

Unperceived Costs of Travel

The perceived cost of travel by automobile is the only cost basis the traveler has on which to make a decision. Often, and most generally, he makes the decision without perceiving any cost at all. Although the drivers of passenger cars and trucks make decisions before and during a specific trip that affect the monetary cost of the trip, it is unknown to what degree the decision is made on the basis of monetary cost. Because there is no cash outlay at the time of decision, it is most likely that the driver is not fully aware of the monetary costs involved. When drivers do incur direct lump sum costs in the process of trip-making, such as for tolls or parking fees, they appear more aware of trip cost than otherwise (*8-8*).

Probably less than 3 percent of passenger car owners keep complete car operating expense records, and no driver is apt to know the precise effects of highway design and traffic conditions on his vehicle running cost at that location and time. It follows then that vehicle running costs play only a small role in trip or travel decisions (*8-8*). The work by Thomas corroborates this conclusion (*8-15*).

Should a driver "perceive" his vehicle running cost and make decisions accordingly (which he seldom does), the general truth is that his perceived costs may vary widely from actual costs. Should he know the actual cost resulting from his decisions, perhaps many of his decisions would be different. Because of varying conditions of the highway, alternative routes traveled, traffic, the weather, and the load in the vehicle, the running cost of a vehicle continually varies. A driver, therefore, is forced to make decisions as to each trip without fully supporting motor vehicle running costs, even though he may want to base his travel decisions on monetary costs.

Drivers' Personal Preferences

The motor vehicle traveler cannot control all of his cost items. Further, he may be interested in satisfying personal preferences rather than economizing monetary costs. The typical producer defined by economics is profit-maximizing. His production function therefore tends toward monetary efficiency, using the least quantity of inputs at the lowest available cost necessary to achieve production of a given quantity and quality of output. The motor vehicle owner and user must likewise be concerned with economic efficiency in that the quantity and quality of his vehicle-miles produced depend on the size of his transportation budget and desired quality of trip, both a function of income. If lower-priced inputs in the least quantity necessary to produce the desired trips are chosen, motor vehicle transportation will tend toward economic efficiency.

When, however, the traveler finds that he can produce the required or desired quantity of travel without strain on his budget, he is free to indulge in more taste-related preference factors and raise the *quality* of his travel. At that point, considerations of travel efficiency are overridden by concern with consumer satisfactions, maximizing the comfort, speed, and convenience that can be obtained with a given budget. At still higher income levels, style and prestige factors enter and the vehicle becomes more than a means of transportation—it becomes a symbol of the owner's status.

At high income levels, money is abundant, but the traveler's time is still limited to a 24-hr day. The marginal value of time begins to exceed the value of marginal dollars due to time's scarcity relative to dollars. (For the same reason, workers may be given time-and-a-half pay rate to induce them to give up leisure hours for overtime work.) "Efficiency" once again enters the picture in the demand for means of producing "travel time reductions," more often preferred than "vehicle running cost reductions." From this demand has flowed the effort to impute a value for the highway traveler's time so as to measure the "time efficiency" as well as the "cost efficiency" of highway improvements in determining their economic feasibility—benefit/cost ratio or rate of return.

In an affluent society personal preferences may come to predominate over monetary efficiency considerations in the provision of government-provided inputs as well. Evidence of this, in addition to the evaluation of travel time reductions, is afforded by the billions of dollars proposed to be spent for highway beautification. This comes near to being a pure consumer preference item, unrelated to efficiency of transportation. Efforts to find a significant statistical correlation between a roadway's beauty and its safety generally have failed, obviating the justification of including beautification as an "economy" factor in cost-benefit analysis.

Economy Versus Personal Preferences

A sharp division must be made between those costs incurred for the purpose of inducing greater highway transportation economy and those that are for the purpose of servicing consumer preferences expressed as demand for higher qualities of service. They cannot be justified on the same basis. The "gains" of greater economy are reflected in resources conserved or used with maximum efficiency, but those gains found in subjective consumer preferences are satisfied through "demand" fulfillment.

The consumer's personal preference justification comes from his willingness to pay for the satisfactions he receives. Such willingness is expressed for private goods, in the market, and for public goods, at the polls and in legislation meeting public preferences. The cost reflects some of the relative utility of private goods; the taxes paid willingly reveal some of the utility of public goods.

Transportation efficiency is thus the proper concern of highway engineers; transportation preferences are the concern of policy-makers and politicians. The subjectivity of preferences makes difficult their evaluation for use in cost-benefit analysis except in the instances when consumers are forced to reveal them (e.g., by paying a toll, expressing a willingness to be taxed for a certain purpose, or in trends in the numbers of people willing to pay for or consume certain public goods). Their relative worth may be better left to the judgment of legislative bodies and decision makers based on whatever available evidence shows a public willingness to have their taxes used to secure certain benefits.

Elements of Monopoly

Highway "demand" exists within a special set of conditions imposed by the institutional framework and cannot be analyzed in the same manner as the demands for goods or trips. The highway itself is a product of collective (collective, public, or governmental monopoly) demand and supply. Collective highway demand is financed by collective highway revenues. The cost of highway construction is spread over the entire user population rather than being charged to the users of a specific facility, as occurs on toll roads. The supply of highways is a governmental monopoly. The related supply of vehicles is under oligopolistic control of a few suppliers: the vehicle manufacturers. Under these conditions, it is impractical to speak of a demand curve for "highways" as such, although one could be drawn for demand for highway use, the ADT or AHT over a single route or route segment.

Lack of Choice

As seen in the discussion of indifference curves and the budget line, the estimation of demand assumes the existence of choice. Price or cost has less influence on the demand curve where no choices are available. Without choice of modes, the amount of highway use and the cost, including user taxes, that can be charged without reducing demand thus cannot be said to indicate a level of highway "demand" calling for new investment of a certain magnitude.

Neither investment funds for, nor choice of, alternative modes presently exist to any significant degree. Most consumers are limited to the automobile for a majority of trips. Only in a small number of urban areas does public transit form an alternate choice of passenger travel. At the low population density that automobility encourages, public transportation often ceases to be economically feasible. Therefore, in most areas, highways monopolize the supply of passenger transportation service. Necessity, not choice, determines that a highway vehicle will be used to meet transportation needs; a "choice" no longer exists.

A theoretical problem has been proposed by Mishan (*8-11*). As trip makers adjust locations, modal choice, and travel patterns to the accessibilities provided by the improvement, substitute locations and modes of travel decline and perhaps disappear through lack of patronage. The gaining modes and locations become the only ones available for fulfilling trip purposes. By necessity, what one would (has to) pay rather than do without the purpose fulfilled by the trip grows accordingly. The demand curve forced higher represents higher levels of consumer's surplus, even at the higher price. As prices rise, consumer's surplus is rising also and the gains conferred by the highway continually grow larger. Users are forced to give up more than the preferred amount to gain the utilities of the highway transportation services. This would tend to inflate the total utility of the highway and any net gains that could be realized by its improvement.

Trip Volumes as Indicators of Utility

Trip Purpose

Places from which commodities can be supplied are normally separated in space from the locations at which they are demanded. The linking of supply and demand locations is the task of transportation. Just as the value of the commodity produced on it is a measure of the productivity, utility, or value of land, likewise the value of the product moved over it, or the utilities or satisfactions resulting from its use, is a measure of the utility of a highway.

To determine a highway's utility, it must be asked, "How does society value the trip purposes fulfilled by highway use?" This involves, first, an investigation of trip purposes over the road. Some indication of this is gained from roadside interviews that ask for the trip purpose.

Table 11 gives a variety of average trip length for each purpose. Although trip length is partly a function of income and the spatial arrangement of land uses and activity centers, there is also an element of trip length and cost related to the expected utility of the trip.

As the utility (benefits, gains, satisfactions) expected from the trip rises, the amount of transportation expense justified in making the trip rises proportionately. A consumer will travel farther to earn or spend $25 than he will to earn or spend $2. Trips with high utility (such as work trips) justify the higher cost of travel in peak hours. Shopping-trip length is also a function of the expected utility of the purchase as measured by their dollar cost. That shopping-trip length is a function of trip utility is supported by Figure 20, which shows a rough correlation between trip travel time and the average amount spent on shopping trips to four regional centers in the Washington, D.C., metropolitan area.

Over and above the high order of utilities offered, the larger commercial centers increase their attraction through the variety of commodities offered. This availability allows the consumer to combine trip purposes, increase the amount of utility obtained, and so justify even higher trip costs and longer trip distances. Greater variety also increases the probability that the consumer will find what he is seeking in type, quantity, and quality of a good and at the price he is willing to pay. In short, it increases his opportunity to "shop" and his probability of finding satisfaction. Higher volumes of sales and more competitors in the same market frequently offer price advantages as well. For these reasons, transportation improvements generally benefit the higher order centers more than the lower order centers because trips to them have a higher utility potential (*8-3*, pp. 137, 266).

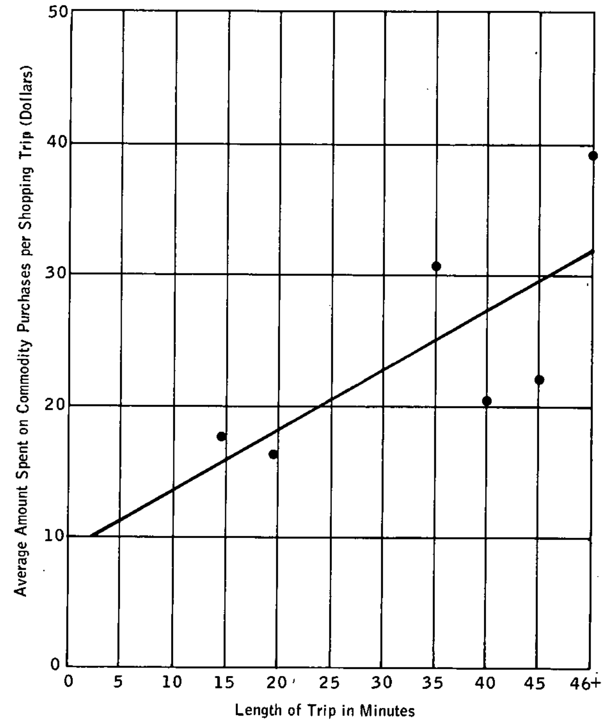

Figure 20. Amount spent versus trip length in time; four regional shopping centers, Washington, D.C., area. Source: (8-25, p. 75).

Origin and Destinations

Other indications of highway or transportation utility come from knowing how origins and destinations (land uses) are patterned and how they interact. From this it is possible to relate the major uses made of the road: proportions of ADT that are work trips, social-recreational trips, industrial goods movements, commercial deliveries, etc. The trip generation and attraction potential of various land uses leads to the projection of trips for various purposes and their aggregation into trip desire lines of a certain magnitude. This consideration becomes the basis for the "gravity model" of traffic assignment that relates size of a center or area to its trip generation or attraction potential via a ratio that includes distance.

Short-Run Demand

Temporarily, short-run demand responds to the times at which various utilities are offered. The utility of employment is high and business practice requires that most persons work the same hours and in close proximity so that interaction between operations, establishments, and persons can be carried on efficiently in furtherance of economic goals, production, and profits. This situation at once creates peak work-trip volumes and justifies the total cost of peak-hour transportation.

Other utilities attach to other trip purposes leading consumers to experiment and adjust the clock time at which trips are made, to the extent possible, so as to hold trip cost, travel time, and inconvenience to a justifiable level relative to the expected utility to be gained from the trip. Demand for local trips is therefore sensitive to temporal changes in cost and qualities of transportation. Changes in transportation cost may be related to congestion (large numbers of vehicles using a highway facility simultaneously, thereby approaching roadway capacity) and spatially due to factors of route location and design (affecting the cost of covering the spatial distance between origin and destination). Highway capacity, route location, and design are fixed, and the only way to secure a trip at lower cost or shorter travel time is to substitute an alternative clock time for the trip when less congestion exists or substitute other destinations reachable by less costly routes.

The response of trip cost to trip demand in the short run for which the supply of roadway capacity is fixed is shown in Figure 21. Choice of the clock time that trips are made and/or the destination to which they are made allows partial control of trip cost. Relating this to the previous theoretical discussion, a lower trip cost will produce a higher budget limit that becomes tangent to a higher indifference curve with greater utility as in Figure 16. This is a "substitution effect"—lower-cost trips for higher-cost trips and related goods.

The response to lower transportation cost affected by highway improvement is to increase the quantity of transportation services demanded and/or the demand for goods and services for which the trips were taken. Hence, the observed effect is that the transportation improvements that

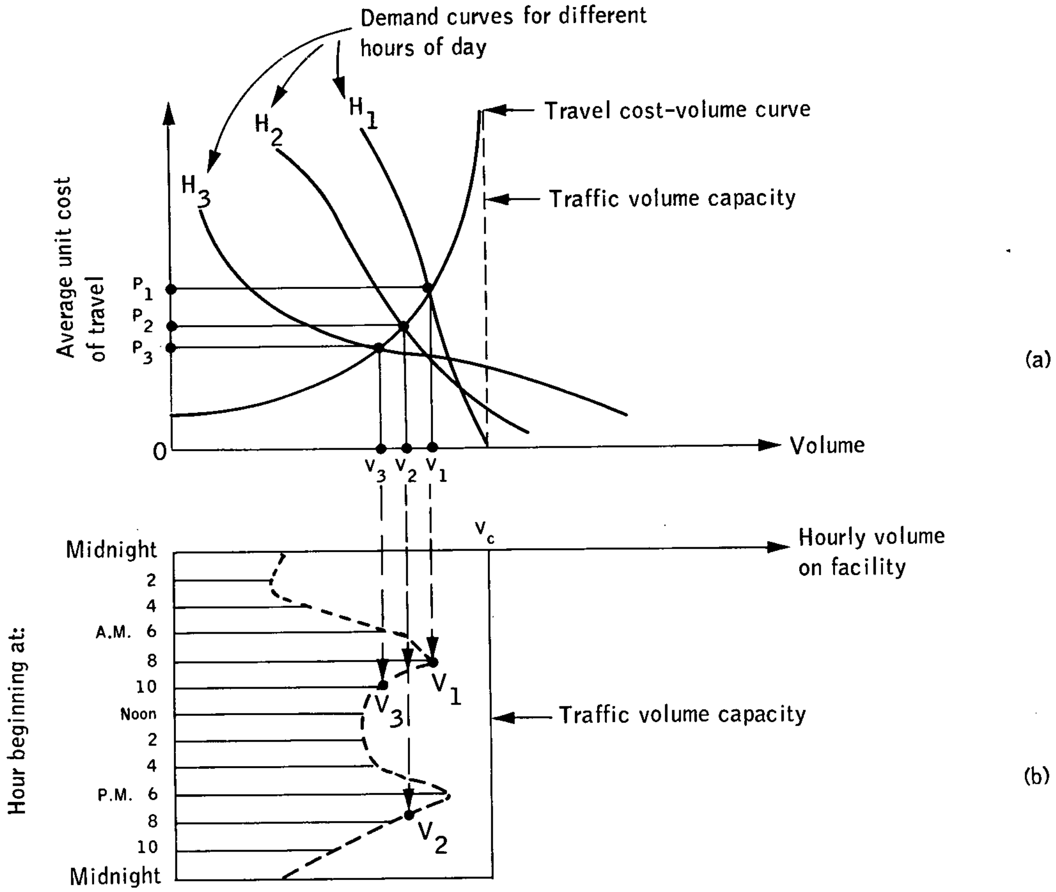

Figure 21. Short-term demand and price-volume relationships.

lower the cost of travel increase trip demands. Trips for the same purpose can then be justifiably made over more hours of the day without reducing the cost-based consumer's surplus.

The effect works in reverse with rising trip costs due to increased short-run demand and congestion. When a demand curve is drawn with price as the ordinate the apparent consumer's surplus is greater than when cost is the ordinate. Transportation expense as a part of the cost above the price paid is one of the factors that acts to make the price-based consumer's surplus greater than the cost-based consumer's surplus.

As more of the potential consumer's surplus price is taken away by transportation costs, the more inclined the consumer is to wait until transportation costs are lower. This means that shopping trips may be delayed to off-peak traffic hours when trips can be accomplished at lower travel expense and travel time.

Alternatively, the consumer may accept substitute commodities or services available from nearer sources of supply—trips to other destinations being discouraged. This leads to the "law of intervening opportunity": a consumer in the market for a commodity will travel no farther and incur no more trip expense than necessary to obtain the commodity. If the commodity exists at more than one location, prices and qualities being equal, the consumer will seek it at the location of least travel cost and personal sacrifice.

In this manner, market boundaries for certain commodities are expanded or contracted temporally and spatially by the raising or lowering of trip cost in those dimensions. This relation of trip cost to space and time is further discussed in the section on location economics, showing the nonuser effects of trip cost variability.

Long-Run Demand

Demand for travel over the years is a function of changes in population (number of demanders), location of trip generators and attracters (distribution of demand), and costs and incomes (level of demand). The "income effect" produced by higher incomes is especially significant for transportation demand in that it generates higher demand levels even without population or location changes.

With higher levels of demand for goods and services go higher levels of demand for transportation necessary to their procurement. In that aggregate demand is the total of individual demands, a general rise in incomes due to prosperity will have the same effect on the population as it has on the individual: a rise in consumer demand for goods and services matched by a rise in the correlated demand for transportation. The theoretical explanation for this effect is shown in Figure 16, which shows how the higher budget limit achievable with increased income becomes tangent to higher indifference curves. Such curves represent the increased utility and satisfactions preferred at the higher level of expenditure on more and finer goods.

Demand for higher-priced goods and services also increases the expenditure for transportation, because a higher proportion of their price or utility is justified to be spent in obtaining them. This means increasing the quantity (longer trips or more frequent trips) and quality (larger, higher-powered, more luxurious cars and demand for higher standards of highways) of transportation.

Although demand shows long-term growth, the supply in terms of highway capacity is fixed in the short run but variable in the long run with ability to accommodate the growth through expansion of highway capacity. Highway improvements made to expand traffic capacity and/or lower trip costs are the result of the ever-interacting economic ties between price, demand, and transportation associated with the consumption of goods and services.

Community Consequences as Indicators of Utility

Economic Effects

As is shown in the following section on location economics, highways, in common with other modes of transportation, have three main community consequences:

1. Development effects.
2. Distribution effects.
3. Spillover effects.

These effects occur as a result of persons spending money, traveling, or otherwise using their resources to gain these utilities or satisfactions that fulfill their needs and desires. In the seeking of these satisfactions, people indulge in economic activity.

Consciously, or unconsciously, intended or unintended, these activities become the main economic effects of transportation investment. The utility of highway investment for the economic life of the community should be considered in the context of these effects. The real "purpose" of highway investment is to (1) link sources of supply and demand; (2) develop resources, facilitate social intercourse and economic trade, provide appropriate degrees of access to key sites for purposes of defense, recreation, tourism, and conservation; and (3) create sound, livable communities through an integration and coordination of land use and transportation leading to successive optimal states that reflect current community goals and values.

Goals and values change. They differ according to the spatial and temporal context in which they are formulated. They reflect the needs, problems, and prospects existing when and where highway investment is proposed to take place. The analyst should be aware of change in spatial and temporal contexts and its implication for decisions made in pursuit of public policies. Policies sometimes outlive the needs and problems that originally inspired them or are inappropriate within certain contexts. Systems analysis of community consequences should show awareness of these factors in determining the community dimension of the total utility of highway investment.

LOCATION THEORY CONCEPTS

Location theory is that branch of economics that deals with the spatial dimension of economic activity. Equilibrium economics is aspatial, dealing with supply-demand relationships as they exist at a point such as a firm, a household, an individual consumer, or aggregated in the national accounts of production and consumption. Location economics puts these various relationships into their spatial context, demonstrating their magnitudes as partially a function of transportation costs incurred in linking sources of demand to their suppliers and vice versa. Highway location and design play a significant role in determining the cost and price of transportation which, in turn, affects the price and thereby the supply and demand for various commodities, locations and parcels of land, and the extent and frequency of human interaction. Some understanding of location economics is therefore desirable in that it reveals the cause and effect relationship between transportation improvement and community consequences stemming therefrom.

Market or Trade Area

The trade area for a commodity is the geographic area within whose boundary exists the total market demand for the commodity. The market demand schedule of equilibrium economics is the sum of the schedules of all the individuals in the market or trade area. Transportation costs frequently determine the geographic extent of the market in that such costs are translated into price (and cost) increases at greater distances from the market center or point of production. Where transportation costs are a significant share of the delivered price, they and the geographic distribution of potential purchasers jointly determine the elasticity of the market demand curve, the percentage by which demand increases or falls for each change in price. When all potential consumers of a commodity are located at the production center where transportation costs are insignificant relative to price, the elasticity of the market demand curve would be the weighted average of the individuals' price elasticities, the weights being the quantities purchased (*8-4,* pp. 57-58).

Market Demand and Trading Distance

To demonstrate the concept of interdependency of demand, cost, price, and trading distance, consider a commodity marketed in only two locations: at A, the market center where no transportation costs apply; and at B, a location at such a distance from the market center that transportation costs add to the local price of each unit of the commodity. At both locations suppose that there are 100 identical individuals, all with the same demand schedule for the commodity. As given in Table 14, at $20 no one desires to purchase the product. At $19 one unit of the product is desired by each consumer, who would take an additional unit of the product for each dollar drop in price thereafter. Because the increase in the total quantity demanded is responsive to the fall in price, the commodity is demand elastic. With the same demand schedule but with the product bearing the burden of a transportation cost of $2 per unit added to the delivered price at B, consumers at B

TABLE 14

DEMAND SCHEDULE FOR A PRODUCT AT THE MARKET CENTER AND A DISTANT POINT

	QUANTITY DEMANDED AT THE MARKET CENTER (A)			QUANTITY DEMANDED AT A DISTANT POINT (B)		
FOB PRICE ($)	ONE CON-SUMER	100 CONSUMERS	DELIVERED PRICE ($)	ONE CON-SUMER	100 CONSUMERS	TOTAL QUANTITY DEMANDED
(1)	(2)	(3) = 100 × (2)	(4) = (1) + $2	(5)	(6) = 100 × (5)	(7) = (3) + (6)
20	0	0	22	0	0	0
19	1	100	21	0	0	100
18	2	200	20	0	0	200
17	3	300	19	1	100	400
16	4	400	18	2	200	600
15	5	500	17	3	300	800
14	6	600	16	4	400	1,000
13	7	700	15	5	500	1,200
12	8	800	14	6	600	1,400
11	9	900	13	7	700	1,600
10	10	1,000	12	8	800	1,800

purchase a smaller total quantity of the product than 100 identical consumers at the market center, A. The differences in quantity demanded at A and at B as given by column (3) minus (6) of Table 14 show the effect of transportation costs on demand. The total quantity demanded (column 7) reveals the result of translating delivered prices and demand to a point, the market center. This demonstrates the dependency of the demand curve on transportation costs and the distribution of the market in space.

From this simple example it is possible to proceed to a consideration of the effects of a change in the cost of transportation due to an improvement in highway transportation efficiency. For this purpose, a second model is hypothesized that, although simplified, contains more of the elements of real-world conditions.

Refer to Figure 22. Assume a market center at A on the surface of an undifferentiated plane on which transportation can be accomplished in any direction at equal cost, the cost rising at a rate directly proportional to distance. Assume that in each concentric ring one unit of distance wide proceeding away from the market center there exist 100 evenly distributed potential consumers of the product supplied from the central point A. In this example it is assumed that each potential consumer demands only one unit of the product but, because of differences in income and taste, some consumers will buy the product at higher prices whereas others will enter the market only if the price falls. To simplify, it is supposed that the aggregate demand schedule for the population within each concentric ring is identical. It also is assumed that each ring represents a transportation price "zone" wherein the transportation price charged at the inner edge of the ring or zone remains uniform throughout the zone. The innermost ring would thus be a "free" zone considered as the market center A. The price would go up in the second zone by the amount of transportation tariff applied to the product as it passed over the inner border of the zone.

Market Before Highway Improvement

In the hypothetical model of Table 15 it is assumed that the transportation tariff in the "before" situation is $2 per unit of distance or per zone. Assuming that the product is sold at the market center at a uniform price of $2 per unit, the transportation tariff increases the price to $4 in zone B, to $6 in zone C, to $8 in zone D, and so forth, as given in column (1) of Table 15. Column (2) indicates the total quantity demanded in each ring based on the relationship between price and quantity demanded shown in the demand curve (Fig. 23) assumed for each ring. This is the situation before the highway improvement lowers the price of transportation. Adding the quantities demanded in each ring reveals that 200 units (Table 15) of the product are demanded from the market center at A, making the total revenues of the supplier $400 at the given price. Column (2) also indicates that the boundary between zones D and E forms the margin or limit of the market in that none of the product can be sold beyond zone D under the assumed price schedule.

Market After Highway Improvement

Next, it is assumed that a highway transportation improvement is undertaken that lowers by one-half the cost of transportation between A and each other zone. The cost would thus fall from $2 to $1 in zone B, $4 to $2 in zone C, and so forth. The delivered price of the product supplied from the market center at A to the zones would fall by an equal amount. The resultant product price in each zone is given in column (3) of Table 15. Assuming that the price-

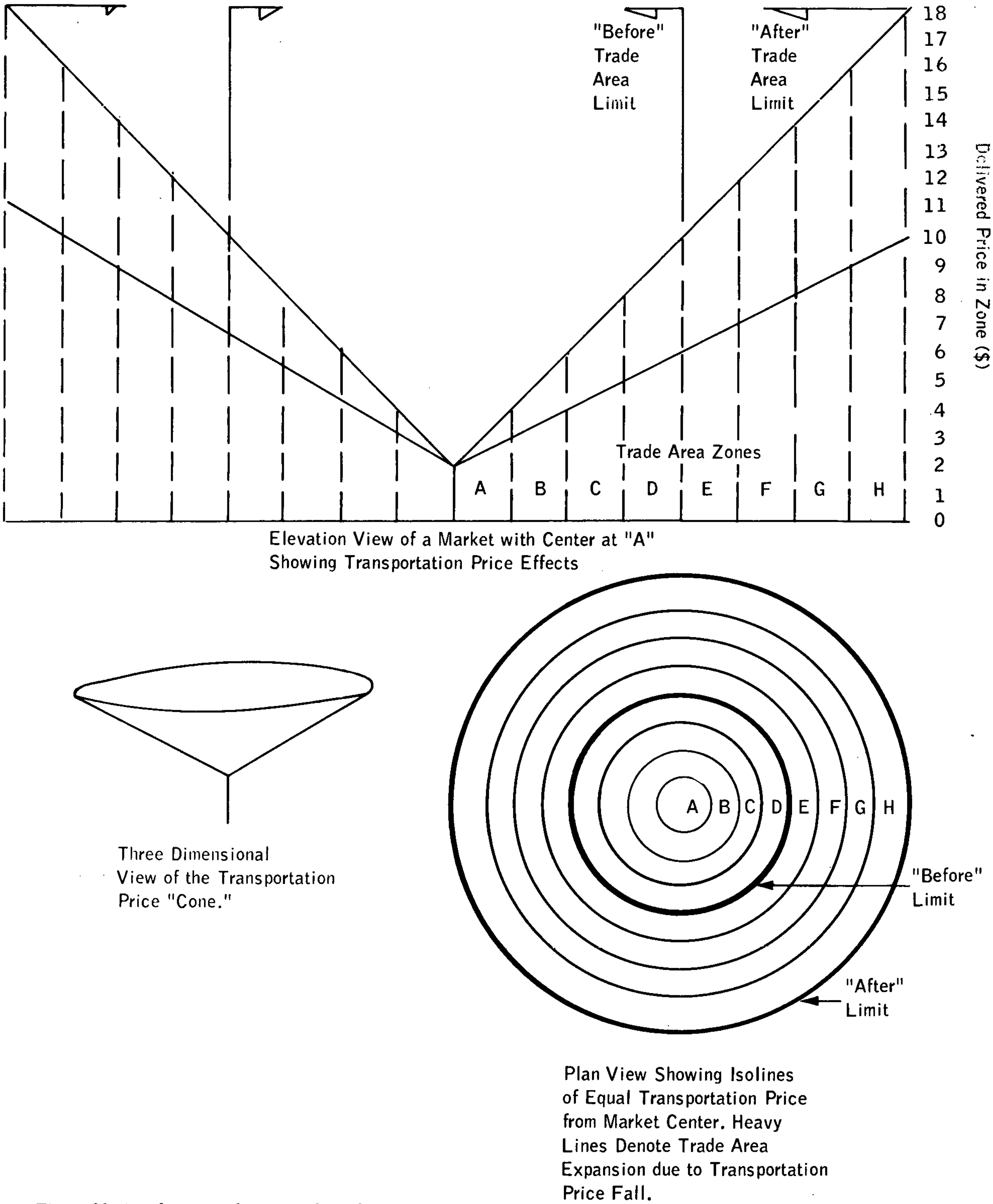

Figure 22. Market or trade area and goods; price as affected by highway transportation cost change.

demand curve for each zone remains the same as shown in Figure 23, the lowering of the delivered price will cause greater quantities to be demanded in each of the zones where the delivered price was affected by transportation costs. The price lowering also brings into the market new zones that before could not or would not purchase the product at the price at which it was offered in those zones. As evidenced by column (4) of Table 15, the aggregate demand increase felt at the market center is for an additional 160 units or for a total of 360. At a constant $2 per unit the supplier's total revenues are now $720. Also evident (column 4) is the outward movement of the trade area

TABLE 15

DEMAND SCHEDULE FOR PRODUCT SUPPLIED FROM MARKET CENTER "A" BY CONCENTRIC ZONES

RING OR ZONE	DELIVERED PRICE BEFORE TRANSPORTATION IMPROVEMENT ($) (1)	QUANTITY DEMANDED AT "BEFORE" PRICE (2)	DELIVERED PRICE AFTER TRANSPORTATION IMPROVEMENT ($) (3)	QUANTITY DEMANDED AT "AFTER" PRICE (4)
A	2	80	2	80
B	4	60	3	70
C	6	40	4	60
D	8	20	5	50
E	10	0	6	40
F	12	0	7	30
G	14	0	8	20
H	16	0	9	10
I	18	0	10	0
Total quantity demanded from market center:		200		360

boundary from the outer edge of zone D to the outer edge of zone H.

From this hypothetical model can be derived the theoretical underpinnings of the observed economic effects of a transportation improvement that significantly affects the cost of transportation. These effects include:

1. Lowering the delivered market price of commodities and services whose movement is affected by the transportation improvement.

2. The increase in demand at the market center for products whose price has been so affected; increased demand resulting from both "substitution" effects and "income" effects described previously.

3. The spatial enlargement of the trade area that is supplied from a single market center. The trade area extends outward to the point where demand for the product it supplies disappears because the delivered price exceeds the total utility offered by the product. Greater utility would be offered by local substitutes at a lower price. Trade area boundaries may also be drawn inside the boundary where total costs would exceed total utility when a prior boundary is formed by the presence of a competing market center.

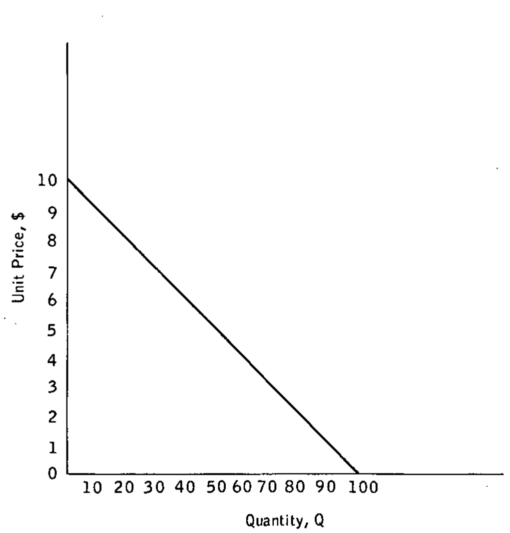

Figure 23. Demand curve of the population of each concentric ring in Figure 22.

Range of a Good

Two essential concepts are necessary in location theory to explain the effects of transportation improvements on commercial enterprise. These concepts are: (1) the range of a good, and (2) the threshold of a good. The first of these concepts expresses the idea that for each service or good there are two relevant ranges to be considered in locating centers of production or commercial outlets. These ranges are defined by Berry and Garrison (*8-3*, p. 191) as follows:

> This range marks out the zone or tributary area around a central place (urban center) from which persons travel to the center to purchase the good . . . . The *upper limit* of the range is the maximum possible radius of sales. Beyond the upper limit the price of the good is too high for it to be sold, either because of the increase of price with distance until consumers will no longer purchase the good (the *ideal limit* where demand becomes zero), or because of the greater proximity of consumers to an alternate competing center (the *real limit*). The range also has a *lower limit*, that radius which encloses the minimum number of consumers necessary to provide a sales volume adequate for the good to be supplied profitably from this central place.

Transportation costs, to the extent that they significantly affect the delivered market price of goods transported from a market center or place of producion, are crucial in determining the range of a good. Improvements or investments that affect transportation costs will be instrumental in altering the range of a good or, more likely, the structure of ranges for all goods that, in turn, will heavily influence the spatial arrangement of land uses.

Threshold of a Good

The concept of the threshold of a good describes that lower market level at which it becomes economically justifiable to offer a good on the market from a given location given the spatial distribution of demand. Berry and Garrison (*8-3*, p. 54)[1] also provide a good definition of the concept of the threshold of a good:

> There is some minimum size of market below which a business center will have no economic justification to supply a good. This is the point at which sales are large enough only for the firm to earn normal profits. It constitutes a minimum scale (or condition of entry) defined by the lower limit to the range of a business center for the good. Such a minimum scale of purchasing power necessary to support the supply of a central good from a business center is here termed the threshold sales level for the provision of the good from a center.

In terms of equilibrium economics the threshold approximates the so-called break-even point where total revenues

[1] Original quotation is found in Berry, B. J. L., and Garrison, W. L., "A note on Central Place Theory and the Range of a Good." *Economic Geography*, 34 (1938) pp. 304-11.

are just equal to total costs. If sales volumes are below the threshold level, the entrepreneur probably would not go into business at a location where this condition existed. If, through lack of knowledge or foresight, he did choose to establish operations, the business would not earn a profit. Where trade volumes are greatly above threshold level at a given location, profits above the minimum attractive level will be earned by the first entrepreneur to take advantage of this situation. His success will encourage competition to arise in the same location and, by sharing the market, profits will be driven down to a "normal" level (equal to what the capital invested could earn in alternative uses; e.g., the market rate of return).

To illustrate this concept and how it relates to the economic effects induced by highway improvements consider the hypothetical case of the enterprise whose market center was denoted A in the concentric zone example of Figure 22.

Figure 24 shows the cost-revenue diagram for the hypothetical product supplier located at the market center A. This fixed cost is $250 for any production up to 500 units, and the variable cost is $1 per unit. The revenue line is based on a market selling price of $2 per unit. At point P the total revenue curve crosses the total cost curve and total revenues are equal to total costs. This point is the break-even point or threshold for supplying the product. At all lower sales volumes losses are being incurred. At higher sales volumes, profits are being earned.

At the potential market volume that existed in the concentric zone example, before the highway improvement was made, a loss would have been suffered. No development would have occurred because only 200 units of the product could have been sold and the break-even volume is 250 units. According to Table 15, the volume of demand after the highway improvement rises to 360 units, bringing total revenues up to $720. At this point, total revenues exceed total costs by $110, which represents the profits of the enterprise at a sales volume of 360 units. At this point, development of the opportunity for profit would take place if this profit of $110 were sufficiently attractive relative to other opportunities open to the entrepreneur.

It is by this process that highway improvements are seen to spark new development, encourage redevelopment, and strengthen previous development. Where accessibility is diminished rather than enhanced, the effect is to weaken or destroy previous development where commodity sales volumes fall toward or below the threshold level. In actual practice, the threshold for entering into business probably will lie above the break-even point; probably in the region where the profits of the enterprise represent a rate of return greater than the entrepreneur's minimum attractive rate of return.

Location Economics

It is now possible to combine the concepts contained in the previous sections concerning equilibrium and transportation economics into a synthesis that models and explains their relationship to location economics. Location economics is basically the theory of the spatial distribution of economic activity (i.e., firms, households, and governmental and institutional services).

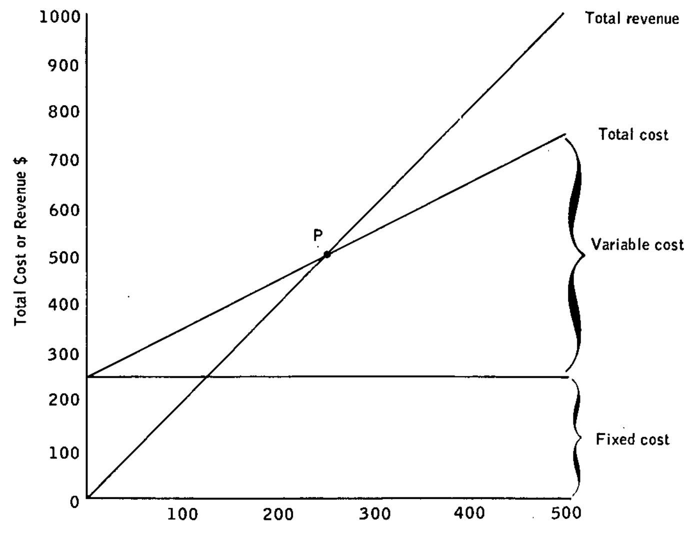

Figure 24. Cost-revenue diagram of product supplier at market center A.

Graphic Representation of Trade Distribution and Highway Use

Figure 25 is a graphic representation of the synthesis of equilibrium and transportation economics into location economics. The figure forms a simplified diagram of the relationships presumed to exist in a hypothetical case. It shows the process by which locations of economic activity are chosen and by which highway traffic volumes are increased or decreased.

Diagram (6), Total Demand of Each Ring, is assumed to represent demand and supply curves existing in each concentric annular ring one mile apart, ranged around a central place where it is desired to place a commodity on the market at a uniform price of $1 per unit. The demand curve reveals that, out of 200 potential buyers in each ring, 100 will demand the commodity at that price on, say, a daily basis. This is the quantity demanded at the equilibrium point E, where the supply curve S, represented as a horizontal line due to its assumed price inelasticity, intersects with the demand curve D.

It is assumed that consumers located in all but the innermost ring (within one mile of the firm supplying the commodity) must pay a total delivered price for each unit of the good equivalent to the FOB price of $1 *plus* transportation or shipping charges of $0.10 per mile per unit additive monotonically away from the center. This monotonic increase in the delivered price of the good due to the transportation rate is shown in Diagram (4), a cross-sectional view of the trade area. The central stem shows a magnitude of $1, the commodity's price at the market center C. The slope of the delivered price line, CX, is a function of the transportation rate of $0.10 per mile and is formed by drawing a straight line through the two points C and R (R being a point five miles from the market center at which point the addition to the delivered price due to the applica-

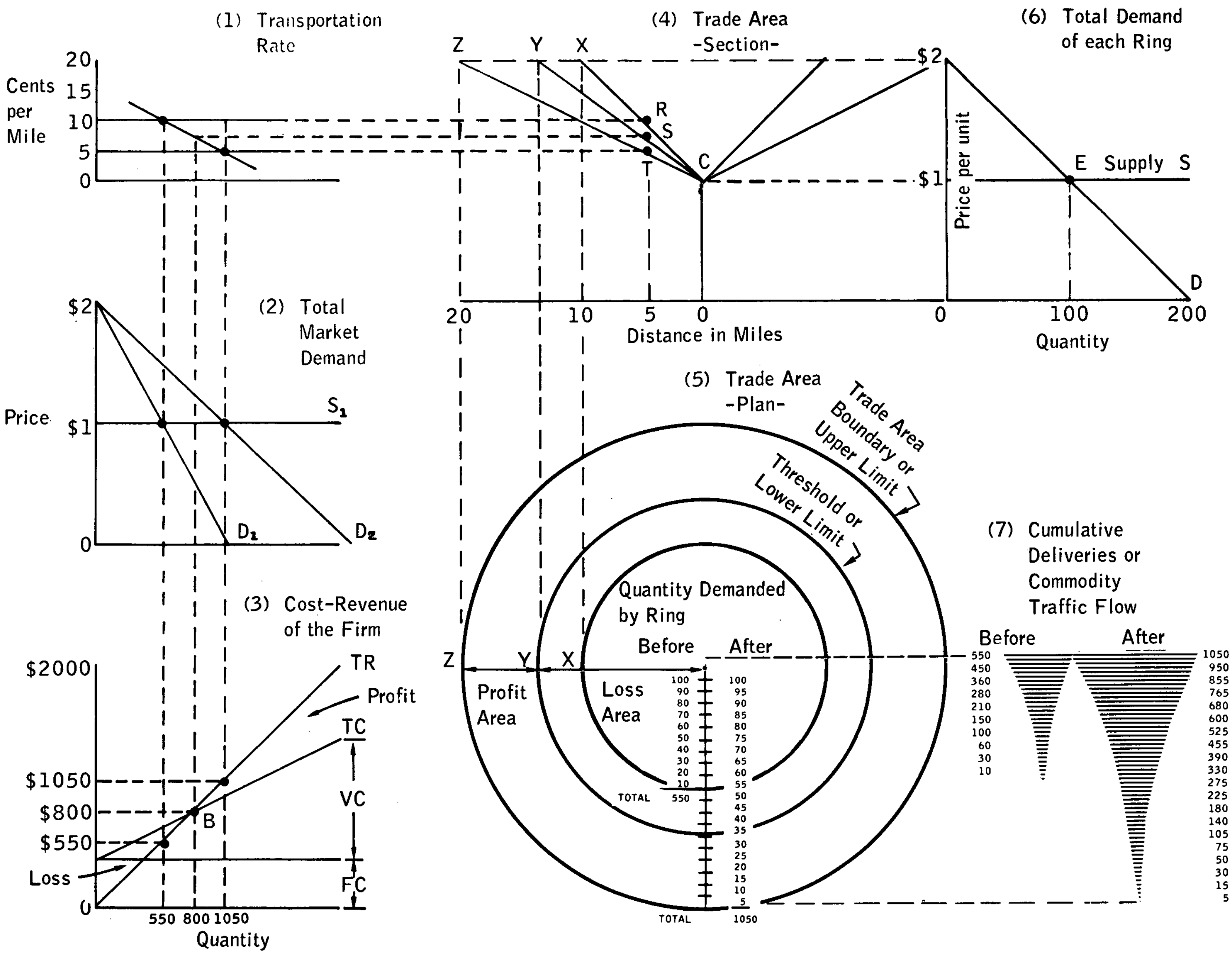

Figure 25. Synthesis: location economics.

tion of transportation charges is $0.50). Using the constant distance of five miles times any transportation rate that may be applicable, it is possible to draw similar "delivered-price" lines whose slopes are determined by the transportation rating per mile. The delivered-price lines CY and CZ were drawn from such computations.

Diagram (1), Transportation Rate, shows the change in the independent variable in this analysis. The dashed lines connecting the various diagrams show the impact of changes in the independent variable on the dependent variables of total demand by concentric ring, the total market demand, the costs and revenues of the firm, the extent and shape of the trade area, and the feedback effect on commodity traffic flows and volumes and their interrelationships. In this hypothetical example, a reduction in the transportation rate from $0.10 per mile to $0.05 per mile will be assumed. The transportation rate is a variable affected by improvements in highway route location and design. The net result is to lower the rate of input of these factors of transportation production. The alternative to reducing the input rate is to shorten the distance or, by a combination of the two, to reduce the total trip cost, the product of distance times rate. The price-related economic impacts of transportation improvements occur theoretically as shown in Figure 25. From an examination of Figure 25 it is possible to proceed to an examination of the impact of the rate change from $0.10 to $0.05 transportation cost per mile on the dependent variables.

By following the dashed lines that trace the impact, first to the right from Diagram (1), it is possible to examine the effect on the trade area in Diagram (4). The new rate creates a new schedule of delivered prices. The old schedule, based on the former $0.10 per mile transportation rate, caused the upper limit of the trade area range to occur at X, 10 miles from the market center. At the new rate of $0.05 per mile the upper limit of the trade area range extends to Z. At that point the delivered price becomes $2. According to the total demand schedule by ring shown in Diagram (6), all demand ceases at a price higher than $2. In other words, none of the product marketed from location center C will be demanded beyond the marginal ring bounded at Z. The trade area has thus been expanded by 10 miles with its new radius being 20 miles, and a new upper limit to the range, defined as the point beyond which demand disappears, has been drawn.

Diagram (5), Trade Area—Plan, provides a geographic representation of these changes in the trade area. Superimposed on this diagram are figures showing the total demand by ring before and after the transportation improvement. In the "before" period, the total demand appearing at the market center C was 550 units per time period (in this case, a day). After the transportation improvement, the total demand felt at C rose to 1,050 units per day.

The Complete Flow Pattern

Following the dashed lines downward from Diagram (1) to Diagram (2), Total Market Demand, reveals the construction of the total demand schedule from these figures. The demand curves meet the vertical price axis at $2 where, according to the demand schedules by ring in Diagram (6), all demand ceases. The uniform FOB price of $1 at the market center is represented by the horizontal supply lines, S_1. The "before" total market demand intersects the vertical axis at $2 and passes through the supply curve at a point reflecting the "before" market demand of 550 units per day. The drawing of a straight line that intersects these two points reveals the total market demand in the "before" period as the demand curve, D_1. The "after" total market demand of 1,050 units per day moves the total market demand to the right on the supply curve by 500 units. The new total market demand curve, D_2 can then be drawn as shown in the diagram, with intersections at the $2 level on the price axis and at 1,050 units on the supply curve.

Diagram (3), Cost-Revenue of the Firm, shows a hypothetical picture of the firm assumed to exist at the market center C. The line labeled TR represents the total revenue of the firm at each quantity of sales (quantity times price). The horizontal line labeled FC reveals the assumed fixed cost of the firm. The line labeled TC shows the total cost of the firm at each volume of sales, the difference between total cost and fixed cost being VC, the variable cost of goods and operation at each sales volume. As the diagram shows, total cost exceeds total revenue out to the point B, the break-even point where total revenue equals total cost. That point is reached when total quantity sold is 800 units for a total revenue of $800, total costs equaling the same amount. At any quantity greater than 800 units, total revenues are greater than total costs to a degree that increases with volume, the difference being the profits of the firm. As shown in the diagram, the total demand in the "before" period is 550 units, a quantity below the break-even point. Under such circumstances, given sufficient knowledge of the market, the firm would not choose to go into business at location C. After the transportation improvement has lowered the transportation rate and the total potential quantity salable from the location C has risen to 1,050 units, thereby exceeding the break-even quantity, the firm could profitably be developed there. The break-even point, B, thus becomes the "threshold" for the firm's going into business at location C.

A dashed line drawn upward from B to Diagram (1) intersects the transportation demand curve related to the price for transportation, a straight line drawn through the volume of traffic delivering the commodity at the before and after prices, at a point representative of approximately $0.075 per mile. Extending this dashed line to the right to intersect with the point S at a five-mile radius from C chosen as the constant by which to multiply the rate in order to derive the delivered-price lines, a new price can be drawn intersecting C and S and extending to Y. A line drawn downward to the trade area in plan view delimits the lower limit or threshold range of the commodity's market from a point C.

In other words, the firm will lose money if its market extends only out to the boundary X. Only when the market's range extends outward *at least* to the lower limit Y, the break-even, threshold, or lower limit range, can an enterprise selling the commodity in question be justified at location C. Only then will it have a sufficient volume of trade to cause total revenues to equal or exceed total costs. The lower limit exists at approximately 13.5 miles from the point C.

Cumulating the demand for each ring shown in Diagram (5), it is possible to graph the cumulative deliveries of "commodity traffic flow" from the market center to the consumers in the various rings. This is shown in Diagram (7). This "commodity traffic flow" assumes that each unit goes out individually over a single radial line, each unit bearing the full transportation cost rate. If shipments could be combined, the unit cost of transportation could be reduced. It is also assumed that goods are shipped via public conveyance to the consumers and that they must bear only the one-way costs of transportation. If consumers came individually to the center for the product, round-trip costs would be relevant.

The "commodity traffic flow" thus represents the quantity of the goods shipped from the point C and its dispersal over the market area, assuming that the only costs are those of radial movement. The "commodity traffic flow" diagram shows the nature of transportation as a derived demand whose volume is directly correlated with the amount of goods or persons moving between points of supply and demand. These movements form the magnitude of "desire lines" and flow diagrams. The distribution of such points over the transportation surface comprises "origin and destinations," and the intensity of supply-demand activity at each origin and destination determines its traffic-generating potential.

Summary of Effects of Changing Transportation Cost

The foregoing theoretical treatment shows how altering (in this case, lowering) the transportation cost results in:

1. Altering the geographic extent of trade areas, thus bringing new demand into the central market place.
2. Creating a correlated shift in market demand at the market center.
3. Creating the opportunity for the development of new enterprises or an increase in the sales of existing ones.
4. Increasing land values through increased demand and sales.
5. Increasing the traffic volume or developing new traffic on new routes.
6. Creating opportunities for roadside development of outlets servicing the needs of the traffic stream.

Combined here, therefore, is the theoretical explanation for the variety of phenomena observed to follow a highway improvement (e.g., changes in retail sales, changes in land values, development and redevelopment of land, increases in traffic volume, the formation of commercial roadside development, and the general geographic restructuring of land use and urban transportation patterns). Such effects can be traced to their common origin in the alteration of transportation cost rates or distances and thereby trip costs and the delivered cost of all the goods and purposes to which such trip costs attach. As in all price changes, both income and substitution effects occur.

The income effects stem from a conservation of resources that would otherwise have been spent on transportation to procure the goods previous to the transportation improvement. With the transportation savings, it is possible to purchase more goods or more transportation with the same number of dollars as previously. Greater efficiency has therefore been achieved.

The substitution effect means that the goods, purposes, trips, or locations made less expensive by the transportation improvement may now be preferred in larger numbers to those alternative goods and purposes not affected and which now appear relatively more expensive. Greater satisfaction or total utility furnished by a given budget has been achieved. Also, demand will be increased for the substituted goods, for transportation, and for the supply at the location that furnishes them at the lower price. Thus, transportation improvements induce more efficiency and greater demand for both goods and transportation.

Based on the forgoing theoretical consideration, the following sections relate highway improvements and travel cost changes to their effects on the community economy and spatial pattern. These effects are classified as:

1. Development effects.
2. Distribution effects.
3. Spillover effects.

DEVELOPMENT EFFECTS

Nature of Development Effects

Development effects are defined here as those derived from the exploitation of the natural resources possessed by land. Land has variegated resources and intrinsic qualitities of environment. Under conditions of demand for the products that land is capable of supplying, there will be a desire for access to it—access that makes its development physically and economically feasible. If the investment in access and the cost of transporting the resource away from the site, when added to other costs of production, do not exceed the price at which the product can be marketed, a profit potential exists. In other words, there is the possibility of a net productivity from the capital investment in a highway, road, or other transportation means, whose purpose is to bring forth the land's productive potential.

Examples of the features of land that give it productivity include its arability, topography, minerals, forestation, scenery, and buildable space. These qualities inhere in particular sites and are not ubiquitous. Therefore, to use these resources, it is necessary to provide access to the specific sites possessing them; a road in no other location will suffice. In this case the land development potential is the determining "benefit" factor in the decision to build a road to that land.

Although development effects are much more in evidence in the early period of a territory's development, they seldom disappear completely as a potential effect. In the United States the opening of the West by canal and railroad led to spectacular developmental effects as the area's resources were developed for eastern and, later, national, markets. The immense potential development effects of urban radial expressways for building up the peripheral areas of the large cities of the U.S. represent the newest American "frontier."

The highway investment contributes directly to the productivity and therefore to the value of the land by providing the access whereby factors of production—labor, capital equipment, other resources—can be aggregated on the site, and a product can be extracted or produced there for local consumption or export. Realization of the development potential of an area thus requires joint investment in capital goods, highways, and other transportation facilities.

Demand for products furnished by exploitation of local natural resources gives rise to investment in the capital goods necessary for their production. Inputs of labor are also required and employment occurs. The needs of those employed give rise to secondary employment in retail, service, wholesale, and construction industries. Settlement thus occurs and, under conditions of continued or increased demand for the local product and its continued ability to supply demand, growth and urbanization will take place. Resource-based communities come into being and develop therefore *by reason of the access* provided to the natural wealth of the area.

Analysis of Development Effects

It is possible, theoretically, to trace the development effects via cash flows and accounts as inputs for primary industries lead to complementary activity, imports and exports, and basic workers use their incomes to fulfill their needs and desires, thereby supporting the nonbasic sector. Although this becomes extremely complex, Mohring and Harwitz (*8-12*, pp. 91-131) propose the application of input-output systems and multi-regional programming to this problem and describe its methods. In the process, the strong possibility exists that a multiplier and accelerator effect may have increased the volume and effect of the original income, through consumption by the recipients as well as through their savings and taxes *if* they are converted to new investment.

The incidence and magnitude and potential for development effects may be identified and measured by economic base analyses. Various methods for making such analyses are described by Tiebout (*8-16*) and works in his selected bibliography. Such a study can indicate the present basic or export industries that are injecting money into the community, the nature of the productive processes served by the road network, the potential for productive gains to the local economy from road locations serving potentially exploitable areas, regions, and sites, and the effect of previous investments in highways on present output types and levels.

The prediction of community returns due to development effects rests on estimates of the demand and supply picture making for the long-run growth or potential for growth of the community. Tiebout suggests "inventories of community assets and liabilities" and the factors of supply that differ from community to community according to local availability of resources, sites, labor, and capital in the first instance and location in relation to suppliers of inputs and the market for the output in the second. Deficiencies in the highway and road network that may be retarding growth may call for investment, with those improvements that produce greatest returns being undertaken first and those that produce lesser returns being assigned lower priorities.

For purposes of evaluating development benefits, traffic counts and similar engineering devices may be of little utility. Estimates of local development opportunities that highway investment can trigger lie in the examination of resource surveys, soil maps, building sites, real estate trends, recreation demands (tourist "exports"), industrial surveys, and from the previously mentioned economic base analyses.

The appropriate criteria for analysis of development effects are those of return on investment. In essence, the government is making an investment of capital in the productive potential of the community (local, state, regional, or national). The net productivity of the capital goods (in this case, highways) is measured in increases in capital investment, employment, and increased output. Returns, as mentioned, can be measured in terms of the net returns from all development so induced and, for solvency considerations, of returns to the community in taxes.

There may be considerations of public welfare that justify highway investments having low or negative returns to the net productivity of the community (such as access to a local park). If so, these must be justified on social rather than economic grounds, and other criteria are applicable.

Highway investment in developing countries and regions relies on evaluation of the development effects for justification in that no traffic exists to provide a computation of the user cost savings counted as "gains" in the usual cost-benefit analysis. The form of analysis to use in such cases is described by Harral (*8-5*).

DISTRIBUTION EFFECTS

Nature of Distribution Effects

Distribution effects are those that occur as a result of each economic unit—household or firm—attempting to locate at the geographic site that optimizes its condition (profits, utilities, satisfactions) according to its goals and value scales. Whereas development effects stem from some intrinsic qualities or resources of the site, distribution effects come from exploiting the site's relationship to other sites, locations, and/or the transportation paths linking them.

Examples of distribution factors include: (1) a factory site in relation to its market, labor shed, sources of its raw material inputs, or some compromise between these such that the transportation cost components of production and distribution are minimized; (2) a retail outlet location relative to its trade area, either central to it or on the roadside of a high-traffic-volume highway so as to maximize sales volumes; and (3) a household location convenient to work, shopping, recreation, and schools so as to keep travel time and expense within a reasonable share of the household's time and money budgets.

Some household locations reflect development effects as they exploit the intrinsic merits of sites producing greater residential satisfaction (e.g., waterfront, views, topography, and vegetation). Such households appear willing to trade off some accessibility to economic and social contacts for more natural amenity. Decentralization of industry and commerce and high-speed radial expressways often provide accessibility to such households, however. Highway building increases the opportunity for such trade-offs.

Each pursuing its own self interest and goals, economic and social units locate and relocate to capture the benefit of a transportation improvement—lower the time and cost of travel between locations with which it has significant and recurring linkages. In doing so, the efficiency gains offered by the transportation investment are maximized and the total transportation bill to the economy may be reduced.

Locations and relocations that produce the ensuing community pattern can be predicted on the basis of knowing the goals and value systems of economic or social units: what accessibilities, linkages, and site characteristics they consider in site selection. Locational requirements interact with the choices produced by the transportation system and its costs, and the supply, competition, and ensuing cost of space (land) to produce geographic patterns of land use and activity. Some of those patterns are modeled in the following sections to show their relationships to transportation modes, system, and costs/prices.

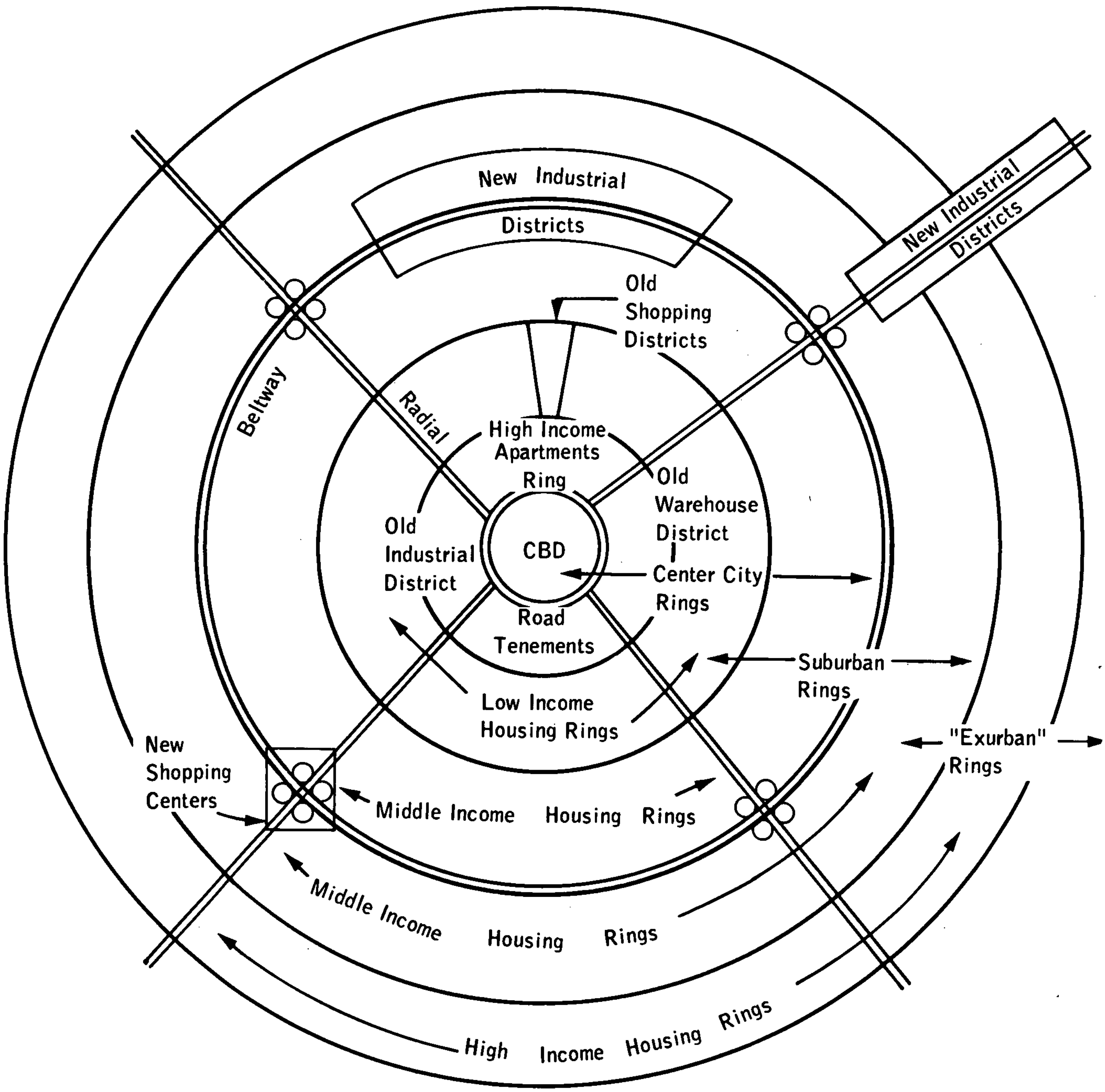

Figure 26. Urban polar coordinate system and schematic generalized arrangement of land uses.

Analysis of Distribution Effects

Analysis of the distribution effects involves tracing the systems effects of geographic movement of households and establishments. This can be done only by looking at the spatial system as a whole, in that effects occur widely throughout it.

The Urban Space Model

Space in an urban system takes the form of a polar coordinate system, shown in Figure 26. The central business district and older industrial centers form the high-intensity core for the surrounding residential areas. The amount of space in successive rings about the core is shown in Figure 27.

Revealed is the monotonic increase in land area ring to ring progressing away from the center, but a geometric increase in total area. It will be noted that space is a scarce resource toward the center, and an increasingly abundant one toward the periphery. The quantity of land at various radii is fixed, being limited to the area of the circle. The total fixed supply of the resource of space available in the urban economy is determined by the radius of feasible development.

Urban spatial boundaries may be formed by a variety of factors (e.g., geographic barriers and land-use locations) but their modification appears to be most sensitive to transportation. Accessibility, travel time, costs, and distances and their tolerable limits for members of the population usually set the urban boundaries. Transportation improvements, by lowering the time or cost of traversing distance, increase commuter ranges and trade area sizes, and encourage decentralization of commercial and employment centers. Such improvements thereby expand the urban spatial boundaries and increase the supply of land available for urban uses.

Residential Distribution Pattern

Distribution of population approximates a normal, or bell-shaped, distribution related to income, family condition, number and age of buildings, and the external economies (conveniences) offered by high-density land use. Typical urban population distributions are shown in Figures 28 and 29.

The interaction of population distribution over the space available produces the phenomenon of the residential density "tent," the number of persons per acre or square mile, which slopes away from the center as shown in Figure 30. Being a ratio of population to space, densities are higher toward the center because, as shown in the urban space model, space declines toward the center, not because population in absolute numbers rises there. As shown, population distribution actually falls off toward the center.

The greater supply of peripheral land made accessible by transportation improvements results in ever-lower residential densities because land supply is constantly increasing relative to demand at greater distances from the city center.

The implication for highway economic analysis is: efficient radial expressways, which encourage decentralization of residences, lower the unit running cost of vehicles (resource consumption) while raising the commuting distance to central work places. In that trip cost is the product of rate times distance, lowering one while increasing the other may mean no economy gains in the long run. Also, if the attraction of low-cost suburban homesites proves popular there is a growing travel cost component due to the marginal social cost of increasing ADT.

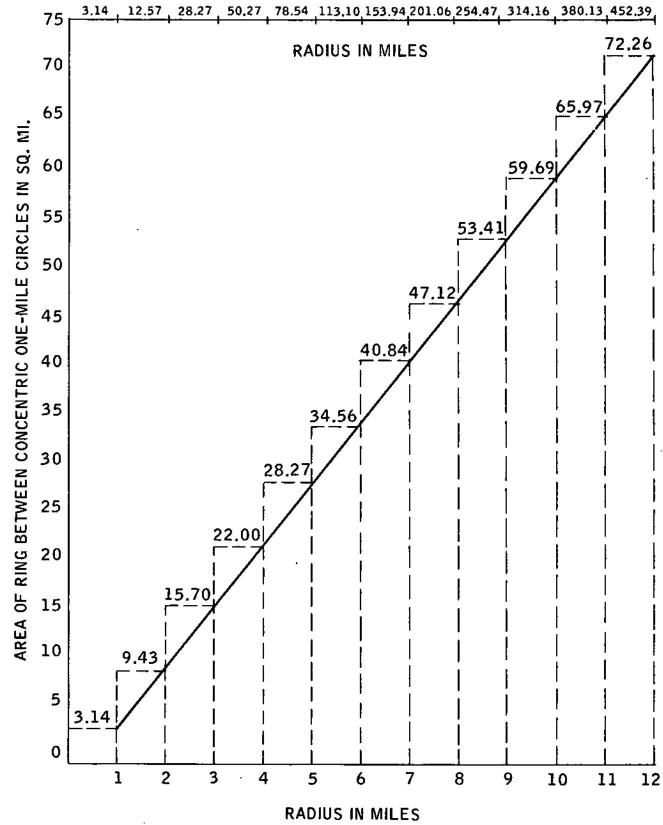

Figure 27. Square miles of area in successive concentric rings one mile in width, by ring and cumulative.

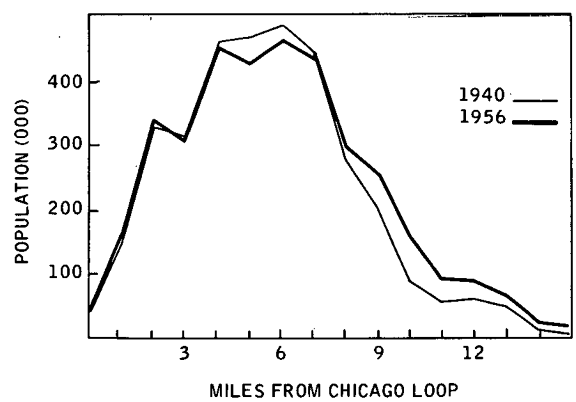

Figure 28. 1940 and 1956 population in Chicago by distance from the Loop, by one-mile rings. Source: (8-26, *Fig. 8, p. 22*).

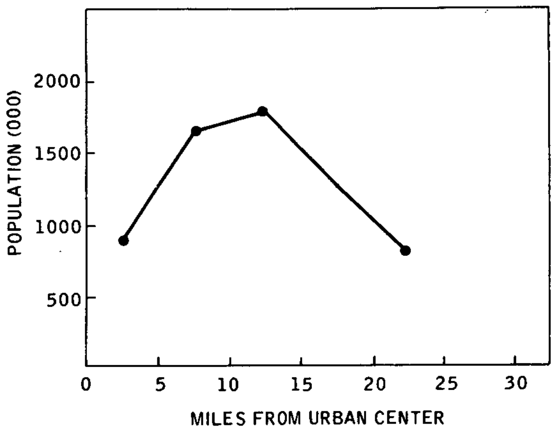

Figure 29. 1960 population in Los Angeles by distance from the urban center, by five-mile rings. Source: U.S. Census, 1960.

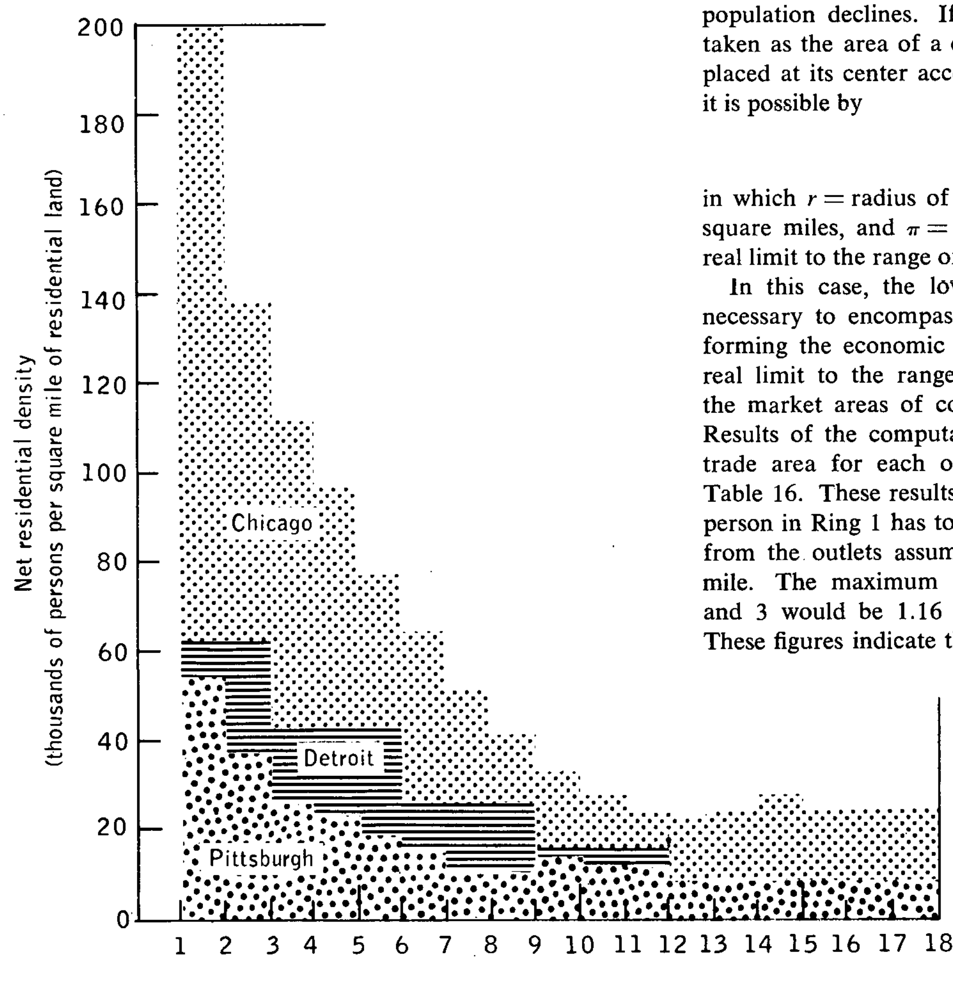

Figure 30. Density "tents" for three U.S. cities, net residential density, by distance from the CBD. Source: (8-27, *p. 207*).

Retail Distribution Pattern—Central Place

To demonstrate the pattern of retail distribution reacting to the pattern of residential density, consider the following hypothetical example. Assume an urban area having the density characteristics shown in Figure 31. Secondly, assume a type of retail trade outlet whose product is desired in equal quantities by all income groups so that population becomes the only consideration in determining the threshold level of demand. Assume that the scale of operations producing maximum profits for each retail store in the chain is one having a potential market of a 50,000 population. Dividing that figure into the total population in each three-mile-wide annular ring about the center of the city produces the total number of retail outlets in each ring having a sufficient threshold for operation. The resultant number of total outlets by ring are given in column (3) of Table 16. It indicates that 10 outlets are justified in Ring 1, 20 in Ring 2, and 16 in Ring 3. Dividing the total number of outlets by ring into the total area of the ring in square miles shows the number of square miles of land area served by each outlet in the ring. The results of this computation are given in column (5) of Table 16.

Evident is the increase in the size of the trade area by successive rings outward from the center as the density of population declines. If the area served by each outlet is taken as the area of a circular market area with the outlet placed at its center according to the central place concept, it is possible by

$$r = \sqrt{A/\pi} \tag{10}$$

in which r = radius of circular area in miles, A = area in square miles, and $\pi = 3.1416$, to determine the radius or real limit to the range of the outlet.

In this case, the lower limit to the range, the radius necessary to encompass the threshold level of population forming the economic justification for the outlet, and the real limit to the range, the distance to the line dividing the market areas of competing outlets, will be the same. Results of the computation of the radius or range of the trade area for each outlet are given in column (6) of Table 16. These results show that the farthest distance any person in Ring 1 has to travel to obtain the goods available from the outlets assumed in this example would be 0.94 mile. The maximum distances to an outlet in Rings 2 and 3 would be 1.16 miles and 1.67 miles, respectively. These figures indicate the increasing reliance inhabitants of

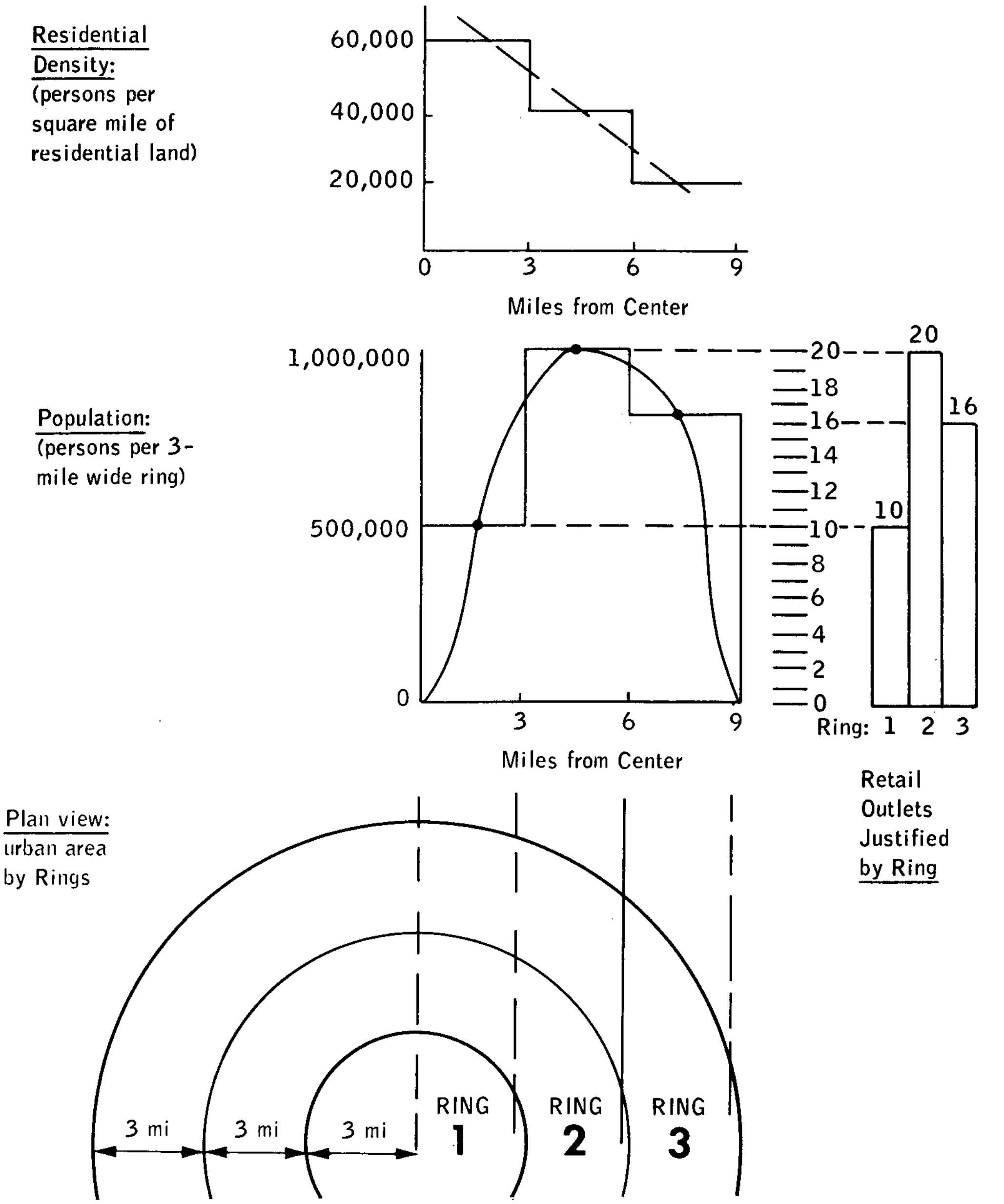

Figure 31. Hypothetical example of retail location patterns for outlets selling a single product.

TABLE 16

HYPOTHETICAL DATA RELATING POPULATION DENSITY TO RETAIL TRADE AREAS

RING (1)	TOTAL POPULATION OF RING (2)	TOTAL OUTLETS WITH THRESHOLD (TOTAL POPOULATION / 50,000) (3)	DENSITY: POPULATION/ SQUARE MILE (4)	AREA SERVED BY EACH OUTLET (SQ MI) (RING AREA / NO. OF OUTLETS) (5)	RADIUS OR RANGE OF TRADE AREA (MI) ($r=\sqrt{A/\pi}$)[a] (6)
1	500,000	10	17,687	2.82	0.94
2	1,000,000	20	11,788	4.24	1.16
3	800,000	16	5,659	8.83	1.67

[a] r = radius in miles, A = area of ring in square miles, and $\pi = 3.1416$.

the outer rings would have to place on some mechanical means of transportation and the greater distance they would travel to obtain goods from the hypothesized outlets. The ranges place the outlets outside walking distance for increasing numbers of the population as density levels decline. Figure 32 shows the location pattern appropriate for the hypothesized outlets of the example under the assumptions given.

To calculate the delivered cost of the good it would be necessary to double the time or dollar cost of a trip to obtain the good in that the total expense of travel applies to a round trip rather than to a one-way trip. For persons in the outermost ring, the cost of a round trip added to the price of the good at its outlet may cause the delivered cost for some to exceed the utility of the good and cause the outer limit to the range to fall inside its real limit set by the boundary of competing market areas. In such cases, the upper limit rather than the real limit to the range would be the relevant one.

The implication for highway economic analysis is: the lower densities of decentralized residential development, that may be encouraged by efficient radial expressways, cause enlarged trade areas for commercial enterprises. This means longer shopping trips and higher total transportation costs than in more central locations. Thus, the economy gains offered by efficient radials and circumferential expressways in their effect on spatial reorganization may be offset by the progressive increase in distance between origins and destinations at greater distances from the urban cities.

The total transportation bill would be higher if commerce and industry did not also decentralize, thereby reducing trip distances for some of the population. This demonstrates that land-use organization and planning, moving origins and destinations closer together, can sometimes sub-

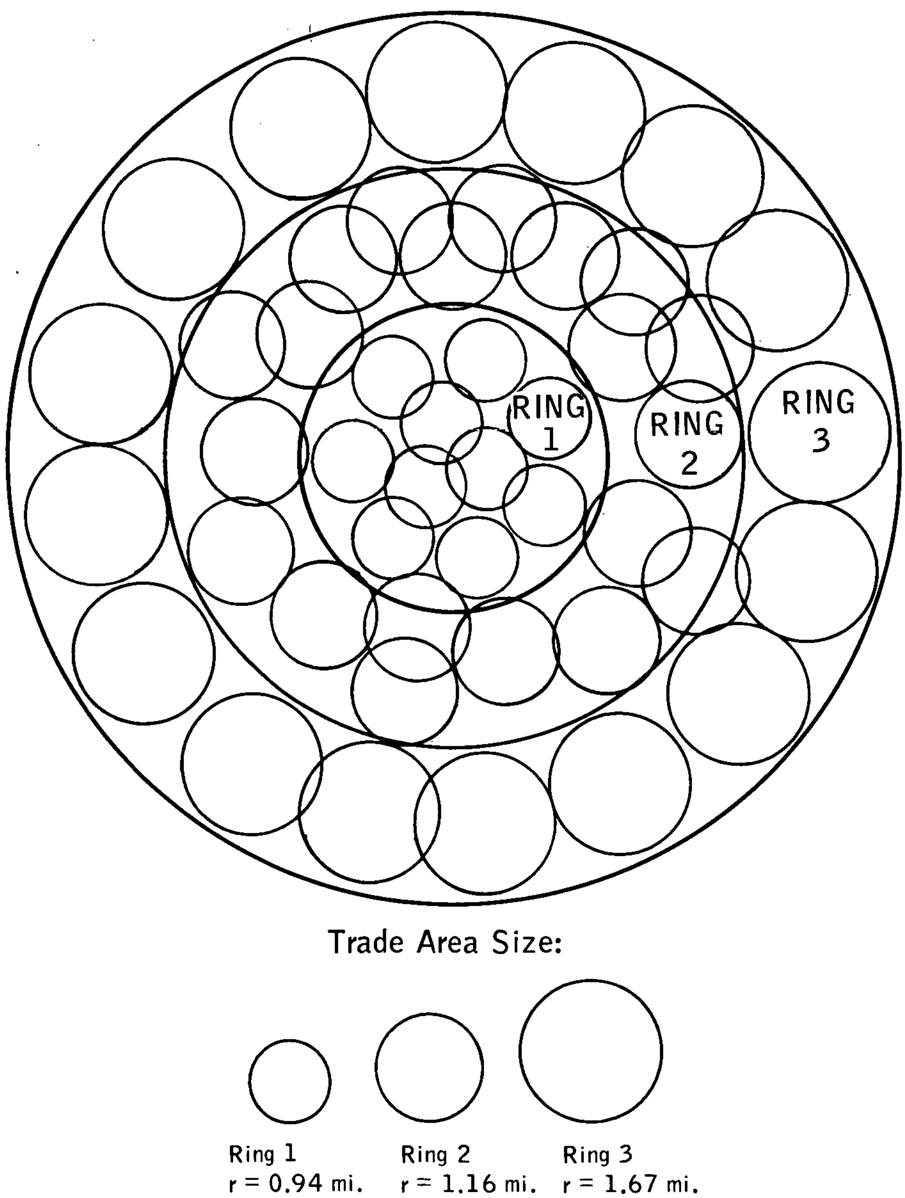

Figure 32. Distribution of trade areas by ring in the hypothetical example.

stitute for transportation investment in producing efficiency, and that lowering costs of transportation in one instance may, according to the development pattern it encourages, raise costs in another.

Roadside Place—ADT Volume

In addition to markets determined by density of residential development, or by location of potential demanders, a second set of markets is formed by traffic density or average daily traffic flows along streets and highways. Enterprises responding to these markets are also sensitive to the type of traffic, local or through, making up the traffic flow.

As traffic densities grow, thresholds for profitable marketing operation are reached for various types of outlets. Therefore, there is a rough observable correlation between ADT and the density and intensity of roadside development in what is commonly known as the "string street" pattern of development. To describe them in more precise terms, Garrison (*8-3*, p. 75) adopted the term "arterial conformation," as differentiated from the "nucleated conformation," the latter having the characteristics of "central place" development. Crossroad locations are usually developed first or most intensively because there the ADT's of the intersecting roads are additive.

Two types of establishment can be identified in the arterial conformation, both of them responding to slightly different market sectors. The first group consists of outlets whose market is the traffic stream irrespective of its source, whether local or "foreign." This group consists largely of enterprises in the gas-food-lodging categories. The second group of establishments consists of those that cater to the local population shopping for family purposes.

Through-Traffic Trade

Traffic volume is a direct indicator of demand for the goods and services provided by automotive service stations. When the ADT reaches a certain level, the probability exists that a sufficient proportion of the traffic will require automotive services in the stretch of highway possessing those volumes to provide a threshold for service station operation.

Restaurants and cafes respond differentially to the volumes and types of traffic according to the nature of the operation and the type of trade that they wish to attract. Restaurants serving full-course dinners locate on main roadways to obtain advertising exposure and ease of access by the resident local population. Such establishments are not overly sensitive to ADT, as witnessed by the number of them that operate successfully on roadways where traffic volumes are typically low. A second type of restaurant or cafe is highly sensitive to traffic volumes but more specifically to through traffic. Such outlets are frequently found in company with motel areas. The through and tourist traffic forms the bulk of their trade and causes them to locate on routes used by out-of-area traffic. A third group of food outlets, highly sensitive to ADT, is that of the short-order drive-ins. Such outlets frequently service the local trade as well as through traffic, often on an impulse basis. High traffic volumes provide the likelihood of continuous trade throughout the day rather than just at mealtime peaks.

Lodging facilities such as motels are sensitive to through-traffic volumes of long-distance travelers. A high proportion of through traffic in the daily volumes of main routes is required to form a threshold for motel operation.

A second consideration is whether the motel is located on the highway system at a point with an appropriate time-distance relationship to the main generators of interstate trips by tourists and businessmen. The large population centers generate cross-country trips roughly proportional to their population. Many journeys begin in the morning and terminate in the evening for purposes of rest and avoidance of nighttime driving. Therefore, motel locations that are a day's drive distant from main routes connecting them will receive the bulk of the demand for overnight lodging. This phenomenon is analogous to the early post houses or inns that were located a day's ride apart.

Motel enterprises face an added difficulty from highway improvement that results in bypasses or limited access because it deprives them of direct exposure or access to the through traffic forming their market. Whereas automotive service stations and restaurants can frequently reorient themselves to a local market, there is usually insufficient local demand for overnight accommodations to preserve a profitable motel operation following the diversion of its market (*8-6*, pp. 8-15).

Local Area Roadside Trade

The remainder of roadside enterprises consists largely of the shopping and convenience goods outlets serving the local market. Their roadside location provides the advantages of advertising and exposure to a wider market than exists in the immediate area. For commuting motorists, the roadside establishments represent an intervening opportunity to satisfy their demands as well as the economy of combining a work and a shopping trip. The roadside location thus broadens the market potential of the establishment. Because such establishments do service a local trade area and because it is usually the through rather than the local traffic that is diverted by bypasses and limited-access facilities, these establishments have been shown to suffer least, if at all, from such highway improvements. Gains in sales may even be experienced due to the reduction in congestion resulting from diversion of through traffic and the resultant ease with which local customers may reach these outlets, find parking, and experience less pedestrian hazard. The delivered price of the goods offered thus appears relatively lower and a demand increase may result, making up for whatever losses are experienced as a results of traffic diversion (*8-6*, pp. 8-15).

In addition to traffic volume, the character of the catchment area served by the commuter facility in terms of population and incomes will also strongly influence the character of roadside development that takes place. For instance, a boulevard extending to a high-income suburb may become a quality shopping street. An example is Wilshire Boulevard in Los Angeles that connects Beverly Hills with the Los Angeles central business district.

The implications for highway improvement analysis are: traffic volume is a market index for certain highway-oriented enterprises. Their profitability and survival depend on a variety of characteristics affected by highway improvement:

1. Visibility and accessibility from roadway.
2. ADT traffic volumes.
3. Composition of traffic stream: local versus "foreign"; and buying power of travelers as suggested by origins and destinations.
4. Time-distance relationship to remote traffic generators that causes some locations to become major stopping points on long journeys. Lowering time-distance will relocate stopover points and may even encourage nonstop trips in some instances.

Analysts should account for these characteristics in evaluating impacts on highway-oriented commercial enterprises. To the extent that such analysis is carried out, greater predictability of land use, land development, retail sales levels, land values, and additional traffic growth become possible.

Centralization Effect

Transportation improvement, by pushing outward the potential market area of a central supplier, may at some point encompass the market areas of decentralized suppliers. The central supplier may now service the larger market area with little or no sacrifice in convenience, delivered price, or time of delivery. He can lower prices due to the larger commodity sales volume afforded by the enlarged market or the carrying of larger inventories. The central supplier may thus be able to replace the smaller suppliers serving the local markets if the enterprises are competitive. If the local suppliers represent branches of the centralized supplier, the firm may be able to economize its operation by closing down the branch operations. Supplying the entire market from a central location gains efficiencies of smaller total inventory, less floor space, fewer employees, and a unified system of accounting and inventory control.

By extension of the potential market, transportation improvements may increase the demands for the goods of existing enterprises as well as create thresholds for additional enterprises. This leads to the aggregation of a variety of activities in a common location central to the expanded market. The diversity of outlets located in one central place provides added efficiency and attraction through: (1) the opportunity for multi-purpose trips, (2) wider choice leading to best buys or the most suitable goods, (3) the increased probability of finding the goods desired, (4) the working of increased competition to reduce prices, and (5) the diversion and participation afforded by crowds. These efficiencies and attractions produce for high order centers more gravitational pull and sales activity than that accruing to lower order centers (*8-3*, pp. 136-38).

Decentralization Effects

The same transportation improvement that allows some enterprises to centralize or to find thresholds for operation from a central place may encourage other enterprises to decentralize to locations productive of greater operating efficiency or, in the case of households, greater amounts of space and amenity conducive to consumer residential satisfaction.

Industrial Decentralization

Developments in the technology of production and transportation have resulted in industrial decentralization in metropolitan areas. Industries serving large national, regional, or metropolitan markets, in order to be central to those markets, do not necessarily have to be centrally located within a city or metropolitan area. It is enough that they have good access to markets. Today, this can be obtained as well if not better from decentralized locations along circumferential beltways and radial expressways. From these locations commodities can flow out to the larger market over the high-speed interregional highways with which the circumferentials and radials connect. Alternatively, supplies can flow, via the expressways, to the center of the local market.

Commutation of suburban employees is made easier by beltways. For this reason, it has been proposed that lateral rather than radial flows may be the more significant ones in the metropolitan areas of the future (*8-6*, pp. 16-18).

The development of automated industrial processes has meant the replacement of labor inputs by capital inputs. A smaller labor force is required by automated industries and frees them of the necessity of being central to the local labor market. Also, the employees required by such operations are frequently technologists whose income and location preferences dictate a residence near the suburban plant. The same automated processes frequently call for continuous operations all on one floor. Noncentral land being less expensive, it is more economical to build and operate such space-extensive plants at a distance from the urban core. Likewise, employees commuting by automobile require parking space. Geared to continuous operation and small numbers of operating and maintenance employees, the work day can extend over three shifts and be arranged so that the contribution to peak-hour congestion is minimal.

Establishments whose control functions require instant internal communication and frequent interaction on a face-to-face basis with members of other establishments probably will keep that aspect of their operation centralized. Operations unrelated to the control function or for which electronic facilities provide satisfactory communication may be decentralized to gain the economy of low land prices, the efficiency of a modern plant, and an absence of traffic congestion. A variety of enterprises have retained executive offices in the central business district while decentralizing their record-keeping, accounting, distribution, and production components.

Residential Decentralization

Residential decentralization has long been a response to accommodating population increase in urban areas, the desire for more residential space, the desire for amenity on the part of the majority of households, and to the interaction of rising incomes and relatively declining transportation cost. Building on unoccupied land is usually less expensive than demolition and rebuilding on previously built-up property. More interior and exterior space can be provided at decentralized locations. Transportation improvement encourages decentralization by cutting down commuter travel time and cost portion of the trade-off between more residential space and the higher transportation costs resulting from low densities and longer distance from central work places. Suburban living is thereby made available to increasing numbers of the population. High concentrations of traffic, leading to a decline in environmental quality and safety in core areas, provide an additional push to move outward. Other "push" factors include segregation, deterioration of housing, and declining quality of services. The previously mentioned decentralization of work places adds a "pull" even as it inconveniences workers living in the central city and induces the "reverse commutation" effect on radial highways (*8-6*, p. 7).

The effects of industrial and agricultural technology, rising population and incomes, and the attractions of space as a residential amenity would probably have caused decentralization of urban populations and activities even without transportation improvements in the form of highways. Highways merely determine the form, extent, shape, and density of the suburban development rather than induce it. The rail technology would have created quite a different development pattern but would not have prevented decentralization. Due to the automobile orientation of the majority of metropolitan populations, highway improvements now dictate the speed and form of development in outlying urban areas. To that extent highways are responsible for the particular form and pattern of urban decentralization but not for its occurrence.

Commercial Decentralization

Decentralization of retail commercial establishments is partly the result of the decentralization of residents in that the latter creates new markets or thresholds for business enterprise. What the suburban shopper may lose in choice and variety in the central business district he frequently makes up for in the convenience and accessibility of the suburban shopping center. Suburbs have become so far-flung that it is likely that the outer limits of the profitable range for many of the downtown department store's goods have now been exceeded. Many items would not be purchased at all if the suburban shopping center did not provide them. Shopping centers thus extend the range of the urban trade area for specific goods at the same time they competitively cut into the trade area of the downtown department store for many other goods. Whereas the downtown department store has undoubtedly suffered, the opening of suburban branches has (1) allowed most large downtown stores to maintain their proportionate share of total sales within the metropolitan area, (2) prevented central parking and congestion costs from becoming even greater, and (3) improved the over-all efficiency of transportation in the metropolitan area by reduced trip lengths between residences and retail outlets (*8-3*, pp. 136-38).

Apart from commercial decentralization that follows a decentralizing population, there is a second decentralizing trend due to the capacity limitations and space-consuming propensity of highway transportation.

The usual effect of transportation improvement is to induce greater diversity in the types of activities taking place in a central location by creating a greater number of thresholds due to the widening of market areas for a potential demand increase. But, as centralization peaks, highway transportation tends to reverse this effect as it contributes to the build-up of other centers.

A central place and its hinterland or market area take the form of a polar coordinate system. Space availability declines as one approaches the center of the system. Highway transportation is a space-extensive mode requiring large amounts of space both for moving vehicles in traffic-generating areas and for storing them at their destination while the trip purpose is fulfilled. The scale of space available for traffic and parking thus limits to a central location the volume of motor vehicle transportation that can take place.

Traffic congestion costs and parking fees reflect the supply and demand relationship for scarce space at the center of a polar coordinate system. These costs drive up the delivered cost of the goods or services obtainable at that location. The thresholds created by lowering the time- or cost-distance to the location are destroyed once more by the terminal costs of congestion and parking. Only those enterprises whose goods have attractive value above the shelf price plus the associated transportation cost will still have thresholds for profitable operation. Other enterprises will be forced to relocate to where the total utility or value has a greater margin above the delivered cost and where the price-based consumer surplus is not wiped out by the cost of transportation. The physical space required to allow circulation and parking and the turnover rate obtainable sets a second limitation on the number of transactions possible in a given location, irrespective of the price and value of goods offered there. A third force tending to reduce the number of establishments in a central location is their physical dislocation to provide additional traffic and parking capacity through construction of new facilities for those purposes.

The net result is to negate one large center with diversified activities and to fractionate and disperse activities into locations where they are more specialized by function (e.g., shopping centers, cultural centers, government centers). Such specialization allows for providing a traffic and parking capacity appropriate to the type and scale of operation. Smaller centers may regain competitive advantages. At the same time, this decentralization may lower transportation efficiency by creating additional trip vectors and destinations necessary to fulfill all trip purposes. The number of multi-purpose trips possible will be reduced. Numerous single-purpose trips or traveling a circuit to various locations to conduct multi-purpose trips will be necessary. Again, there is the paradox of transportation improvements designed to lower transportation cost creating a pattern of dispersed centers that raises travel time and costs.

Some specialized goods, services, or activities may require an entire metropolitan population for a sufficient market to form a threshold. If a threshold volume of demand for them can neither be attracted from the dispersed population due to distance and congestion and parking costs at the metro-center nor be attracted to an off-center location, those goods, services, and activities may not be offered. The potential diversity and choice of goods, services, and activities available in the metropolitan area as a reflection of its buying power may never be realized.

Specialization Effect

The contribution of transportation improvement to specialization is lowering the delivered price of "imported" goods from locations of specialized production so that they can replace the now relatively more expensive local products. When producing for a larger market the "foreign" supplier may be able to reduce his price further by the practice of scale economies resulting from the larger volume of sales.

The local community gains by selling abroad those products local conditions allow to be produced least expensively and importing those products that other centers can produce at least cost according to their own local resources and conditions. Each supplier, when producing his own specialized goods most efficiently, contributes to the general economic welfare. The consumer is afforded a greater diversity of goods at lowest possible price, thus increasing the total utility and satisfaction available from his income or budget. The supplier gains by enlarged profits through efficient production and high sales volumes. Each community, relieved of the necessity of fulfilling all of its own needs, benefits from trade and the specialization brought about by transportation improvement and the extension of market areas.

Social Cost of Distribution Effects

Geographic shifts of various economic units, households, and commercial and industrial firms occur in an attempt to capture the advantages produced by a highway improvement. They seek to gain increased utility or satisfactions, higher sales, or lower cost of production. In this they are acting rationally as individuals.

Unfortunately, as Samuelson (*8-13*, pp. 12-13) points out, what is individually rational is sometimes collectively irrational. It is from the working of this principle that many of the distribution effects appear to be community social costs. The present highway programs appear to distribute benefits in urban areas in a progressive manner and costs in a regressive manner.

The unit gains from highway improvements tend to decline toward the urban center as highway costs (both user and nonuser) increase. Unit gains grow toward the urban periphery as relative costs (user and nonuser) decline. Unit travel costs go up with traffic volume increase. Traffic volumes rise as highways approach the urban center. Therefore, road-user unit travel costs rise toward the urban center and decline toward the periphery. Nonuser social and economic costs appear to follow the same pattern.

These social distribution effects arise from the fact that income groups are spatially distributed in urban areas in a manner roughly related to their incomes—progressing from lower incomes at the center to higher incomes toward the periphery. The pattern has exceptions, such as the enclaves of high-income households that are located near the center of many cities, and low-income ghettoes that are found in some outlying areas. Over all, however, the generalized pattern holds true (Fig. 33). This geographic pattern of income groups forms the basis for the progressive and regressive aspects of income distribution due to highway development.

SPILLOVER EFFECTS

Spillover effects consider the highway from the standpoint of its performance characteristics as a land use rather than as a transportation facility. Whereas development and distribution effects occur as a result of the change in the relative transportation costs and accessibilities between locations, spillover effects result from the physical presence of the highway and the traffic using it.

Spillover effects (also called by economists "external economies" and "diseconomies") are those aspects of the highway that cause gains or costs to others than those whom the highway was intended to serve.

Analysis of Spillover Effects

Highways with high traffic volumes have performance characteristics similar to an industrial land use. Large numbers of machines are used to mass-produce transportation services, resulting in such negative spillovers as air pollution, vibration, glare, noise, and litter.

Highways, according to their design and location, are also capable of providing positive spillovers for nonusers in their vicinities, particularly when they assume the aspect of a park area providing greenery, pleasant views, recreation space, lighting, and attractive structures. Planted roadsides are often capable of buffering the highway's negative spillovers from adjacent land users. A description of the more prominent spillovers follows.

External Diseconomies

1. Air pollution.—Automobiles pollute the air as the result of burning gasoline and diesel oil to power internal combustion engines. Exhaust emissions include noxious gases—carbon monoxide, nitrogen oxides, sulfur oxides, hydrocarbons, lead compounds—and particulates. Costs accrue to the community in the form of respiratory ailments and other health hazards to individuals, damage to vegetation and property, visual and olfactory discomfort due to fumes, reduction of sunlight and visibility of distant views by smog, and atmospheric temperature increases (with possible weather modifications). In addition to exhaust emissions, particulate matter in the form of dust may be raised by air currents from passing automobiles. Air pollution is usually localized, being concentrated in areas of high traffic volumes. Where auto use predominates in urban areas and air masses tend to be stable for long periods, smog becomes an over-all community problem, however.

2. Noise.—Motor vehicles emit noise from engine operation, horns, tire friction on pavements, and displacement of

air. Noise levels are particularly high when vehicles are accelerating or cornering, when the muffler is defective or inadequate, and when vehicles are present in large concentrations, with no sound-deadening buffer between the traffic and thc car. Under these conditions, the noise may be annoying to persons and a nuisance to activities in proximity to the highway.

3. Aesthetic environment.—Built to vehicular rather than human scale, highway structures can be massive, barrier-like, and extensive features of the environment. Blocking of light, air, and views may ensue. Without proper design the highway structures may be unsightly. Being out of scale to "human scale" buildings, objects, and persons in the environment, highways may have a displeasing visual effect. Highway lighting or headlights of vehicles using it may cause annoying glare for adjacent property users.

Popularization of highway use has had further aesthetic costs. The large signs meant to be read by high-speed highway travelers add to the conflict of scales. Parking lots multiply the number of "dead spaces" (areas without

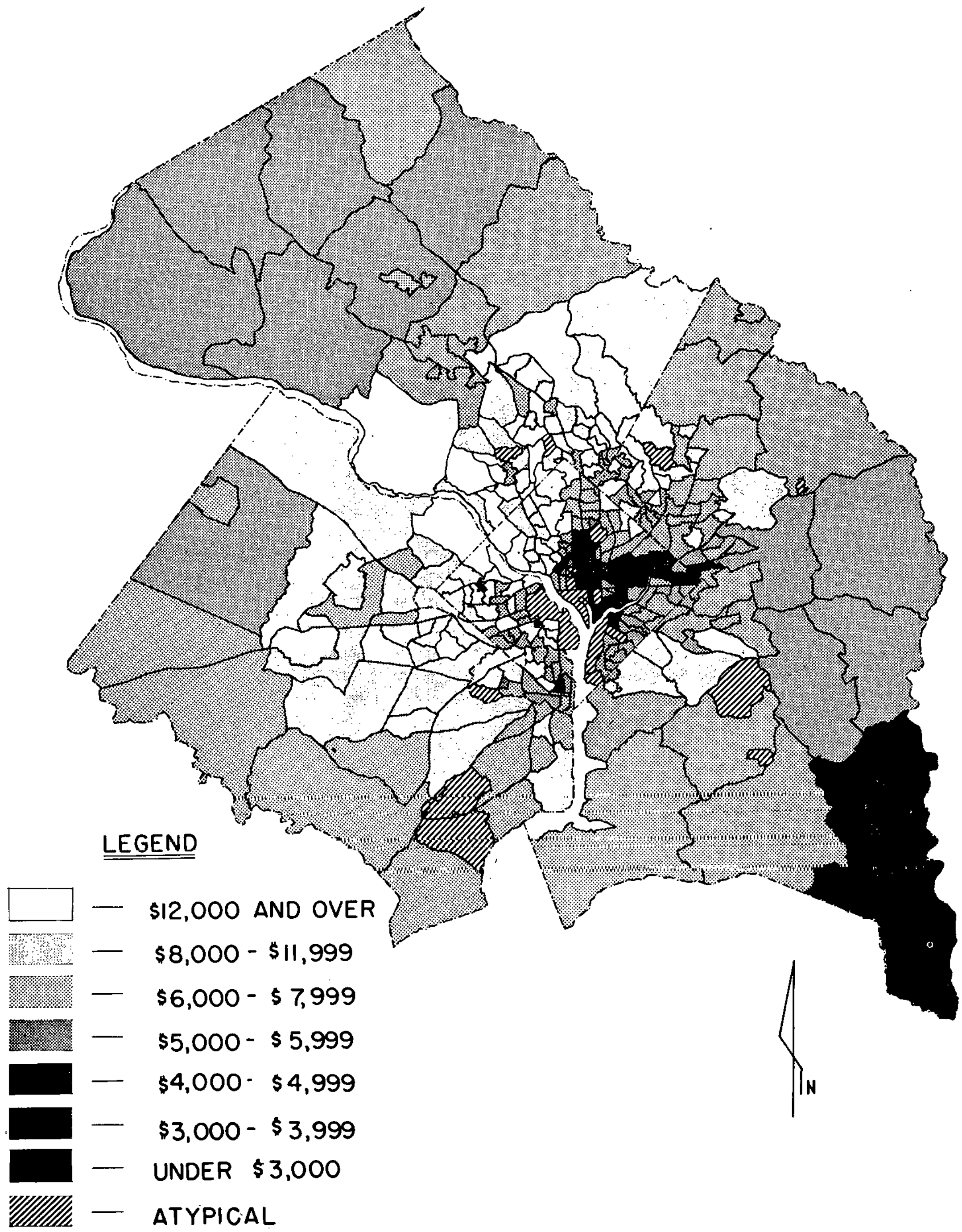

Figure 33. Median family income of individual tracts, Washington, D.C., SMSA, 1959. Source: (8-24, *Fig. 3, p. 30*).

human activity) in community shopping and business centers. Auto graveyards are also aesthetic liabilities. Litter left by highway users is a community aesthetic cost that usually has a monetary cost for pickup and disposal.

4. Pedestrian conflict.—Pedestrians' time, risk, and energy costs are increased by highways and highway use. Delays are encountered at crosswalks while waiting for a signal change or a break in traffic. The mix of autos and pedestrians brings risk of accident. The presence of a limited-access highway in areas of high pedestrian traffic may mean longer walks to destinations via the limited number of crossover points.

5. Vibration.—Vibration set up by heavy vehicles may be transmitted to neighboring properties, annoy occupants, and weaken structure walls and foundations.

6. Drainage.—Removal of natural ground cover in the process of clearing right-of-way may increase the amount of water runoff, cause flooding, erosion, or water pollution.

External Economies

1. Parkways.—Pleasant scenery, views, and recreational opportunities have been created by parkway treatment of highways or joint development of highways and adjacent scenic areas or parklands. Parklike roadsides also reduce the magnitude of negative spillovers to adjacent land and have been shown to favorably affect property values.

2. Lighting.—Highway lighting may project into adjacent areas and make them safer from crime or accidents.

3. Drainage patterns.—Engineering of the highway's drainage system may improve the drainage pattern of the adjacent area, preventing flooding and erosion.

4. Advertising.—Commercial enterprises, visible from high-volume roadways, attribute an advertising value to their visual accessibility.

5. Air rights.—The air-rights space over depressed roadways or under elevated viaducts has been used to advantage for a variety of purposes (e.g., buildings, recreation space, storage, and parking).

6. Clearance of blight.—Visually, economically, or socially blighted areas (e.g., slums, dumps, and dilapidated structures) that were community liabilities have been removed for and replaced by rights-of-way.

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CHAPTER NINE

SOCIAL AND ECONOMIC NONUSER CONSEQUENCES OF HIGHWAY IMPROVEMENTS

The objective of this chapter and the related detail in Appendix B is to isolate and describe the social and economic consequences of highways in such manner and detail that they may be (1) identified and associated with highway location, design, and construction, (2) forecast in quality and quantity, (3) compared in their importance and values, and (4) related in timing, incidence, spatial coverage, and lasting qualities.

This chapter is intended to afford the highway designer, the highway administrator, the economic analyst, and the decision maker a basis for understanding the social and economic consequences of highway improvements and how they impinge on the road user, the community and its goals, and the totality of economic and social activities.

DEFINITIONS AND CONCEPTS

The discussions herein are related to certain technical terms and concepts, which are defined and discussed in the following.

Definitions

Consequences of a highway improvement are changes in the status quo occurring as a result of the improvement that probably would not have occurred or would have occurred in different locations or time periods without the improvement.

Change means that a variable is somehow different at a later point in time than it was at an earlier point in time. The change can be *quantitative,* more or less of the variable being in evidence according to the standard by which it is measured, and/or *qualitative,* better or worse, more desirable or less desirable, than the previous condition or some norm or ideal. Quantities are capable of enumeration; qualities are capable of description.

Quantitative measures assume that the variable in question can be objectively measured by counting observable common units. *Qualitative* descriptions involve value judgments that interpret change on the basis of deviation from some observable condition or norm or in terms of subjective viewpoints.

The emotional, aesthetic, intellectual, logical, or other reactions of the viewer inform him whether the change is good or bad, better or worse, more or less desirable, more beautiful or more ugly than previous conditions. Even the quantitative measures must, at some points, become the subject of value judgments. Otherwise, it cannot be known whether "more or less" is "better or worse," "beneficial or detrimental." This interpretation is subject to paradox and ambiguity, in that what is "beneficial" from the viewpoint of one individual or group may be detrimental from that of another.

Consequences may be *economic*—affecting cash flows, their inception, distribution, direction; and/or *social*—affecting human interaction and activity as measured by time and space budgets, human behavior, and the incidence of social and anti-social phenomena—their times, places, manner, quantity, and quality and the goals and values reflected therein.

Highways as Implementers of Change

Highway consequences, whether economic, social, or a combination (socio-economic), occur due to the highway's characteristics as: (1) a transportation facility, (2) a transportation mode having a set of unique performance characteristics, (3) a land use, and (4) a service produced by the consumption of other goods and services.

Highways as a Transportation Facility

As a transportation facility the highway brings about social and economic changes in the following ways.

Highways alter the relative accessibility between locations and the cost of transporting goods, services, and persons between them and thus influence the final cost of the goods, services, and satisfactions themselves.

Changes in the cost or price of travel per passenger-mile, or freight ton-mile, raise or lower the cost of goods, services, or travel for various trip purposes. Consumer and producer reaction to these changes, as pointed out in Chapter Eight, help determine what trip purposes are worthwhile and their length and frequency according to what goods or services are made to appear relatively less or more expensive, and what geographic locations are made more or less accessible as points of supply or as points of destination.

The vehicle operating cost, travel time, and psychological factors of transportation thus generally determine how economic and social activities will be geographically arranged and what will be the spatial extent of markets, urban areas, economic regions, and similar identifiable geographic areas. Changes in costs may lead to restructuring of spatial relationships; development and redevelopment; growth and decline in supply and demand for the affected goods, services, and sites; migration of activities, firms, and households; and alteration of spatial boundaries. Such changes in turn have a feedback relationship on the traffic patterns and volumes using various portions of the highway system as changes in land use (origins and destinations) alter traffic generation levels and average daily traffic.

Altering the accesibility to land changes the supply of land, locations and sites having specific accessibility characteristics due both to change in cost and transportation mode. This affects land prices and values. Price equilibrium between supply and demand by competitive sellers and bidders dictates the development of the land in its "highest and best" (i.e., most productive) use—that use that justifies the price or rent.

Limited-access highways, for example, limit the amount of land or number of sites having superior transportation service to that supply found at interchanges. Where, before, land users seeking the most accessible sites had the relatively large supply forming the roadsides of major unlimited access highways, they must now compete for the smaller amount of land available at interchanges. This leads to the high intensity of land use at those locations—intensity that sometimes generates traffic sufficient to interfere with operation of the interchange.

Where a new superior highway facility places a large supply of rural land within the commuter radius of urban workplaces, residential developers are attracted by comparatively low-cost land. Their new housing, at lower prices, attracts a broader market while increasing profits, the difference between price and costs. This practice causes "leap-frog" development: building on discontinuous tracts separated by undeveloped land, an inefficient pattern, expensive to serve with public facilities and utilities.

Highways influence the timing of development, its form and intensity. Residential developers are often the first to exploit the new accessibilities established in urban areas. When residential developers do come first, they may preempt the most favorable sites, especially those near interchanges. This forces the commercial and industrial users that follow to compete for a reduced supply and to occupy it more intensively.

The traffic-generating or -attracting propensity of certain land uses linked as origin and destination over certain segments of the transportation network determines the traffic on those links. The addition of or improvement to links *changes the traffic streams* (*ADT*) flowing over them, brings about substitutions between modes and links, and generates travel that did not occur before. These changes affect the productivity of the land having an access to the links along roadsides and at interchanges, exploiting the market represented by the traffic stream.

Highways help determine development patterns suitable to their efficient operation and reflecting exploitation of the opportunities they create due to changes in transportation cost, in transportation mode, and in system design.

Highways as a Transportation Mode

Certain vehicle performance characteristics induce changes in environmental, social, and economic variables. The use of motor vehicles influences aesthetics; the "way of life" factors such as prestige, status, entertainment, symbolism, population density, and life styles; and the practices of business and industry. Characteristics of the mode that create these changes include travel speed, space, flexibility, convenience, vehicle quality and differentiation, comfort, privacy, and cost. Highways do not induce these social and economic effects, but the preference of this mode of transportation to other modes by a majority of travelers means that the environment adjusts to account for the characteristics of the mode. Population densities, for example, change so as to balance traffic generation with transportation capacity and mitigate congestion.

Changes in system characteristics within and between modes of transportation affect their demand levels and the social and economic change correlated therewith. For example, the mobility, flexibility, and relatively low traffic capacity of motor vehicle travel makes low land density development both possible and necessary if congestion is to be avoided. Rail transit has inflexible lines and interchange points, limited mobility due to passengers becoming pedestrians, and high-capacity levels that make high-density development both possible and necessary to efficient and solvent operation.

Operating characteristics such as privacy, comfort, modernity, speed, personal control, or lack of same, further affect consumer preferences and the "modal split." Quite different and distinct environments and aesthetic features emerge from each mode of transportation—pedestrian, rail transit, motor vehicle, water, and aircraft. Choice of mode helps determine the incidence of the forms of development peculiar to each. As changes in cost of transportation affect the spatial extent of development, changes in operating characteristics of transportation affect its three-dimensional form.

Highways as a Land Use

As a land use, the highway replaces former land uses with a new use (the highway) with implications for relocation of households and commercial activities, altering of social and economic relationships, destruction of buildings, and changes in the property and other tax structures.

Highways alter the former supply-demand equilibrium in the land market. They increase demand for relocation sites and space by adding the dislocatees to normal turnover demand while depleting the existing space supply due to destruction of residential, commercial, institutional, industrial, and recreational space to provide transportation space. A related systems effect is the complementary space that must be made available to serve the system, including space for service stations, parking lots, garages, new and used car lots, vehicle graveyards and junkyards, and improved connector and collector streets, interchanges, ramps, and loading areas. The changes in land supply and demand for various uses establish a new set of equilibria and a new schedule of prices for space, often at a higher level in that demand is increased while supply is reduced.

The increase in the supply of land made newly accessible, of course, may have the counteractive effect of reducing the impact of the disequilibrium and moderating the price change that would otherwise occur. In all this there are implications for land values and taxes pegged to the prices and rents for land.

As a user of land, the highway has certain performance characteristics that are "spillovers" affecting neighboring land and its use and patterns of local circulation and communications (see Chapter Eight). The statement that expressways are useful for the purpose of "separating incompatible land uses" ignores the concept that the highway itself may be incompatible with certain uses (e.g., residences and hospitals). Industrial and some commercial land uses have long been required to screen out the nuisance aspects of their operation through distance and/or landscaping where they abut residential property.

The degree to which a highway forms a visual or physical barrier will produce nonuser costs and benefits. What land uses it replaces in the original right-of-way taking and what land uses it later attracts or repels as complementary or noncomplementary uses are other nonuser consequences.

Highways as Generators of Consumption of Other Goods and Services

As a transportation "system" producing transportation services, highways and their users generate demands for certain inputs according to the "production function" of transportation. This consists of goods and services applicable to:

1. The way.
2. Traffic controls and services.
3. The vehicle and its consumption of resources.
4. The operator.
5. The terminals, and storage facilities.

Any changes in the amount of use of the transportation system or changes in the cost of using it will affect the incomes of the various suppliers of input goods and services and the quality of transportation service received by the user. Either will alter prices according to supply-demand equilibria and the degrees of monopoly, oligopoly, and perfect competition present. The systems effects of shifts in demand include the effects of such shifts on the suppliers of products to the motor vehicle transportation system who also supply inputs to other markets affecting prices there also. Suppliers' costs and prices will be affected by the efficiencies and economies of production they are allowed to achieve by means of increased demand.

SIGNIFICANCE OF SOCIAL AND ECONOMIC CONSEQUENCES

The mere fact that highways produce certain social and economic consequences does not indicate the significance of the changes. It is desirable to know also how much of the total cost or benefit the consequences represent and how relatively important the people consider the change to be—whether and how much they would pay to have certain effects increased, alleviated, or eliminated. Public policy with respect to highway transportation needs to be founded on what the citizens desire in transportation and what trade-offs they will accept. Unfortunately, however, it is most difficult to discover what the people desire, and the public's appraisal of proposals for improving highway transportation is usually only a superficial expression of opinion.

The solution to the problem, in contrast to the road-user costs and benefits, is difficult because certain effects of highway improvement cannot be measured or quantified. Although units exist for counting such variables as land values (dollars), traffic (ADT), noise (decibels), and displacement (number of people or residences), other consequences are intangible or subjective in nature (e.g., sentiment attached to an historic site, aesthetic reactions to a billboard or to an elevated structure, and the psychological impact of relocation) and cannot be measured.

Nonuser consequences occur in environments, natural and human, and are highly variable. This leads to a wide range of possible reactions to identical highway configurations in various locations. The regularities in human behavior and natural phenomena in reacting to highway change have often led to similar consequences in various locations. Because of local conditions that are different everywhere, and variations in peoples' willingness, ability, means, and desire to adjust to changed conditions, there will be a wide range of likely outcomes and varying degrees of probability that any one consequence will occur. For this reason, the analyst's desire for a single-valued nonuser costs and benefits total (Chapter Ten) for insertion into one grand project cost-benefit equation is probably impossible to achieve. He will be faced with a range of likely outcomes, some of which are more likely than others, but none of which is certain.

Highway consequences occur in a "wholistic" environment in which other actors and factors are operating simultaneously and in interaction to produce change, often in complex ways. Some of these other factors produce the same effects as highway improvements. Some consequences credited to highway improvements may have had other causes. Added traffic generation, for instance, can come from highway improvement, increase in spendable income or population, or from land-use change, or, more likely, from a combination of all three. Sensitivity analyses are useful in gauging how much change is highway-induced (*9-7*, pp. 79-82).

Highways may be a necessary but not a sufficient factor to produce change. A highway improvement may allow new resources to be tapped, but their actual development can occur only after further investments have been made in extractive plant. The investment in both highway and plant would therefore be countable as the "costs" required to bring forth the benefits—the value of resources extracted. The mere presence of a highway in the absence of other factors may be insufficient to produce change.

CONTEXT OF CONSEQUENCES

Consequences of highway improvements take place in a variety of interacting dimensions and contexts: (1) time, (2) space, (3) social, (4) economic, and (5) political. Some definitions of these factors are prerequisite to obtaining the necessary perspective on consequences.

Time Dimension

Consequences of highway improvements occur during four time periods:

1. Pre-construction period.—In the pre-construction period, planning, hearings, route location and design selection, and right-of-way acquisition are carried on. These processes begin to initiate locational shifts to accommodate the highway by likely-to-be-affected households and establishments in the corridor. Strategies are executed to avoid anticipated costs, maximize anticipated gains, and minimize hardships.
2. Construction period.—The construction period causes a certain amount of local disruption to social life and business and lengthening of local traffic patterns, plus problems of dust, mud, noise, and similar nuisances for the households and establishments adjacent to the right-of-way. The inconveniences and nuisances, like the effects of the pre-construction processes, have a short-run and limited geographic impact.
3. Post-construction period—short run.—In the post-construction short-run period certain shifts of land uses and traffic take place to capture the user benefits and accessibilities offered by the new facility. Land value windfalls and excess profits may be earned during this period of adjustment. Certain commercial establishments oriented to the previous status quo may experience losses, or gains.
4. Post-construction period—long run.—Over time, as other portions of the highway system are improved, adjustments in attitudes and practices, and development and redevelopment related to the facility, will have exhausted its possible advantages. The locational shifts and land value changes related to the facility will diminish. An equilibrium condition that relates land uses to the characteristics and capacities of the facility will be reached. Profits will be "normal," and the facility may even begin to encourage some added shifts by a growing erosion of the initial advantages it offered.

Consequences, according to type, degree, and longevity, should be viewed within the proper time dimension, whether short or long term, to improve the decision-making perspective. Some consequences may lose their ominous aspect when it is known that they are only short run; others may be viewed with more concern when it is known that they will appear or exist in the long term.

Space Dimension

In a spatial dimension, it is necessary to examine four spatially differentiated areas of impact of a highway improvement:

1. The right-of-way.
2. The corridor.
3. The local system and community.
4. The regional system (economic area, state, region or nation—according to the effect being traced).

Highway consequences may be widespread, creating costs and benefits in remote locations not encompassed by the localized examination of consequences in the immediate corridor that has characterized many economic impact studies (*9-3*, p. 27). For instance, the presence of a highway improvement may generate migration of industrial plants from other areas to capture the benefits of the improved service. A corridor impact study would count the changed land use and value as a "nonuser benefit." The area from which the plant moved probably would count the loss of industry, land values, and employment as a "nonuser cost." For this reason, NCHRP Project 2-2 proposed a systems approach to costs and benefits in order to trace them out (*9-3*, p. 27).

Social Context

The social context of highway improvement involves personal values of the populace. Like economic consequences, social consequences have a surrogate: time and space budgets. The space that people allocate to various uses and the patterns in the use of their time provide some indication of their values and preferences. Presumably people allocate their time and space only to those activities they consider worthwhile (e.g., those representing their personal or social values). Therefore, the changes in the use of space and time for human activities induced by a highway improvement provide indicators of the social consequences. These are objective measures and leave aside all considerations of motivation and ethical judgments over whether the uses of time or space are "good" or "bad." Activity patterns represent "life styles" that affect and are affected by transportation changes.

The incidence rates of various social phenomena tell how people use time and space and for what purpose. Rates of crime, delinquency, dope addiction, and other pathologies may indicate certain socially unacceptable uses of time or space. Other uses, such as higher educational levels, organizational memberships, and religious activity, may indicate more constructive uses according to the scale of cultural values held by a particular society. These are matters for subjective judgment and can be applied to the objective realities only by way of weighting certain results and consequences as to their relative desirability or undesirability. The analyst is limited to reporting social phenomena resulting from highway improvement. Evaluating their meaning is the task of decision makers.

Economic Context

The economic forces described in Chapter Eight, interacting with and responding to changes in transportation costs affecting relative accessibilities on a geographic surface, are mainly responsible for producing the observed patterns of urban and regional development. Social, aesthetic, and other values also play a role in determining the pattern of development. However, an economic surrogate for these values can often be discovered. Also, economics is the most rigorously and scientifically developed of the social sciences. It has a highly developed body of laws, principles, and analytical techniques, plus a propensity to deal in quantitative measures. All this makes economic development models appear most useful in determining the consequences of highway improvement.

To be useful, economic models of development related to transportation should be evaluative as well as predictive. That is, the model must say with some accuracy what will occur as a result of certain public policy route location and design decisions affecting accessibility and transportation prices, and it must also be able to provide economic evaluation of those decisions in terms of the costs and benefits of public actions taken in pursuit of those decisions.

A second concern must be with the scale at which the effects and the evaluations take place. At the aggregated scale of the metropolis or region, broader consequences and larger patterns may be viewed. Many of the costs and benefits may be found to balance out on the basis that activity has not been gained or lost but merely transferred geographically to capture some of the benefit engendered by the change in accessibility patterns. On the other hand, such an aggregative analysis fails to capture some of the localized effects that are of immediate concern to affected households, individuals, firms, institutions, and governmental jurisdictions from whose viewpoint the public action may entail more loss than benefit, or vice versa, and for whom statements of over-all gain or over-all balancing of costs and benefits may appear irrelevant.

There are three major elements of economic impact (see Chapter Eight):

1. Development effects.
2. Distribution effects.
3. Spillover effects, or externalities.

In the case of development effects, the highway is producing "true" benefits. It has induced the creation of new wealth. The use of resources represents positive gains in the economy and the gross national product (GNP).

Where distribution effects are involved, the highway has not generated any new wealth or encouraged any new development that uses new or idle resources but has merely redistributed the present supply of wealth geographically, or among varying establishments, social or income groups, or jurisdictions. In other words, one receives what the other gives up, but no change in the GNP is induced thereby.

Spillover effects, or externalities, are those benefits received or costs borne by persons other than those for whom such costs or benefits were specifically intended. These form a special case of distribution effects and represent indirect costs or gains occurring over and above those anticipated for the highway in its anticipated use as a transportation facility.

Economic consequences are those representing cash flows, payments of money, or values estimable in money terms. They may be objectively defined and traced by means of examining market indicators and determining where values or wealth are being created (production); where intermediaries are arranging for their distribution (exchange); and where and by whom they are being used (consumption). Each of these processes represents a flow of money as a surrogate of wealth and a medium of exchange. Examination of how highway improvements affect such cash flows, altering their creation, magnitudes, direction, and recipients, leads to an understanding of the economic and social consequences of highway improvements. The budgeting of consumer expenditures among various commodities, goods, and services at the point of final demand is an indicator of relative values in the economy and forms an aid to resource allocation.

Political Context

The political context of highway improvement consists of the public policies at work in determining the nature and scale of the improvements. Policies and political actions are the expression of community values and are made either directly by the electorate or by their chosen or appointed representatives. Here too, there is a surrogate for community values: votes, opinion polls, and various avenues of public response such as hearings, assemblies, and the press. People express their community values and collective preferences by these means, just as they spend their money, time, and space budgets to express their economic, social, and personal values.

Persons making decisions concerning highway improvements are therefore constrained to consider the flow and trend of public votes and opinions and to follow the policy of the people in arriving at decisions. Political consequences should be considered to the same extent as economic and social consequences. To neglect them is to incur eventual costs in negative feedbacks (e.g., budget cuts, restrictive legislation, and vetoed decisions).

HIGHWAYS AND GOALS

Highways are built for a purpose: to serve efficiently and effectively the demand for movement of goods and persons between locations. Highways do this effectively when they provide direct, convenient connections between origins and destinations with sufficient capacity to service the demand for movement between them. They do it efficiently when they provide this service at least cost of resources, time, risk, and psycho-physical energy. The measures of effectiveness related to these "internal" or user-oriented goals of the highway system have appropriately been couched in terms of: (1) how well facilities meet the travel demands revealed by "desire line" analyses showing traffic demand vectors and magnitudes, and (2) which of the alternative route locations and designs capable of servicing the demand does so at least total annual transportation cost.

Community Goals

Society and the components of its hierarchy, states, communities, neighborhoods, firms, households, and individuals, likewise possess goal structures. Each level of the hierarchy, as determined by the decision makers at the level, is engaged in a series of actions chosen as means of gaining their own goals at the least expenditure of their resources. With numerous actors involved in self-interested goal optimization, conflict is inevitable. The goal fulfillment of some hinders or prevents goal achievements by others.

Conflict of Transportation Goals with Community Goals

Highway departments, in pursuing the optimization of user benefits, are at some points in conflict with certain nonusers whose goals are unserved or ill-served by the highway improvement. Anticipating the changes to be wrought by the improvement, these nonusers are informed by their self interest that their costs are likely to exceed whatever benefits they derive from the improvement. They therefore oppose the proposed change. Those standing to have their goals fulfilled or to gain as a result of the improvement will promote execution of the change. The greater the stake of either losers or gainers, the more willing they will be to oppose or encourage the improvement. This may explain the extreme views, pro and con, represented at public hearings and the absence of many whose losses or gains are so minimal that time or money expenditures to oppose or support the improvement do not appear worthwhile.

Feedback effects of highway improvements do have external impacts outside of those affecting users of the system. Highway administrations are a governmental entity devoted to the public interest and thus are responsive to public reaction to their improvement programs. Therefore, highway decision makers are constrained to become informed of the other goals structures with which they are interacting and how and to what degree they are abetting or frustrating the fulfillment of the goals of other levels of the hierarchy.

Knowledge of the consequences of highway improvements has a variety of utilities:

1. It has the effect of allowing (1) the avoidance of inflicting certain costs, or (2) the increasing of certain benefits through: (a) finding that some "costs" will not occur, contrary to uninformed opinion, thereby avoiding the delay of prolonged controversy and the agony of uncertainty, (b) finding that the costs can be avoided or benefits increased through compromise—making marginal changes in location and design whose costs are less than the benefits to be gained, (c) providing a basis for compensating for certain unavoidable costs and taxing certain benefits, (d) discovering benefits that offset certain costs to the same party, (e) providing factual information for use in damage suits, hearings, and legislative policymaking, and (f) providing for shifting certain costs to other jurisdictions, agencies or individuals, especially those receiving benefits.

2. It allows benefit maximization by enabling decision makers to examine the nonuser goals structures to determine how the highway can be turned into a positive force for realizing more of these goals. Alternatively, they can determine what accommodations or adjustments may be required to alleviate whatever costs are foreseen. Whenever the costs cannot be eliminated or alleviated, preparation to accept the costs can be made as the price of allowing other goals to be fulfilled. Where such costs are unacceptable, it alerts decision makers to begin the search for alternative solutions, substitutions, or opposition in favor of status quo maintenance or prepares them to bear the alternative costs and consequences arising from rejection of an improvement.

Potential Effects of Highways on Nonuser Goals

A highway improvement can have three potential effects on a nonuser goal. The improvement can aid and abet, be neutral, or inhibit or deny goal fulfillment in full or in part. Positive effects may be termed the benefits, or gains; negative ones, the costs, or losses. Vital to considering benefits and costs is the "for whom," or point-of-view consideration. Benefits to some (such as higher land values for landowners) may be costs to others—the occupants of the land whose rents are increased. Unless highway decision makers are to adopt a position of neutrality or indifference and let costs and benefits of nonusers "fall where they may," they will wish to consider the redistributional effects of their decisions and evaluate whether those receiving the benefits are particularly worthy and whether those paying the costs have the ability to pay. The criterion specified by welfare economics is that of Pareto optimality—a solution should either be one that leaves everyone better off, or, failing that, one that, while leaving some better off, leaves no one worse off.

Highways as Aids To Community Goals

For those wishing to use highway improvement to further community goals, it is important for them to know the consequences of highway improvements in order to discern those goals that highway improvements naturally tend to optimize and what goals highways tend to militate against or deny. Once the difference is known, there will be less confusion over what highways can and cannot do based on what they do do in terms of certain goals at all levels of society. For instance, a community goal may be the achievement of "a bedroom environment." Highway transportation may tend to create an environment that is quite the opposite. Opting for highway improvements will produce highway-oriented development even in violation of the goals and in spite of manipulations and safeguards. There must be a positive relationship between goals and means to their fulfillment. A community must adopt that mode or system of transportation that fulfills its goals; or else it must accommodate its goals to the consequences produced by the transportation system it chooses.

Choice of mode and its system configuration then becomes a key developmental decision for a city, region, or nation. Society must choose a set of objectives and goals that matches its transportation system and the development and life styles it naturally produces. Where the two do not match, frustration is inevitable. No amount of later manipulation of route location and highway design will affect the over-all result.

IDENTIFICATION AND DESCRIPTION OF CONSEQUENCES

Responsible persons at all levels of decision making and policy making with respect to highway transportation, within and without highway departments, should have an adequate knowledge and understanding of the road-user, social, and economic consequences of highway location, design, and use. The social and economic consequences are so numerous, so difficult to predict precisely, and so variable from place to place that full understanding of them and accurate forecast of their happening is too much to expect. Nevertheless, approaches toward this accomplishment are in order to aid in the process of route location and design.

Classification of Consequences

Many schemes of classifying the consequences of highway improvement can be developed to serve various purposes. A scheme to serve the present purpose should bring into focus the wide variety of consequences and indicate some of their relationships.

The classification of consequences in Table 17 is based on a combination of the consequences as a result of action (change in land value, number of persons displaced) and the action itself (dislocation and relocation). Table 17 serves two purposes: (1) it affords a fairly comprehensive compilation of consequences and their over-all relationships, and (2) it is the key to the individual description of specific consequences presented in the final major section of this chapter and in Appendix B.

The consequences are classified into 15 categories as given in the table.

The Classification System

The classification system lists categories of affected variables by type (e.g., residential, industrial, commercial) and the variables themselves as subcategories. It is intended to allow the analyst to select those variables or combinations of variables with which the analyst, the decision maker, or public is most concerned. The total list of variables likely to be affected by a transportation improvement is so long, and the time and expense of their total analysis are so great, that a complete analysis of every consequence probably would be neither feasible nor economically justifiable.

The classification scheme and description of variables contained in this chapter and Appendix B is designed to aid anyone engaged in highway design, study, or planning to systematically identify, analyze, predict, and evaluate consequences, relating them to the entire field of consequences. Table 17 gives the complete listing of variables by major category, then by a particular variable.[1]

[1] The major categories and many of the variables were identified and synthesized into the present scheme on the basis of previous classifications and listings of variables found in the following references (*9-1—9-6*) and personal sources and knowledge.

The major heading identifies a category of consequence variables based on the observation that: (1) similar persons, groups, or objects are frequently affected in similar ways by highway improvements, (2) interested groups at public hearings frequently coalesce according to their common interests or point of view, and (3) most highway impact and urban planning research variables have been classified in this manner.

Scheme of Presentation of Consequences

Consequences are related in Table 17 to their context: the area, space, and time dimension in which they mainly occur or are especially prominent and whether they are predominantly economic or social in character.

The information in the table is repeated in the write-up of each individual variable found in Appendix B. The write-ups, which discuss the consequences in detail, are broken down into the following sections:

1. Consequences.—A description of the sort of change, quantitative and/or qualitative, that has been observed or can theoretically (in the absence of research) be assumed to occur as a consequence of highway improvement.
2. Gains and utilities.—The type or class of persons or groups receiving beneficial effects from the improvement (incidence); the manner in which the gains or utilities are received; and the units of measurement in which gains or utilities are counted, where that is possible.
3. Costs and losses.—A similar treatment of the negative effects stemming from the highway improvement.
4. Decision-making factors.—Norms, guidelines, limits, or other considerations on the basis of which consequences, costs, and gains can be evaluated or judged for their tolerable or desirable limits, desirability, or lack of same.

Using the System

The formats of Table 17 and Appendix B were designed to provide the analyst with a uniform means of isolating and identifying the major variables acted on by a highway improvement. In addition, he is given an indication of the context within which the change usually occurs so that he may zero in on those variables central to his concerns.

For example, an analyst concerned with highway effects on the various variables might go down the side listing of variables in Table 17, choosing those at issue in a particular case and observing checks in the rows to determine their context. If, however, the analyst's concern was with, say, urban area impacts (for the urban planner), social impacts (for the sociologist), right-of-way impacts (for a right-of-way agent), pre- and during-construction impacts (for a relocation agent), or long-term impacts (for a regional planner), Table 17 could be entered via the heading and the checks in the columns could be observed to discover which variables to study.

Having formulated a listing of variables and contexts from Table 17 the analyst is prepared to go to the variable descriptions in Appendix B. There he will find a description of consequences that informs him of the usual direction and magnitude of the change in the variable and the incidence of gains and losses due to the change. The case example in Chapter Fourteen indicates how the variables

TABLE 17

SOCIAL AND ECONOMIC CONSEQUENCES OF HIGHWAY IMPROVEMENT BY AREA, TYPE, LOCATION, AND TIMING

SOCIAL AND ECONOMIC CONSEQUENCE VARIABLES	AREA		TYPE		LOCATION				TIMING			
	URBAN	RURAL	ECONOMIC	SOCIAL	RIGHT-OF-WAY	CORRIDOR	COMMUNITY OR SYSTEM	REGION OR NATION	BEFORE CONSTRUCTION	DURING CONSTRUCTION	AFTER CONSTRUCTION -SHORT TERM-	AFTER CONSTRUCTION -LONG TERM-
1. Aesthetics												
A. The View from the Road	X	X		X	X	X					X	X
B. The View of the Road	X	X	X	X	X	X					X	X
C. Highway-mode-Induced Aesthetic Effects	X	X	X	X	X	X	X				X	X
2. Agriculture												
A. Access to Improved Road		X	X	X		X	X				X	X
B. Economic Units (Size of Farm Unit)		X	X		X	X				X	X	X
C. Productivity		X	X			X	X	X			X	X
D. Dislocation		X	X	X	X	X			X	X	X	X
3. Commercial												
Commercial sales receipts and incomes:												
A. Change Due to Dislocation and Relocation	X		X		X	X			X	X	X	
B. Change Due to Barrier	X		X		X	X				X	X	
C. Change Due to Population Change	X		X			X					X	X
D. Change Due to Income Group Change	X		X			X				X	X	X
E. Change Due to Traffic Volume Change (Bypass Effect)	X		X				X				X	X
F. Change Due to Accessibility Change (Trade Area)	X		X			X					X	X
G. Change Due to Community Price Change (Resulting from Transportation)	X		X				X	X			X	X
H. Rental Property Receipts	X		X		X	X			X			
I. Employment	X		X			X	X			X	X	X
J. Land Use	X		X		X	X	X			X	X	X
K. Land Value	X		X		X	X	X			X	X	X
L. Effect on Public Transportation	X		X	X		X	X				X	X
M. Parking	X		X		X	X	X			X	X	X
4. Community Government												
A. Community Services and Facilities	X		X		X	X				X	X	
B. Park, Recreation and Open Space	X		X	X	X					X	X	X
C. Non-Highway Government Revenue and Expenditure Changes	X		X		X				X			
D. Public Policy and Laws	X	X	X	X	X	X	X	X	X	X	X	X
E. Community Goals	X	X	X	X	X	X	X	X	X	X	X	X
5. Construction												
A. Community Social and Economic Effects During Construction	X		X	X	X	X	X			X		
B. Immediate Effects on Highway Construction Industry	X		X				X	X		X		
C. Long Run Effects on Non-highway Construction Industry	X		X				X	X			X	X
6. Employment												
A. Employment Change Due to New Land Use Development	X	X	X			X	X			X	X	X
B. Employment Change Due to Dislocation and Relocation	X	X	X		X	X	X		X	X		
7. Environment												
A. Noise	X	X	X	X		X				X	X	X
B. Air Pollution	X		X	X		X	X	X			X	X
C. Vibration	X		X			X				X	X	X
D. Drainage Patterns	X	X	X		X	X				X	X	X

TABLE 17 *(continued)*

SOCIAL AND ECONOMIC CONSEQUENCE VARIABLES	AREA		TYPE		LOCATION				TIMING			
	URBAN	RURAL	ECONOMIC	SOCIAL	RIGHT-OF-WAY	CORRIDOR	COMMUNITY OR SYSTEM	REGION OR NATION	BEFORE CONSTRUCTION	DURING CONSTRUCTION	AFTER CONSTRUCTION -SHORT TERM-	AFTER CONSTRUCTION -LONG TERM-
8. Industrial												
A. Industrial Development	X		X			X	X	X			X	X
B. Industrial Dislocation	X		X		X				X	X		
C. Industrial Relocation	X		X			X	X			X	X	
D. Industrial Land Use	X		X			X	X				X	X
E. Industrial Land Value	X		X			X	X				X	X
9. Institutions												
A. Institutional Dislocation and Relocation	X		X	X	X					X	X	X
B. Institutional Accessibility and Patronage Change	X		X	X		X				X	X	X
10. Population												
A. Population Growth	X	X		X		X	X					
B. Population Density	X			X		X	X					
C. Population Geographic Shifts	X	X		X			X	X				
D. Population Distribution	X			X			X					
11. Public Utilities												
A. Utility Joint-Use of Right-Of-Way	X	X	X		X					X	X	X
B. Utility Dislocations and Relocations	X	X	X		X	X			X	X		
C. Utility Patterns and Costs	X		X				X				X	X
12. Residential Neighborhoods												
A. Rents, Costs and Prices of Replacement Housing	X		X			X	X		X	X	X	
B. Residential Relocation Costs	X		X		X				X			
C. Social and Economic Relationships of Dislocatees	X		X	X	X	X			X	X		
D. Quality of Neighborhood Life	X			X	X	X			X			
E. Property Values in Right-Of-Way Before Taking	X		X		X				X			
F. Neighborhood and Community Stability	X		X	X	X	X					X	X
G. Neighborhood and Community Linkage Patterns	X		X	X		X					X	
H. Residential Land Development	X		X			X	X				X	X
I. Residential Property Values	X		X			X	X				X	X
J. Neighborhood and Community Patterns	X			X		X	X				X	X
K. Social Life and Social Patterns	X			X		X	X				X	X
13. Road User												
A. Accident and Safety	X	X	X	X	X	X	X	X			X	X
B. Running Costs--Distance Related	X		X		X	X	X			X	X	X
C. Running Costs--Land-Use Intensity and Population Density Related	X		X		X	X	X				X	X
14. Spatial and Geographical Changes												
A. Local	X	X	X	X	X	X	X		X	X	X	X
B. Metropolitan	X	X	X	X			X				X	X
C. Regional	X	X	X	X				X			X	X
15. Urban Form and Development												
A. Land-Use Inventory	X		X				X			X	X	X
B. Land Values; General	X		X			X	X				X	X
C. Central Business District	X		X	X	X	X	X	X		X	X	X
D. Urban Form and Development Patterns	X		X	X		X	X	X			X	X
E. Real Property and Land Taken for Right-of-Way; Use and Value	X		X				X			X	X	

may be analyzed quantitatively, qualitatively, or in money terms for route and design comparison purposes.

This format offers a list of the sort of information needed by the analyst and decision maker in approaching an investigation of highway nonuser consequences. By offering each variable separately, the analyst is able to choose those that appear most significant to a particular problem. This obviates the need to investigate a comprehensive listing of variables in each case that might include numerous insignificant or irrelevant ones.

This approach recognizes that analysis has a diminishing returns effect. There is a level of research effort past which the additional expenditure to extend or improve the analysis does not produce equivalent or greater returns in terms of bettering the decision or the decision maker's ability to make it. The opposite may be the case; a decision maker confronted with too many options, facts, pros, and cons may be bewildered into indecision.

It is vital that the analyst confront only the issues raised in each instance; that the key questions asked by the decision maker or the public are answered.

Each highway improvement decision exists in its own social, economic, political, space, and time context and does not yield to uniform treatment. The structure of the analysis must conform to the circumstances and to the state of the system, both transportation and land use, of which the improvement is a part. For instance, an urban neighborhood may be concerned about displacement effects, a rural community about the highway as a barrier, a small town about bypassing, a shopping district about competing commercial development at interchanges. An improvement may be the first in an area and likely to encourage a high degree of "development" effects. Or it may be an addition to a fairly well-developed system with more "distribution" effect potential. None of these situations fits the same analytical mold. To lump them would be raising issues that may be irrelevent to the populations concerned while neglecting others they consider primary. Each analysis requires custom tailoring to the situation encountered. The approach adopted here attempts to make that possible by allowing the variables to be chosen individually and structured to meet the requirements of each case.

Also, the variables listed extend from broadscale to minute. This recognizes that informed decisions are required at all levels, from policymaker to design and location engineer. Often the effects of decisions reached at one level of decision making cannot be altered by decision making at another level. Individuals, other than the ones responsible, receive praise or blame for consequences over which they have no control. For instance, once it has been decided that an urban area will emphasize freeways as its primary form of transportation investment, there is little the engineers designing the system can do to control air pollution. On the other hand, policy makers cannot be held responsible for a hazardous curve or a scenic vista—those being engineering and design considerations. To pinpoint the focus of concern at any one level of decision making is to indulge in faulty and incomplete analysis. Needed are both detail and broadscale overviews; systems analysis and concern with localized effects. Again, the format of Table 17 and Appendix B attempts to allow for hierarchical levels of decision-making responsibility by including variables appropriate to the various levels.

In addition to going to Appendix B to determine the consequences, the analyst should review Table 9, where the same variables are set in a matrix with factors of engineering design and location. The matrix reveals both the approximate extent to which each of the variables is affected by engineering decisions and the extent to which the engineer (rather than some other decision maker) is responsible for producing or altering certain consequences. By this means the engineer can determine those consequences he can modify by alternatives of highway location and design.

BRIEF DESCRIPTION OF CONSEQUENCES

A brief treatment of the consequences corresponding to the 15 major categories follows. It is intended to provide a capsule overview of the consequences treated in detail in Appendix B. The itemization at the end of each category refers to the breakdown used in Appendix B.

1. Aesthetics

The large group of social factors involved in highway transportation includes aesthetics, natural beauty, and pleasant environment. Beauty is an abstract quality for which there is no prescribed measurement or description, but it is a universal factor. Each person has his own intuitive measurement of the beautiful and the ugly. All individuals prefer beauty to ugliness within their own specifications.

Aesthetics with respect to highways is always a controversial factor, but a real and important one in highway design. Because, generally, natural beauty (satisfying views and scenes) is not priced on the market, no individual or no community knows offhand what price should be paid in highway design to create the beautiful or to preserve natural beauty. It is only when he is confronted with a specific situation that an individual might make a decision on the price he is willing to pay to receive or to preserve beauty. This situation is bound to continue with respect to highways. The only answer to the value of beauty is found in individual, personal judgment, preferences, and priorities. Thus, with respect to the aesthetics of highway design, the decision maker must rely first on his understanding of what the public prefers and second on his own judgment as to how well the features of highway design add to or detract from these aesthetic values.

Some measure of the value of recreation facilities, public parks, band concerts, and zoological parks to the community may be obtained by various measurements of their use and their dollar cost to operate day after day. The number of vehicles entering a park and the number of people who listen to a band concert are direct measures of the values of these community assets. On the other hand, beauty and the aesthetics of design are hard to measure in terms of their use, because there are few places that people travel to specifically to view beauty or few places where an entry fee is paid for this purpose. The aesthetics of highway design and the weight to give such quality is further complicated by the fact that the criteria for beauty change from generation to generation and among different peoples.

The topics covered in Appendix B are:

1. The view from the road—a user-oriented consideration that impinges on nonuser use and development of land.
2. The view of the road—a nonuser orientation that considers how well the highway integrates with its environment visually.
3. Highway-mode-induced aesthetic effects—include effects that are not directly attributable to any one highway or highway improvement but to all the influences that have made highway transportation the predominant mode in the United States. This, in turn, has influenced how the environment appears and the ways in which it is continually adjusted to accommodate the operating characteristics, the system requirements, and the forms of development related to automobility.

2. Agriculture

Highways have made a notable contribution to the social and economic welfare of farmers. From the time that surfacing of dirt roads got the farmer "out of the mud," highways have affected farm life and productivity in a number of beneficial ways:

1. Allowed the consolidation of rural schools into larger, more efficient units.
2. Brought postal, fuel, and supply deliveries to farmers more economically and made community services such as bookmobiles and mobile health units more widely available.
3. Allowed the farmer greater latitude in choosing crop rotation and timing by providing all-weather year-round transportation.
4. Reduced travel time to market and trade centers materially, thus allowing for more daily work time in production activity.
5. Ended the isolation of farmers by allowing them greater participation in the social and civic life of the community even to the extent that some farmers are now town dwellers and "commute" to their farms.
6. Enabled the farmer to spread his holdings in that machinery and livestock could be transferred among dispersed fields.
7. Decreased the cost of transportation through lowering operating and maintenance costs. At the same time, spillover effects of road-generated dust that spoiled certain products and increased home cleaning chores were reduced.
8. Contributed heavily to the mechanization of farming by providing "truck" highways in combination with power farming.

These and other advantages have abetted technology in making United States agriculture outstanding in terms of productivity.

Modern Interstate highways, limited-access turnpikes, and expressways have introduced new benefits for farmers at the same time they have brought some new problems.

Generally, the costs and benefits of highways to agriculture are classified under four headings in Appendix B:

1. Access—the farmer's access to various destinations and to his own land and separated holdings.
2. Economic units—the basic farm unit as a viable economic entity capable of producing a satisfactory income and living.
3. Productivity—the amount produced per unit of input: labor, capital, entrepreneurship, and raw materials.
4. Dislocation—the preemption of farmlands by highways and urban uses.

3. Commercial

The effects of a highway improvement on the commercial sector occur as a result of the improvement affecting one or more of the following variables: population, income groups, and price.

1. Population.—People are the demanders for commercial goods and services. Their number helps set the volume of demand along with the variety of their needs and wants that dictates what mix of goods and services they procure and the quantity of each. Highway improvements will influence sales of outlets where they cause population densities to change.
2. Incomes.—Buying power is determined by how much the population has to spend. Highway improvements cause shifts in income group location which, in turn, affects commercial sales.
3. Prices.—Costs set what goods and services appear to offer the most utility and satisfaction in exchange for the buyer's limited economic resources. A highway improvement basically affects "price" through a change in "accessibility."

"Accessibility" means an increase or reduction in trip cost and includes time, operating cost, psycho-physical energy, availability and price of parking, and presence or absence of congestion. These costs add to the delivered price of goods and services. According to their magnitude, they will influence the buying decisions of the public to procure certain goods and services and from what outlets and locations. The usual desire is to minimize cost for a given quantity or quality of goods or, alternately, to get the most quantity and quality possible with a given budgetary allocation. Both cases call for seeking the lowest delivered cost. Because prices for many goods are fairly constant among locations, the lowest delivered cost is often the result of trading at the most accessible location. Hence, highway improvements have the effect of altering trade areas and the sales volumes of affected enterprises through affecting accessibility and delivered cost with both "income" and "substitution" effects.

"Income" effects mean that the total market basket costs either more or less in dollar terms for the same quantity of goods after the improvement. The greater efficiency and accessibility offered by the facility infers that, for its users, there will be an increase in real income—the same amount of goods at less cost or more goods at the same cost. For those not using the facility whose accessibility may have been adversely affected by barrier effects, by transit price rises or service deterioration due to auto-for-transit substitution generated by the improvement, or by dislocation of former commercial outlets whose alternatives are further afield, there may be a loss in real income—the same market basket now costs more or the same amount of money buys less.

"Substitution" effects mean that similar or alternative goods and services, that appear to sell for relatively less after the improvement than the goods and services formerly purchased before it, will now be substituted so as to reach the same level of utility and satisfaction at less cost or at the same cost. The enterprises and locations dispensing the relatively lower-priced substitute will proceed to capture the trade of those substituting away from former products, services, outlets, and locations.

Commercial impact topics in Appendix B are:

1. Commercial sales receipts and incomes:
   a. Change due dislocation and relocation.
   b. Change due to barrier.
   c. Change due to population change.
   d. Change due to income group change.
   e. Change due to traffic volume change (bypass effect).
   f. Change due to accessibility change (trade area).
   g. Change due to price change (resulting from transportation).
2. Rental property receipts.
3. Employment.
4. Land use.
5. Land value.
6. Effects on public transportation.
7. Parking.

4. Community Government

Highway improvements have the potential for changing the quantity and quality of community government services and facilities in a variety of ways:

1. Causing population density change that alters the pattern of needs for various service and facilities.

2. Displacing population or facilities for right-of-way with the effect of altering the distribution of demand for facilities and services.

3. Changing the relative accessibility of facilities and the cost of mobile services due to: (1) lowering time-cost of transportation via the highway improvement, (2) raising time-cost due to the barrier effect of limited-access highways, and (3) replacement or development of new facilities through joint use, joint development, or air-rights programs connected with the improvement. The barrier effect often has the result of redistricting the service areas of facilities in the vicinity of the highway.

These changes may be beneficial or disbeneficial, requiring costs and adjustments, according to circumstances.

One of the more serious problems in the area of community facilities has been that of the taking of urban park and recreational land for highway route locations. This has the advantage of reducing the cost and controversy that attach to takings of residential, commercial, and industrial land. However, it reduces the supply of a scarce urban resource with high social value.

Impacts on government nonhighway revenues and expenditures from highway improvement are likely to occur as follows.

Revenues and expenditures within rights-of-way are modified prior to right-of-way taking. The period of waiting and uncertainty prior to taking induces property deterioration that may lower property tax revenues. The same deterioration causes public expenditures to rise in the area to counteract the blighting effects. The new loss becomes a burden on the remaining taxpayers and may cause a reduction in their share of services.

Revenues and expenditures within the entire jurisdiction are differentially affected by the system effects of the highway improvement in inducing the location, dislocation, and relocation of various tax-producing and revenue-consuming activities. This includes industrial plants, commercial enterprises, and households.

Other government concerns (namely, public policy and laws and community goals) are also affected by highway improvements.

Highway improvements generate consequences that are in accord with or are at variance with public policy, laws, or community goals. Where accordance is reached, there is a harmony of public desires and consequences. Where conflict exists or impairments to the public health, safety, or welfare arise, there is a possibility of remedy by law, policy, or the expenditure of public funds.

Public policy and law issues that typically arise from highway improvements concern such things as modal balance, air pollution and noise levels, highway safety, traffic control, zoning, parking, public expenditure for streets and highways, route locations and designs, revenues and expenditures, and urban renewal.

Goals of the community are affected by highway systems and improvements in the way highways induce or encourage certain environmental changes that may or may not be in accord with the goals. Where they are in accord, there is no conflict. Where they do not agree, either the goals must accommodate the consequences, the highway must be modified to more nearly match the goals, or alternative modes capable of more closely fulfilling the goals must be substituted.

The topics covered in Appendix B are:

1. Community services and facilities.
2. Park, recreation, and open space.
3. Nonhighway government revenue and expenditure changes.
4. Public policy and laws.
5. Community goals.

5. Construction

Construction activity has a three-way effect:

1. Neighborhoods are disrupted during the construction process. Streets are blocked, access is hampered, congestion may worsen, detours are necessary, and there may be nuisance effects of noise, dirt, and dust raised by earthmoving equipment.

2. The construction industry is benefitted from the injection of funds that employ their services and labor. In construction programs of the magnitude of highway proj-

ects, this may be a considerable boost to a local economy for the short term.

3. In the long run, the construction industry may continue to benefit as the highway's altered set of accessibilities sparks successive rounds of development designed to take advantage of those accessibilities.

The effects covered in Appendix B are:

1. Community, social, and economic effects during construction.
2. Immediate effects on highway construction industry.
3. Long-run effects on nonhighway construction industry.

6. Employment

Employment responds to highway improvement in two ways:

1. There is the effect of short- and long-term increases in construction employment due to the investment in highway improvement and the ensuing development that takes place to capture the advantages of the accessibility provided. There is opportunity for new employment arising from highway access to resources or to land in advantageous quantities and locations that can be used by new industries. According to where industry locates and its employees settle, additional employment may be created in secondary and tertiary sectors as outlets develop to furnish retail goods and services to the population.
2. There are employment shifts or redistributions from the effect of employers moving voluntarily to capture the accessibility advantages of the highway improvement. Others move involuntarily due to right-of-way displacement. There may be no net gain in employment from these shifts—only a change in the geographic area that will form the "labor shed" for the relocated enterprise. Plants frequently use relocation as an opportunity to modify their operations. The effect on employment may be mixed: gains in growth enterprises that add capacity and accompanying employment; losses in growth enterprises that add capacity but automate their production process; and total loss in marginal enterprises that go out of business.

These effects are explored in Appendix B under two topics:

1. Employment change due to new land-use development.
2. Employment change due to dislocation and relocation.

7. Environment

Highway improvements affect two environments—natural and human. Environmental impacts are largely spillovers—unintended side effects. They include visual and aesthetic effects (covered under category "1. Aesthetics")—noise, air pollution, vibration, and drainage patterns.

Vehicular noise can be a nuisance to nearby residents due to its effects on sleeping patterns and the ability to converse or listen without interruption. There may also be long-term effects on the nervous system from noise.

Air pollution creates aesthetic problems due to effects on visibility, health problems due to its effects on the respiratory tract, and a botanical problem wherein it affects vegetation. The odors that frequently accompany large concentrations of exhaust fumes are also environmental problems.

Vibration can be annoying to persons as well as damaging to structures over long periods.

Drainage patterns are frequently affected in rural areas where natural water courses are diverted or dammed and new ones are created. These changes may create problems of flooding, erosion, or ponding, with possible negative effects on farmland. It may also affect the migration of fish—a concern of conservationists.

These topics are discussed in Appendix B under four headings:

1. Noise.
2. Air pollution.
3. Vibration.
4. Drainage patterns.

8. Industrial

Highway improvements introduce new accessibilities that offer transportation efficiencies and economies. Sensitive to means of cutting costs in order to increase profits or lower prices (thereby increasing sales volumes), industrial enterprises are often prompt to exploit the accessibility gains offered by a highway improvement.

Industrial plants have become prominent land users along metropolitan portions of the Interstate System—particularly in outlying radial and circumferential corridors. Although some of the plants may be new to an area, others are likely to be ones relocated from some other site in the vicinity. Relocation may be either voluntary or due to rights-of-way takings.

The reasons for industrial location decisions are numerous and vary from industry to industry and sometimes from plant to plant according to the particular productive processes of the enterprise and the ways in which it can use the advantages created by the improved facility.

The topics discussed in Appendix B are:

1. Industrial development.
2. Industrial dislocation.
3. Industrial relocation.
4. Industrial land use.
5. Industrial land value.

9. Institutions

Institutions are one more of the numerous land uses affected by rights-of-way takings. Unlike other land uses, they not only have an economic value bound up in land and structures but they also carry a great deal of social value and affective significance due to the functions they perform and the values they symbolize. These values frequently make the functions emotional issues in route location controversy.

Like other population-serving activities, institutions have service areas and patronage threshold levels. Alteration of these levels either by rights-of-way takings, limitation of access, or change in accessibility will alter the range of attraction (service area) and the patronage level of the institution. The way in which these factors are altered will determine whether the institution prospers, survives or fails, or operates efficiently. A systems effect will occur as institutions are removed to acquire their land for right-of-way and their former patrons redistribute themselves to alternative sources of institutional services.

The topics discussed in Appendix B are:

1. Institutional dislocation and relocation.
2. Institutional accessibility and patronage change.

10. Population

Highway improvements affect a variety of population or demographic variables in a number of ways.

Number of population rests on the availability of income-producing jobs (or amenities available for consumption as in the case of retirement centers). The economic base or primary industries form the nucleus around which the supporting retail and commercial sector forms. Highway improvements can influence total population by attracting additions to the economic base. These, in turn, have a multiplier effect on the nonbasic sector represented by the nonbasic/basic ratio.

Age, sex, race, marital status, family size, income, and tenure are likewise influenced by the character of the basic and nonbasic labor force, the skill mix required, its turnover, and the incomes paid to its members. Sometimes, as in the case of college and retirement communities, these variables are influenced by the character of the population subsisting on transfer payments as well as that engaged in wealth-producing, distribution, or service activities. Highway improvements affect these variables mainly in regard to their geographic distribution. Highways play a part in centralization and decentralization of similar age, family size, racial, marital status, income, and tenure groups.

Population density is more obviously related to highway improvement, being the ratio of population to area, usually square miles or acres, either gross or net in residential land use. Highway improvements affect the amount of land accessible to workplaces and shopping according to time and distance tolerances. Such land is developable for residential use. The more residential land available relative to population, the lower the density possible. As land coverage becomes saturated, highway improvements in the form of increased capacity allow land to hold greater numbers while preserving the balance between trip generation and transportation capacity, thus making higher densities possible.

Geographic distribution of industry workplaces influences residential distribution, which in turn influences commercial workplace distribution. As highway improvement affects the geographic location and/or accessibilities among any of these activities, it will generate geographic shifts in the others. Geographic population distribution and densities are the resultants.

The aspects of population explored in Appendix B are:

1. Population growth.
2. Population density.
3. Population geographic shifts.
4. Population distribution.

11. Public Utilities

Highway improvements have three sets of consequences in terms of public utilities:

1. Highway rights-of-way provide space for utility lines and permit easier access for installation and servicing. This is a valuable benefit considering that the alternative to joint use of the highway right-of-way is paid-for easements across private property.
2. Utilities must absorb, be compensated for, or share the cost of relocating utility lines to accommodate highway rights-of-way and reconstruction.
3. Insofar as highways influence the pattern, density, and type of land development, there will be a correlated differentiation in the cost of utilities designed to serve such development. Length and capacity of lines, scale economies, volume of customers relative to capacity, and number of connections all influence the capital, operating, and maintenance cost of utilities.

The consequences discussed in Appendix B are:

1. Utility joint use of right-of-way.
2. Utility dislocations and relocations.
3. Utility patterns and costs.

12. Residential Neighborhoods

Highway improvement impacts on residents, housing, neighborhoods, and communities take place for a variety of reasons.

1. Right-of-way taking dislocates residents and reduces the supply of housing, with systems effects on prices, rents, vacancies, household expenditure patterns, relocation costs, and the dislocatees' psychological health and their social and economic relationships.
2. Right-of-way location decisions, if prolonged, and route location announcements, if they substantially precede actual taking, may cause a deterioration in neighborhood quality over time, with systems effects on property values and government revenues and expenditures in the affected area.
3. Right-of-way taking may have an impact on neighborhood and community stability due to displacement, barrier, and spillover effects.
4. A highway improvement that creates a barrier and a new set of accessibilities will have an impact on neighborhood and community linkage patterns by various modes.
5. New accessibilities and capacities created by the highway improvement will, in the presence of demand for housing, create new residential development opportunities. Residential land use and land values will reflect the change.
6. The neighborhood and community will change to accommodate the residential shifts and the increase in automobile use and ownership in part attributable to the improvement.
7. Social life and social patterns will tend to change in accordance with environmental change and the characteristics of the mode of transportation used by a majority of the population.

The subjects discussed in Appendix B are:

1. Rents, costs, and prices of replacement housing.
2. Residential relocation costs.
3. Social and economic relationships of dislocatees.
4. Quality of neighborhood life.

5. Property values in right-of-way before taking.
6. Neighborhood and community stability.
7. Neighborhood and community linkage patterns.
8. Residential land development.
9. Residential property values.
10. Neighborhood and community patterns.
11. Social life and social patterns.

13. Road User

Nonuser consequences have feedback effects on highway users and the highway improvements they use.

Accident and safety records are influenced by the roadside development premitted to take place following the improvement. Turn movements, distractions, and traffic volumes induced by roadside traffic generators influence the incidence of accidents. The mix of motor traffic and pedestrians in the right-of-way likewise affords increased probability of accident.

Motor vehicle running costs respond to distance. Distance is, in turn, affected by the geographic extent of development as determined by the interaction of the vehicle's range, capacity, and speed, the system pattern, and time- and cost-distance tolerances for various trip purposes.

Development and redevelopment responding to the highway improvement sets the location and intensity of activities (traffic generators). Origins and destinations and desire line patterns shift to match these changes. Motor vehicle running costs respond to conditions of traffic flow and access through their effect on stopping and starting, speeds attainable, and degree of congestion that produce various running cost rates per mile.

Road-user feedback topics discussed in Appendix B are:

1. Accident and safety.
2. Running costs—distance-related.
3. Running costs—land-use-intensity and population-density related.

14. Spatial and Geographical Changes

Transportation is a means of overcoming space. It links activities separated in space such as resources and factory, home and work, wholesaler and retailer, farm and market. Transportation changes in general, and highway, road, and street improvements in particular, have their consequences revealed within a spatial or geographic framework.

Under the impact of a transportation or highway improvement, activities will develop and redevelop, locate and relocate, to take advantage of the superior service, the enlarged capacity or the economies, efficiencies, and accessibilities afforded by the improvement.

Having jurisdiction over the routing and design capacity of the routes and ways in most modes of transportation places the government in a strategic position. By manipulating route locations and designs it is able to shape development and the location of activities of various sorts to suit policy and goals or fulfill the needs and demands of the government or the population.

By transportation planning with an eye to consequences, local jurisdictions can influence the timing, extent, intensity and direction of their land development; metropolitan jurisdictions can provide coherence and a degree of coordination between disparate parts of the urban region; regional authorities can influence the economic health of depressed areas and direct growth patterns and resource exploitation in more optimal ways from the standpoint of efficient use of productive capacity and conservation of scarce resources.

The influence of highway improvement on geographical change is discussed in Appendix B under the headings:

1. Local.
2. Metropolitan.
3. Regional.

15. Urban Form and Development

Transportation modes according to their accessibilities, capacities, efficiencies, and operating characteristics and the extent and nature of their systems create a unique environment. Urban three-dimensional form and a pattern of urban development emerges that is accommodated to the attributes of the predominant mode. Improvements in the facilities of any mode, to the extent that it causes that mode to become more popularly used and substituted for other modes, promotes this tendency.

An auto-oriented society will produce auto-oriented cities. Their form and development patterns will be different from transit-oriented or pedestrian-oriented cities.

Having passed through eras in which pedestrian and transit travel predominated, American cities possess the contrasting patterns and forms of all three orientations.

The tightly clustered buildings, the narrow, often winding, streets punctuated with squares and plazas, found in the "walking city" portions of central Boston (Beacon Hill), New York (Greenwich Village), New Orleans (the Vieux Carré), are typical of pedestrian-oriented development.

The transit-oriented city is represented in the pattern by: (1) intensive corridor developments where accessibility was continuous, as along streetcar lines, and (2) dense clustered development around rapid transit stations where accessibility was sporadic, as in the case of subway or railroad lines. Typical examples of streetcar corridors include Commonwealth Avenue, Boston; Delmar Boulevard, St. Louis; and Connecticut Avenue, Washington, D.C. Examples of subway and railroad oriented development include Harvard Square, Cambridge; Chicago's North Shore communities; and the towns along New York's Long Island Railroad and Philadelphia's Main Line.

Similarly, auto-oriented cities have a typical form and pattern. It includes low-density residential development, sometimes called "sprawl," punctuated with extensive shopping centers and industrial parks, both provided with copious parking space. Ribbon commercial development along unlimited access thoroughfares is another typical feature in the pattern. Los Angeles, Oklahoma City, Denver, and other cities of the West that have had most of their development occur in the period of the automobile's predominance are examples of this type.

Choice of mode is thus an important developmental decision.

Urban form and development effects stemming from highway improvements are discussed in Appendix B under the following topics:

1. Land-use inventory.
2. Land values; general.
3. Central business district.
4. Urban form and development patterns.
5. Real property and land taken for right-of-way; use and value.

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CHAPTER TEN

TECHNIQUES OF EVALUATING ALTERNATIVE PLANS

Chapters Six, Seven, Eight, and Nine and Appendix B discuss the road-user and nonuser consequences of highway improvements. The terms "market factors" and "nonmarket factors" are used in a general sense to indicate, respectively, the road-user consequences and the nonroad-user consequences. Mainly, the road-user consequences are the market-priced items of running cost of vehicles, traffic accidents, and travel time. Therefore, the road-user costs and benefits can be expressed in dollar terms. On the other hand, the nonuser aesthetic, social, economic, and welfare factors are often highly subjective in their values and are not factors of highway transportation that can be easily priced in terms of the market.

Highway system planning and highway design give attention to both the road-user and nonuser consequences. In the final decision process, the decision maker must make his decision, giving proper consideration to both the road-user consequences and the nonuser consequences. The decision maker is faced with the nonattainable desire to put the user and nonuser factors together in some form of direct cost-benefit numerical value that would give him a reliable index as to what his decision should be. The nonpriceable factors are also to be considered in some form of cost-effectiveness or effectiveness analysis. See Figure 4.

Although certain analysts and decision makers desire to reduce the decision process to applying some form of mathematical formula, no way has yet been discovered to do so, and there are many reasons why they should not do so, even though they may attempt it.

OBJECTIVE OF ECONOMIC ANALYSIS AND THE DECISION PROCESS

There is only one main objective to the efforts put into measuring and analyzing the cost inputs, and the beneficial and adverse outputs of alternative proposals for improving highway transportation. Specifically, this single objective is to provide the decision-making person or body with information helpful in finding the best over-all alternative as the one to approve for final design and construction. Thus, the economic analysis is made not to find a decision but to produce results that will assist the decision-making process.

The generally applied benefit/cost ratio or rate of return analysis, to determine the relative values of cost and of benefits, is applied to those proposals wherein the main factors can be dollar priced. The six methods of analysis described in Chapter Six pertain to proposals of highway improvement that can be dollar priced both in cost and in benefits. Chapter Three, on the other hand, discusses cost-effectiveness in the sense that perhaps the costs of achieving an improvement can be quantified in dollars but that the benefits or effectiveness of the improvement cannot be dollar priced. Thus, it is evident that the total process of economic analysis of highway transportation improvements has to be approached through consideration of factors in both the market and nonmarket classifications.

All public bodies and highway officials are aware that for every proposed improvement to a highway system or to a specific highway route there will be individuals who will suffer certain adversities while others in the nonuser classification will gain physical, mental, or monetary benefits.

Paralleling these nonuser consequences are the direct benefits to be enjoyed by the highway user. Most of the nonuser consequential factors are those that must be evaluated by individuals on a subjective basis. The decision maker must face the fact that these nonuser values, whether positive or negative, depend on whose viewpoint is being used; further, that the values change not only with persons but also with time, place, situation, quantity, and quality of the factors involved. Because of the character of personal preferences involved in the nonuser factors it generally follows that the decision maker should reach the decision that is the best for the community (neighborhood, city, region, state, or nation) at large. But there often is no positive way to measure the differences in the alternatives for highway improvement to determine which alternative is the better one for the community at large. There may be a problem of determining, for example, whether the taking of 10 acres of parkland is a proper sacrifice to avoid moving 32 families from their present location. Another problem might be that of deciding whether the cost of depressing a freeway is balanced by the desirable aesthetic qualities created thereby in comparison to building an elevated freeway at less cost.

In endeavoring to reach the decision that is best for the community, it is usually borne in mind that the community probably has some long-range objectives and values as well as the specific currently expressed preferences.

DESIRE FOR RANKING AND RATING SCHEMES

The difficulties and risks involved in approving proposals for highway system and highway project improvements involve subjective appraisals of many of the factors involved. Because of this subjective nature of the decision and the viewpoints involved, the decision maker may hunt for guidelines or specific indices as to what his decision should be. He may hunt for easy and obvious decisions that will reduce the required intensity of his thinking to a minimum and at the same time assure a high probability of having made a good decision. It is highly doubtful whether really helpful decision guides can be developed that combine the road-user factors and the nonuser factors into one over-all index pointing to the preferred alternative. Furthermore, any universal model or formula to be proposed probably will inject a subjective rating of values in some sort of point assignment system, so that subjective ranking is introduced before the decision process, rather than as a part of the decision process.

For the past ten years or so, highway engineers, highway officials, and decision makers have talked about devising a scheme to combine the market and nonmarket factors into one over-all single numerical answer to indicate the relative desirability of the improvement alternatives being considered. It is obvious that, to achieve this objective, the market factors have to be expressed in the same terms as the nonmarket factors, or vice versa. The early thinking toward this objective has been to devise a system of ranking in priority, or in effectiveness, the nonmarket factors or the alternatives of design with respect to the nonmarket factors. In general, these schemes have proposed the use of numerical weighting factors applicable separately to each alternative. This then becomes a process of applying subjective judgment to rank the alternatives in the early steps of the analysis process.

The engineer's desire to have some form of rating system for economic analysis can be compared to his development of the sufficiency rating index for existing highways. The sufficiency rating system, however, is remarkably different in its base and in its intent from the decision process of selecting the best alternative of highway location and design. Sufficiency ratings are based on design standards pertaining to the desirable dimensions and structural capacity of the highway physical components. The rating system is nothing more than a comparison of the degree to which an existing highway section reaches the desired standard of design. A rating factor is introduced arbitrarily by assigning the over-all structural design so many points, the safety features so many points, and the geometrics so many points, based on the standard. At the lowest order, the points assigned, say, for shoulder width or pavement width can be somewhat automatically determined because of the desired standard dimension. But weighting the preference for highway safety against the preference for structural design and against geometric design is a subjective process.

In the economic analyses with reference to the nonuser consequences, no standards exist from which to measure economy, adequacy, satisfactions, or preferences. Thus, from the lowest order of individual factors to the final weighting of aesthetics against community goals and against land use, the process is wholly subjective. There are no standards on which to base any sort of rating or ranking system, except personal judgment.

Where the final decision process is in the hands of engineers, the engineer may not feel competent to judge the relative merit of the social factors and the broader economic factors. The engineer, being accustomed to dealing in physical designs that can be measured and costed to acceptable degrees of reliability, is sometimes lost when he gets into the field of strictly subjective judgments on factors unrelated to engineering. Therefore, he may seek artificial means and supports of judgment that lead him to models, formulae, tables of values, and weighting schemes. But, better, he should be guided by advice and evaluation from sociologists and economists.

Although there seems to be no reliable way that the road-user consequences can be arithmetically combined with the nonuser consequences, the decision maker may employ rating and ranking systems or a device to record and classify his judgments relative to the nonuser group of consequences and, under certain arrangements, to compare the road-user and nonuser consequences.

GENERAL CONCEPTS APPLIED TO RANKING AND RATING OF ALTERNATIVES

The selection from a group of mutually exclusive proposals for a highway improvement of the one proposal that best satisfies the goals is a choice of preferences from among nonhomogeneous or unlike choices. Further, each possible choice carries with it acceptances of both desired and undesired results. Trade-offs are in order. The real problem is one of choice of values, when different people express different values for the same factor.

The Evaluation Problem

Often each of the highway improvement alternatives may have attractive and unattractive factors. Although these factors can be identified, they often cannot be isolated, discarded, or regrouped. The problem is not equivalent to sorting apples, by size, color, perfection, green, ripe, and over-ripe, so that in the end the apples are sorted, and regrouped by size and quality so that they are easily ranked, basket by basket.

Not only are the factors in highway transportation preference widely different, they do not have wholly common criteria for comparison. For instance, consider what measures are available to determine a preference between any pair of the following factors:

1. Traffic noise.
2. Human suffering from personal injury.
3. Destruction of an old (but attractive) church building.
4. Moving of 22 families.
5. Giving up of 20 acres of parkland for highway purposes.
6. Gaining an attractive scenic view from the roadway.
7. Reduction by 7 min of the travel time between points A and B.

The difficult selection among these types of factors is made doubly difficult by the trade-offs involved. To confine traffic noise to a location where noise is not objectionable may mean a trade-off of road-user travel time, or accepting an unsatisfactory plan for a community recreation area.

Methods of Approach to Evaluation

Before a group of alternative plans for accomplishing essentially the same objectives (mutually exclusive alternatives) can be ranked or rated for the purpose of identifying that alternative judged to be the preferred one, when all objectives and all consequences are considered, three steps are required:

1. The objectives must be identified.
2. Some standards or criteria must be identified as a measuring device to determine the degree to which an objective is reached.
3. The viewpoint of final decision must be chosen as a measure of establishing the relative worths of the several objectives. Note: certain pairs of objectives will be in conflict with each other.

Instead of approaching the evaluation of the alternative plans by determining the degree to which they attain goals, or objectives, the approach may be made by comparing the social and economic consequences. This comparison is basically one of ranking or rating several groups of consequences on the basis of their contribution to benefits, adversities, or their favorable and unfavorable factors.

Tables 18 and 19 give factors involved in these approaches. The tables also illustrate a fundamental fact that controls the final answer. Not only are the alternative plans to be ranked as to choice based on the net attainment of the end objectives, but it becomes necessary also to rate the objectives and the consequences as to their respective values. Ranking the objectives or the consequences is not sufficient to identify the choice alternative. Ranking the objectives or the consequences (listing them in order of first choice to last choice) is easier than rating them (assigning quantitative relative values to each objective or to each major consequence). This specific ranking and rating is independent of the alternative highway plans.

The ranking act is simply one of deciding whether one perfers pears to pork chops to potatoes. The rating process introduces the degree of one's preference for pears over pork chops, pork chops over potatoes, and potatoes over pears, under changing quantities of supply. Under conditions of normal supply and demand this rating act is similar to establishing one's indifference curve for any pair of offerings. For instance, if one assigned values (rate) of five pears to three pork chops, three pears to four pork chops, and two pears to seven pork chops, in effect this is stating that one would be equally satisfied with any of these three combinations of pears and pork chops. And when the choice has to be made from more than two items, the total ranking becomes more difficult.

The conclusion is correctly drawn that whether one is ranking or rating highway objectives, community objectives, or highway consequences, he is attempting a choice between two or more alternative highway improvement plans on the basis of factors of merit that cannot be reduced to a single figure by any known logical, reliable, or obvious manner. The answer must be one of a subjective choice between pears, pork chops, and potatoes, and, often, from more than three items.

To make this evaluation process more complex (and more uncertain) consider assigning dollar value to the objectives in Table 18 or the consequences in Table 19. The highway physical factors and the road-user cost factors can be expressed in market dollars, but none of the highway objectives or community goals can be, and but few of the consequences can be expressed in dollar costs or dollar benefits.

The literature in the past few years has had an increasing number of papers on this problem of evaluating proposals for transportation systems and projects. Some of the major contributions are reviewed in the following.

SPECIFIC RANKING AND RATING SYSTEMS

To illustrate the status of the literature on evaluating alternative plans involving the nonmarket consequences, reviews of selected literature follow. Also, some of the specific procedures of ranking and rating are given.

Richard A. Lamanna, "Value Consensus Among Urban Residents" *(10-27)*

This article deals with a comprehensive attitude survey taken in Greensboro, N.C., by interview of 211 adult white and Negro residents of both sexes. These individuals were asked to state the relative importance they attach to certain conditions or subjects the interviewer presented. There was a total of 13 items. In the end, the author rated the replies

TABLE 18

GOALS AND OBJECTIVES OF HIGHWAY IMPROVEMENTS THAT MAY BE CONSIDERED IN EVALUATION OF ALTERNATIVE PLANS

A. Objectives directly affecting the highway users:
1. Minimize motor vehicle running cost.
2. Minimize motor vehicle travel time.
3. Minimize traffic accidents and their cost.
4. Maximize travel comfort and convenience.

B. Objectives directly pertaining to highway design:
5. Minimize the monetary cost of highway construction, maintenance, and operation.
6. Maximize the quality of travel service.
7. Provide for high-capacity facilities to be used by maximum percentage of total area traffic.

C. Objectives related to community transportation:
8. Maximize coordination and integration of total transportation system of all modes.
9. Provide adequate transportation to all land areas and land uses in accordance with land-use plans.

D. Objectives related to community development factors:
10. Enhance the achievement of the over-all regional and community development plans.
11. Preserve and enhance the community goals and attributes in support of its desired type of community.
12. Enhance the provisions for national defense and emergency transportation.
13. Conserve open space.

E. Objectives related to community social factors:
14. Preserve the historical and "sacred" areas and objects.
15. Minimize the adversities to residents and establishments occasioned by ROW procurement and route location.
16. Preserve the desired social attributes of local areas and the community.
17. Provide for and preserve neighborhood unity.
18. Minimize air pollution.
19. Minimize the nuisance from noise.
20. Preserve and enhance natural beauty and scenic enjoyables.
21. Maximize the pleasing effects of aesthetics and design to achieve effects compatible with local areas.
22. Enhance the opportunities for recreation.
23. Minimize the disruption of activities during the construction phase.

F. Objectives related to economic factors:
24. Minimize the adverse consequences to business, trade, and industry, before, during, and after construction.
25. Maximize conservation of resources.
26. Preserve land values.
27. Promote land use in accordance with economic development plans.

TABLE 19

CONSEQUENCES OF IMPROVEMENTS TO HIGHWAYS—FAVORABLE AND UNFAVORABLE—INCREASES AND DECREASES ARE INCLUDED

A. Highway user:
1. Vehicle running cost.
2. Travel time.
3. Traffic accidents.
4. Comfort and convenience.
5. Travel distance.
6. Disruptions to travel during construction.

B. Physical highway and highway department:
7. Road-user tax revenues.
8. Construction budget.
9. Maintenance and operating budgets.
10. Traffic policing.
11. Shifting of traffic among routes.
12. Shifting of ADT's because of changing land use.

C. Community transportation:
13. Transfers of trips between modes.
14. Intergovernmental coordination.

D. Community development:
15. Park land.
16. Open space.
17. Slum clearance.
18. Utility services.
19. Population movements.
20. Land-use zoning.
21. Suburban growth.
22. Central business district.

E. Community social factors:
23. Physical barriers to social exchange.
24. Relocated families.
25. Relocated social functions and facilities.
26. Disruption of political boundaries.
27. Disruption of service and educational boundaries.
28. Changed living conditions, standards, environments.
29. Cost of living.
30. Relocation of places of employment.
31. Welfare activities.
32. Housing supply and demand.
33. Crime.
34. Fire, health, and police protection.

F. Community economic factors:
35. Business volume and relocated business.
36. Disruptions during construction.
37. Alteration of trade areas.
38. Access to place of business activity.
39. Land value.
40. Land use.
41. Competition in business.
42. Assessed value of taxable property.
43. Labor supply.
44. Environment.
45. Capital requirements for moving, remodeling, rebuilding, reestablishing competitive position.
46. Training and retraining of employees.
47. Land severance effects.

given by those interviewed 3, 2, or 1 on the basis of very important, somewhat important, and not especially important, respectively.

The items considered were of the following type:

1. Accessibility.—Schools close enough so that children can walk to them; and shopping facilities not too far away.
2. Mobility.—Good roads and sidewalks; convenient public transportation.
3. Under the heading of "Social Values," "Status" was one item, meaning "the right kind of people in your town."
4. Sociability was an item, "A friendly town that has the type of people with whom you can stop and chat awhile on the street and visit often; and friends close by."

It is significant that "good roads and sidewalks" was rated by all interview groups as being the item of highest importance.

This scheme of ranking or rating is not especially applicable to the problems of selecting the best alternative for highway improvements. However, it does illustrate the technique of how the public can be sampled and interviewed in such a way as to get the public's relative evaluation of certain factors of community living. Although surveys of this type would indicate what the people preferred, the results would not necessarily indicate whether they had a sound basis for their preference or whether they were looking at the statements from the viewpoint of the community as a whole or from their own individual situation.

The article has some value to the highway planner in gaining ideas of what the people in Greensboro thought were the better values to look for in their community and how other communities might be surveyed for that information.

Robert T. Eckenrode, "Weighting Multiple Criteria" (*10-12*)

Eckenrode is concerned with identifying reliable methods of collecting data on human judgments of the relative value of a series of items. He sets up three hypothetical situations and then uses a team of 6 to 12 judges to rate the importance of the criteria set forth as the specifications for the system involved. The systems were:

1. A specific air defense system development in which the criteria were: (1) economy, (2) early availability, (3) lethality, (4) reliability, (5) mobility, and (6) troop safety.
2. A general (hypothetical) air defense system development, in which the criteria were the same as in item 1.
3. A personnel selection problem, in which six judges rated the following factors as those important in filling a specific employment position: (1) previous personnel subsystem experience, (2) technical competence, (3) demonstrated capabilities for fiscal planning, (4) work planning, (5) maintaining good client relations, and (6) good staff relations.

The three sets of criteria for the three individual situations were tested by the judges by six different methods:

1. Ranking.—The individual criteria were ranked on the basis of 1 for the most valuable and increasing numbers to the least valuable.
2. Rating.—The criteria were presented next to a continuous scale marked off in units from 0 to 10, and the judge drew a line from each criterion to any appropriate point on the value scale. He was then permitted to select points between numbers or to assign more than one criterion to a single position on the scale.
3. Partial Paired Comparisons I.—This method was a system of a partial matrix in which the judge selected chose his best from each pair of alternatives or factors.
4. Partial Paired Comparisons II.—This method was similar to item 3, except that each possible pair of criteria were arranged in pairs on a horizontal line and the judge circled the one he considered the more valuable.
5. Complete Paired Comparisons.—This system was the same as item 4, except that each possible pair of criteria was listed a second time but in reverse order from the first listing.
6. Successive Comparisons.—In this method, the list of criteria was presented to the judge who tentatively assigned a value of 1.0 to the most important criterion and then assigned decimal values between 0.0 and 1.0 to other criteria in order of importance. The judge then modified the value of his first choice (the choice given the 1.0 value) such that its value was more than the total of all the other items if he judged it to be more important than the total of all the other items combined, or less than all others if he judged it to be less. He then repeated this situation with his chosen criterion as being second most valuable.

These general methods of ranking proved that a set of judges who were qualified in the particular area would find high agreement on their selection of the criteria of most importance and in their relative ranking of these factors. This agreement is probably related to the fact that these judges had similar values and similar knowledge within the area being studied. The method might work well in connection with the choice of alternatives in highway location and design, or in the relative ranking of the desirability or undesirability of certain of the nonroad-user consequences, provided the judges had similar backgrounds.

The judges must have more or less a common background to get the high agreement that was obtained in this experiment. In the case of highway improvements it would be difficult to get a set of judges together that would have a common background as well as somewhat personal subjective values along the same relative lines. Considering that a highway improvement in a community should meet the expectations and goals of the community, and that individuals and groups in the community often reflect different viewpoints as to what is desirable and what is undesirable, it is likely that judges making a ranking similar to the one described might not gain a high degree of agreement if they represented the viewpoints of the different local groups.

Russell L. Ackoff, "Toward Quantitative Evaluation of Urban Services" (*10-1*)

Ackoff discusses the general subject of evaluating urban services, including transportation. He attempts to develop suitable measures or models by which the relative values can be determined. The author applies his general concepts to transportation and education services. He believes that although much is lacking today in the way of measuring the value of urban utility services as well as other social and economic types of efforts and services, it is likely that over the years considerable improvement will be achieved in methods of measuring these items.

Ackoff states three different kinds of measures of the effectiveness of a service: (1) the amount of input required to obtain a specific output, (2) the amount of output yielded by a specific amount of input, and (3) the difference between the amounts of output and input or the ratio of the two.

Ackoff sums up the basic requirements of his system (*10-1*, p. 97):

> To sum up, in order to provide a quantitative evaluation of a service we must identify the participants, their relevant objectives and the associated inputs and outputs, for each of which a suitable scale should be specified. If

> more than one scale is used, these should be transformed into some one effectiveness scale (usually monetary) and, finally, the utility function of the effectiveness scale should be constructed.

This quotation does not set out something startlingly true, but it does represent good logic. The difficulty of applying this logic, however, is that one does not know how to transform certain of the desirable and undesirable consequences of highway improvement into monetary values. This inability has been the problem from the beginning. Finally, it is most difficult to construct any kind of utility or effectiveness scale for many of the factors involved.

Where a standard goal or a standard criterion can be set forth and described quantitatively, then, of course, a standard of effectiveness can be reached by measuring the degree by which the particular alternative reaches the quantitative size of the particular goal. For instance, how can aesthetic values be described quantitatively or on a scalar device whereby the degree that aesthetic goals are attained could be measured?

Ackoff lists five objectives of a transportation system (*10-1,* p. 103):

1. To minimize cost.
2. To minimize travel time.
3. To minimize harm (i.e., achieve maximum degree of safety).
4. To minimize lost energy (i.e., to permit transportation to be accomplished with a minimum expenditure of human energy).
5. To maximize enjoyment. Enjoyment here includes comfort, convenience, smooth rides, and clear air and other similar personal preference factors.

For these input objectives, Ackoff suggests more or less well-known procedures for scaling the objectives in terms of dollars of cost, applying this scheme to specific cost measures of highways and motor vehicles, to travel time, and to highway safety measures.

For the item of energy dissipated by an individual in achieving his transportation, he suggests experiments to obtain the individual's monetary evaluations of his energy expended in accomplishing a particular activity. This process might be somewhat similar to determining what an individual does pay for travel time reductions when he uses a toll or other market-priced facility. On the other hand, it is highly hypothetical that individuals could arrive at any sort of value to place on the energy whose expenditure they avoid by buying transportation, such as paying for not walking upstairs by riding on an escalator, or paying for not carrying heavy objects from one place to another, or similar types of energy expenditure activities.

Ackoff makes similar suggestions to determine the value of enjoyment with a particular reference to the comfort and convenience items. Here again determining what an individual would pay to achieve certain degrees of comfort and convenience is a most difficult determination.

Ackoff suggests that actual field experimentation be made in connection with transportation systems to find out what people are actually willing to pay to enjoy certain other personal preferences such as minimum energy consumption, maximum enjoyment, comfort and convenience, and similar items. An over-all value of a transportation system is suggested to be measured in man-miles per year or as a unit of production.

Ackoff does not specifically arrive at a method to use in the decision-making choice between alternatives of design, and particularly so with reference to a specific evaluation of certain of the nonuser consequences. He does not propose the use of ranking or rating systems but does propose to reduce everything to a dollar value on the basis of getting the figures that the people would be willing to pay for achievement of certain personal preferences or for the avoidance of certain factors that are distasteful to them.

Ackoff's objective is primarily to determine the value of urban transportation services. It is not directed specifically to the decision-making choice among alternatives that may be available for a transportation system or for an improvement to a facility on an existing system.

U.S. Department of Transportation, Federal Highway Administration, "The Freeway in the City" (*10-38*)

In this book on the general principles of planning and design there is a short description of "Value Methodology" (*10-38,* p. 118).

During the past few years, intensified study has been made of value methodology, the means and possibilities of assigning values to both quantifiable and unquantifiable factors. Although the road-user economic efficiency can be measured in easily quantified terms using the dollar, it is perhaps impossible for intangible costs and benefits to be expressed in dollar units. It is desirable, therefore, to develop some sort of substitute scheme by measuring the relative values of alternative highway improvement proposals that involve cultural, political, ethical, aesthetic, technical, and economic factors.

This book makes a brief statement of the attempts, as disclosed from the literature, to clarify the nature of community needs and environmental objectives with respect to giving them some form of values in connection with choosing alternatives. "All methods hinge upon the assumption that the collective value judgments of the community have been or can be accurately measured and expressed. This is, of course, shaky ground" (*10-38,* p. 119). The report recommends that further research on value methodology should be encouraged (*10-38,* p. 119). In the meantime, the report recommends (*10-38,* p. 119) that

> [T]he most effective system of rating all cost and benefits is one which:
>
> 1. Gives accurate mathematical values to all factors or alternatives (such as land acquisition costs or maintenance costs) to which a cost or benefit can be so assigned.
> 2. Quantifies all other attributes (such as families dislocated, taxable land taken, or new land made accessible).
> 3. Describes through expert opinion those attributes (social, historic, and aesthetic, among others) which can be neither costed nor quantified.

Morris Hill, "A Method for Evaluating Alternative Plans: The Goals-Achievement Matrix Applied to Transportation Plans" (*10-22*)

In Chapter 2, Hill makes the assumption that within the planning process the goals of the community have been identified and ranked and that alternative courses of action to achieve these goals have been identified. The logical next step is the comparative evaluation of the alternative courses of action in order to identify that course of action that in the best way would probably gain the goals of the community. This step, of course, is the cost-benefit analysis or effectiveness analysis type of action.

The goals in public agencies are similar to those included in the cost-benefit analysis of private business. There are differences, however. In the public agency, economic efficiency must concern itself with the allocation of land, labor, and capital, and the most profitable projects are those that are developed to the point where the marginal benefits equal the marginal costs. However, in this particular approach, the costs and benefits often cannot be identified or quantified or be priced on a market basis. Also to be considered are many external economies and diseconomies involved in public works improvements or public programs at large, such as education.

In Chapter 3, Hill presents his general plans for his goals-achievement matrix that is proposed for the evaluation of alternative plans. It is based on a measurement of the achievement of objectives as they are defined for each particular proposal. The total matrix includes the goals (ideals), objectives, and policies. This general concept assumes that the goals of development in a single functional sector of the community have been identified and that the relative value attached to each of the goals by the community also has been established. It is further assumed that the alternative courses of action have been designed to attain the desired end points of the total plan. This particular proposal of the author does not set forth anything really new. It is still the question of evaluating alternative plans for achieving certain objectives in the light of how well the plans achieve the goals. When it is realized that the goals or objectives are often complex and that they are associated with certain diseconomies, or unadvantageous consequences, the crux of the whole thing is still the problem of choosing between (1) different desirable consequences, (2) different undesirable consequences, and (3) desirable consequences and undesirable consequences.

Goals of Highway Investment

The general goals of a highway investment improvement will vary with the particular type of improvement proposed, from the speeding up of traffic at an intersection to the construction of an urban throughway clear across the urban area. Each of these projects would have certain minor goals as well as major goals. It is also to be observed that goals can be stated negatively as well as positively. For instance, goals could be "not to set up barriers that would disrupt neighborhood patterns," or "not to increase air pollution," or "not to add to noise prevalence."

Hill states the following (*10-22*, p. 57):

> Both tangible and intangible consequences should be taken into consideration in the determination of appropriate courses of action . . . These objectives, whether expressed in monetary terms, in quantitative terms, or in qualitative terms, determine the nature of the costs and benefits which should be considered in the evaluation of the plans, how they should be measured, and how they should be recorded.

Hill also states (*10-22*, p. 61):

> In view of all the above, the following approach is recommended for the measurement of tangible consequences and the treatment of intangible consequences in the evaluation of plans. When factors of production are acquired on the open market and are competitively priced, market prices may be used. When products of the public sector are disposed of on the open market in competition with similar products from the private sector, market prices are again a suitable index. When market prices are not a reliable index, e.g., in the case of a public monopoly, and/or in the case of the use of unemployed resources, "shadow pricing" is recommended. When prices are not available, and quantitative effects are evident which cannot be translated into money terms in any meaningful way, then these quantitative effects should be recorded. When quantitative effects cannot be determined, the consequences should be expressed verbally as clearly and precisely as possible. Above all, with respect to any quantification, the analyst should beware of unjustified accuracy. Aristotle's admonition, "Look for precision in each class of things only so far as the nature of the subject admits," is a good guide to follow.

Hill defines "external effects" as follows (*10-22*, p. 62):

> External effects are those effects which cause an individual or group to derive benefits or suffer cost from the provisions of goods or services to another individual or group. As noted above, many of the activities in the public sector are government responsibilities precisely because of the external effects arising from their provision.

Evaluation of Alternatives

In Chapter 5, "The Evaluation of Urban Transportation Plans," Hill presents his basic plan for evaluating the alternatives.

The first step is the identification of the types of goals that might be furthered or might be hindered by transportation improvements. Hill outlines along the following lines:

1. Ideals:
   a. Increase economic welfare.
   b. Improve health and safety levels.
   c. Increase happiness.
   d. Increase social justice.
   e. Other.
2. Objectives:
   a. Reduce air pollution.
   b. Reduce noise.
   c. Reduce unpleasant visual effects.
   d. Reduce rate of accidents.
   e. Increase physical efficiency.
   f. Increase resource use.
   g. Improve project efficiency.
   h. Other.

3. Policies:
   a. Pedestrian-vehicular separation and local traffic separation.
   b. Modes of transportation.
   c. Expressways, arterials, and distributor streets.
   d. Aesthetic design standards.
   e. Planning and landscaping.
   f. Other.

Hill next, by use of a matrix, indicates the general relationships between policies, objectives, and ideals, indicating in his matrix a figure "1" or "0" as to whether there is or is not a direct relationship between policies and objectives on the one hand, and objectives and ideals on the other. The author next takes the objectives and breaks them down into three main areas: (1) those objectives affecting the entire urbanized area, (2) the objectives affecting the immediate environment of the transportation route, and (3) the objectives mainly affecting the user of the transportation facility.

In Chapter 6, "An Exploration of Some Transport Objectives," Hill discusses, in turn, air pollution, noise reduction, and enhancing the visual effects of transportation. The author presents considerable detail to explain the various factors involved in the objectives named and discusses them in terms of their effect on transportation, and then effects on their own value (i.e., the value of the factor with respect to the community).

In Chapter 7 Hill gives brief analyses of other objectives such as open space, preservation of historical sites, reduction of community disruption, increase of comfort and convenience, increase of project efficiency, and increase of resource use. These objectives are described with respect to their character, their quantification, how they may be achieved, and what the highway may do to make the factors less valuable as well as more valuable.

A Case Study—Cambridge, England

Chapter 8 is "A Case Study: The Goals-Achievement Matrix Applied to Transportation Plans for Cambridge, England." In developing the case study, Hill sets forth the particular objectives applying to the improvement being considered for Cambridge, England. He then makes a large matrix table in which vertically the area is divided by types of land use such as that for colleges, residential areas, commercial areas, public buildings, open space, car parking, and transportation facilities. Then horizontally in the matrix table the author lists the factors of objectives such as noise level, air pollution level, unpleasant visual effects, accident rate, and peace of mind. His evaluation then of alternative plans A and B is simply that he enters into the matrix one of the following symbols to indicate the relative values of alternatives A and B with respect to the qualities of objectives listed horizontally across the top and the particular area involved listed vertically:

(=) = The same value, subject only to secular change.
(+) = Increase relative to the secular change.
(−) = Decrease relative to the secular change.
NA = Not applicable.
A > B = A is superior to B with respect to the goal achievement.
A = B = A is equal to B with respect to goal achievement.
A < B = A is inferior to B with respect to goal achievement.
I = No clear outcome.
NC = No change.
E = Considered elsewhere.

Hill then, for each area of land use, summarizes the individual evaluations as to indicating the relative choice of A over B for that land area and for each particular group of objectives.

Measurements of Effectiveness

So far, in its application, this method does not deal with the weighting in any respect of the factors or the alternatives concerned. It is simply an indication, briefly, plus or minus, as to whether Plan A or B is more favorable at a particular location for each specific objective.

It is noted that this system still is subjective as indicating which of the alternative plans, A or B, is preferred with respect to a particular objective. On the other hand, there are instances where the measurement can be made numerically; for instance, in the reduction of access points, in the reduction of facilities for parking, in the removal of people from locations, or in the destruction of businesses or public buildings.

Hill states (*10-22,* p. 276):

> However, although this procedure may facilitate the making of rational decisions, it does not per se enable a decision to be made. The key to making a decision is the relative weighting of the objectives and their incidence of achievement.

The author then admits that the application of his plan depends on subjective weighting of the relative values of the factors included in the list of objectives and an additional weighting of the areas of different land use. No conclusion as to the choice of alternatives A and B can be made as a result of the process set forth by the author until these weights are applied. In applying the weights, the subjective process must again come into play.

In the concept of Hill's plan, there is first the subjective decision made in comparing the locations and the specific objectives as to whether they are equal, or plus, or minus values with respect to each other. A second subjective factor is entered if a weighting system is used with respect to the objectives on the one hand and the land-use classifications on the other. In the last analysis, this particular proposal of Hill's is nothing more than an organized method of comparing the results of different plans for transportation improvements with a set of social and economic and community objectives that describe what the community would like to reach in the way of short-term and long-term goals. The degree to which A and B reach these objectives or serve them is a matter of subjective judgment more often than it is not. Furthermore, not all objectives would have equal weight to the people of the community. They must have some sort of a preference scale as between objectives.

Therefore, when a weighting scale is introduced, further subjective factors are included.

In Chapter 9, "Conclusion," Hill states (*10-22*, p. 300):

> We have shown that by determining the objectives of transportation plans, by employing measures for the achievement of these objectives, by the alternative plans proposed and by the application of a weighting system, it is possible to decide which plan best serves the set of objectives. In this way we are able to apply a method of plan evaluation which is consistent with the rational planning model that is described in the first chapter.

Summary Evaluation of Hill's Plan

Based on his ranking, Hill's plan indicates which of the alternatives better serves the objectives of the community. On the other hand, it is to be remembered that his determination is a product of personal subjective evaluation with or without weighting the relative desirabilities of the various items within the over-all list of objectives. One good feature of Hill's goals-achievement matrix is that, for a transportation system serving an area or for a route serving some distance, he breaks the land use into different classes so that each land-use area can be considered separately.

Hill states (*10-22*, p. 304):

> The key to decision-making by means of the goals-achievement matrix is the weighting of objectives, activities, locations, groups or sectors in urban areas. By the application of relative weights, we have shown that it is possible to arrive at a definite conclusion. We have also shown that by changing relative weights, one can arrive at an entirely different conclusion.

The author states plainly that the weighting of the different factors involved in the analysis is the key that controls the ultimate conclusion to be drawn from the analysis. Therefore, because the weighting process has to be a subjective process, this total process gets right back to the situation at the beginning. In other words, the decision maker has a decision to make and he must make it on his own subjective basis. Perhaps the goals-achievement matrix such as Hill suggests would help the decision maker reach a conclusion, but it certainly does not give him any specific aid as to determining what factors should be given more weight than other factors in his decision.

This dissertation is a good discussion of the problem of decision making in transportation. Hill brings into vision the road-user and nonroad-user factors and tries to present them in an understanding way to give a good picture of the complexities involved. His goals-achievement matrix is a plan that might result in a good working tool for the decision maker to have handy, provided he realizes that if other persons fill out the matrix table for him it is their subjective judgment that results in the plus and minus and equal signs. If the decision maker fills it out himself, it might help him visualize his own attitude toward the problem of decision. In the end, use of Hill's plan might lead to a decision on a little sounder basis as far as the decision maker individually would be concerned.

Hill's thesis has been published in brief form as "A Goals-Achievement Matrix for Evaluating Alternative Plans," *J. American Institute of Planners,* Vol. 34, No. 1 (Jan. 1968) pp. 19-29. See also Morris Hill, "A Method for the Evaluation of Transportation Plans," *Highway Res. Record No. 180* (1967) pp. 21-34.

Washington State University, College of Engineering, Research Division, "A Study of the Social, Economic and Environmental Impact of Highway Transportation Facilities on Urban Communities" (*10-41*)

Two features of the Washington State University publication make this a good report for those interested in the economic and social consequences of highway improvements in urban areas, with particular reference to the final decision process in selecting the alternative route and features of engineering design. The forepart of the report dwells in considerable detail and in an authoritative manner on the over-all philosophy, standards, and factors that are considered in urban transportation planning, with particular reference to route selection and highway design. The second feature of importance is the ranking and rating system proposed, not that this system is especially desirable, but the accompanying discussion sheds much light on the problem and the process of final decision making on urban transportation improvements.

The report lists 14 area divisions of the city (*10-41*, p. 83), or they might be considered segments of the route described by the land-use areas along the route. Each of these areas is discussed with reference to how the area might be affected by the urban freeway. Generally, each of these areas is summarized by a brief rating scheme such as that given in Table 20. This rating scheme varies somewhat in its application to the different land areas considered.

Rating Scale for Route Selection

A rating scale for route selection is discussed (*10-41*, p. 131). The introductory material points out that a rating scale that merely selects a route regardless of the treatment of the highway and the areas it traverses would be worthless. There is an attempt in the rating and in the discussion to tie the highway's environment and its physical aspects together to form a complete unit of transportation considering all of the social and economic factors involved. This consideration is a step into systems analysis. The rating is tied to the listing of location standards given in the report. These standards represent aspects of the highway design that should be considered. The standards do not necessarily pertain solely to highway design. Perhaps a better wording would be that these itemized statements of goals or principles of designs are guideposts that should be followed in locating the highway.

The rating is made on the basis of 0 to 10 and is applied to each section of the route according to specific land-use development. Generally, the report gives what would be considered as the worst case under a particular factor and the best case. The inference is that the worst case would receive the lowest possible score and the best case could receive the highest possible score.

There is also provision for weighting of the rating according to some standard of relative weights between the different factors that receive individual ratings. This process is given in Table 21.

TABLE 20

RATING SCHEME FOR LAND-USE AREAS ALONG HIGHWAY ROUTE [a]

SCALE:	Is the type of freeway chosen dominant?		
	How is it dominant?	By width	
		By height	
		By support system	
	What action will be taken?	Isolation by distance or by the use of a tunnel	
		Isolation by objects, man-man or natural	
		Appropriate development of the character of the space by the road	
	Will a good scale relationship be achieved by the action taken?		Rating:________
NOISE:	Is the noise from the freeway objectionable?		
	How is it objectionable?	Because the road is very close	
		Because of changes in grade	
	What action will be taken?	Isolation by distance or by the use of a tunnel	
		Isolation by a barrier	
	Will the noise be reduced to an acceptable level by the action taken?		Rating:________
BARRIER:	Is a visual barrier created?		
	How is it created?	By the support system and the nature of the space under the road.	
		By the width of the visible road surface.	
	What action will be taken?	The selection of an appropriate support system	
		The development of a suitable pattern on the underside of an elevated freeway	
		The development of planes related to the support system	
		The provision of continuity of ground under elevated freeways	
		The creation of long controlled views through and over	
	Will the action taken reduce the barrier effect to the minimum?		Rating:________
CHANGE:	Does the freeway create opportunity for constructive change?		
		As a neighborhood spine	
		In the development of well landscaped open space	
		In the development of space for activities	
		In other ways	Rating:________
LOCATION:	Should the freeway be here at all?		Rating:________

[a] Source: (*10-41*, p. 105).

The five major guides (each with subdivisions) for rating the route location are:

1. The freeway as a part of a city plan (Table 21).
2. Continuity and fit to the whole city.
3. Respects for "sacred" areas.
4. The driver's experience of the city.
5. The effect of the freeway on the environment.

Rating Scale for Social Impact

Social impact is discussed (*10-41*, p. 139), which leads to a rating scale (*10-41*, p. 163). Table 22 indicates the social elements considered and the central value assigned to each. The grand total of central values is 100.0.

These central values indicate a relative weighting of the value of the factors listed. They could be applied to the factors in a city at any existing time and then could be used as a basis of ultimate weighting of the changes, plus or minus, to be experienced through the building of an urban freeway or other highway improvement.

Rating of Economic Factors

The third main rating is of the economic considerations. The main summary table (*10-41*, p. 173) is reproduced as Table 23.

An important feature of this rating is the separation into three future time periods, with the heaviest weight being given to the 0- to 5-year time period, because of its higher discounted present value. It would also be logical to divide the social factors into future time periods, because many immediate social hardships would not be lasting consequences.

Desirability Rating of Route Alternatives

A desirability rating is described (*10-41*, p. 178). This rating is an attempt to prepare for the decision maker some sort of a summary and specific rating for the alternative routings. The rating is divided into three separate ratings: Form A, For Appearance Considerations: Form S, For Sociological Considerations; and Form E, For Neighborhood Economic Considerations. These three forms appear as Tables 24, 25, and 26.

The ratings are given for three time periods covering a total of 50 years. The first period is for the first five years; the second, 6 to 25 years; and the third, 26 to 50 years. The desirability or advantage of any proposed highway route

TABLE 21

RATING AND WEIGHTING SYSTEM FOR FACTORS OF THE ROUTE PLANS [a]

5. The Freeway as Part of a City Plan	L.1, 3, 5, 10
A. Respect for City Plan	Rating________ Weight________
Worst Case: The route is chosen in a way which conflicts with long-range planning proposals for the city.	
Best Case: It is part of a comprehensive plan for the whole area.	
B. Integration with Other Transportation Systems	L.2
Worst Case: The route is chosen on its own without relation to other systems.	Rating________ Weight________
Best Case: The route is part of an overall plan which includes mass transit systems and planning to reduce peak hour use of freeways.	
C. Integration of the Freeway with Architecture	D.3,4
Worst Case: The freeway simply cuts its way through buildings.	Rating________ Weight________
Best Case: It forms the core of new groups of buildings conforming both to the scale of the freeway and to the human scale.	
D. Integration of the Freeway with a System of Parks and Open Spaces	L.4
Worst Case: Landscaping on the freeway is purely ornamental.	Rating________ Weight________
Best Case: A coordinated system of landscaping in depth relates to the freeway and the city.	
E. Planning for Expansion and Control over Setback Area	L.9, 24
Worst Case: A limited right-of-way does not allow for expansion or proper treatment of setback area.	Rating________ Weight________
Best Case: A wide right-of-way is acquired to protect the urban areas and allow for expansion.	

[a] Source: (*10-41*, p. 133).

with regard to the considerations listed is not necessarily the same throughout the entire life. Therefore, the ratings for three different periods help to give more precise consideration to the time value of the consequences. The three ratings are weighted in their relative importance or significance as shown on the form. A route may be desirable with regard to its effect on the value of residential property, but the over-all significance of this effect may be small. The rating system then provides an additional measure to separate the highly desirable from the moderately or lightly desirable consequences.

This rating scheme seems to resolve itself into two subjective determinations: (1) a desirability rating on the basis of 1 to 10, and (2) a weighting factor presumably on the same basis of 1 to 10. When multiplied, the two factors give the weighted rating of that particular economic or social factor for that particular route alternative and its particular length section. This procedure appears to be a little complicated, and, in the end, when all the ratings and weights are combined, it is uncertain just what the result represents. This, of course, is one of the fundamental objections to rating systems, because they are so subjective in character and often, when the ratings are combined, the composite rating is more or less a meaningless, quantitative abstract value.

Table 27 gives summary Form C for the ratings and introduces a table for route comparison, Form R.

A final Form D is presented to represent a ratio of desire divided by cost. See Table 28.

Over-all Evaluation of the Washington State University Scheme

A general comment on the total rating system presented in this publication is that it is complex, hard to understand, and, in the end, does nothing more than record the subjective measures of whoever performs the rating. There are few guides that can be followed to achieve consistency in rating between individuals.

Some of the merits, however, of the total system are that the author: (1) starts out with a consideration of separate land uses, (2) separates the entire route into sections according to land uses or area development, (3) exposes the reader to the large number of social and economic factors as well as the highway engineering factors involved, and (4) in the end in some way or another brings all these factors into some form of relationship. The total job indi-

TABLE 23

ROUTE RATING FORM E-1—NEIGHBORHOOD ECONOMIC CONSIDERATIONS ATTRIBUTABLE TO ROUTE SELECTION [a]

Route .... Section .... From .... to ....

Item Code	Item Affected	Desirability Rating (1-10) (1)	Relative Importance Weighting (Base 10.0) (2)	Desirability Weighted By Importance (Col. 1 x 2) (3)	Time-Period Weighting (Base 10.0) (4)	Combined Desirability Importance Time-Period Weighted-Rating (5)
	0 - 5 Year Time Period					
E - 1	Residential Property Values	6	1.0	6.0	6.0	36.0
E - 2	Residential Relocation	4	0.7	2.8	6.0	16.8
E - 3	Business Property Values	7	1.6	11.2	6.0	67.2
E - 4	Business Site Development	7	1.8	12.6	6.0	75.6
E - 5	Commercial Relocation	5	1.1	5.5	6.0	33.0
E - 6	Opening New Markets	5	1.3	6.5	6.0	39.0
E - 7	Service to Employment Centers	6	0.5	3.0	6.0	18.0
E - 8	Service to Shopping Centers	6	0.5	3.0	6.0	18.0
E - 9	Service to: Churches, Clubs, Recreation and Community Services	7	0.7	4.9	6.0	29.4
E - 10	Relocation of Churches, Clubs, Recreation and Community Services	5	0.8	4.0	6.0	24.0
	Total	**58**	**10.0**	**59.5**	**6.0**	**357.0**
	6 - 25 Year Time Period					
E - 1	Residential Property Values	7	1.2	8.4	3.2	26.9
E - 2	Residential Relocation	5	0.3	1.5	3.2	4.8
E - 3	Business Property Values	8	1.7	13.6	3.2	43.5
E - 4	Business Site Development	8	1.9	15.2	3.2	48.7
E - 5	Commercial Relocation	5	0.7	3.5	3.2	11.2
E - 6	Opening New Markets	5	1.5	7.5	3.2	24.0
E - 7	Service to Employment Centers	7	0.7	4.9	3.2	15.7
E - 8	Service to Shopping Centers	7	0.6	4.2	3.2	13.4
E - 9	Service to: Churches, Clubs, Recreation and Community Services	8	0.9	7.2	3.2	23.0
E - 10	Relocation of Churches, Clubs, Recreation and Community Services	5	0.5	2.5	3.2	8.0
	Total	**65**	**10.0**	**68.5**	**3.2**	**219.2**
	26 - 50 Year Time Period					
E - 1	Residential Property Values	8	1.4	11.2	0.8	9.0
E - 2	Residential Relocation	5	0.1	0.5	0.8	0.4
E - 3	Business Property Values	8	1.9	15.2	0.8	12.2
E - 4	Business Site Development	9	2.0	18.0	0.8	14.4
E - 5	Commercial Relocation	5	0.1	0.5	0.8	0.4
E - 6	Opening New Markets	5	1.6	8.0	0.8	6.4
E - 7	Service to Employment Centers	8	0.8	6.4	0.8	5.1
E - 8	Service to Shopping Centers	8	0.8	6.4	0.8	5.1
E - 9	Service to: Churches, Clubs, Recreation and Community Services	8	1.2	9.6	0.8	7.7
E - 10	Relocation of Churches, Clubs, Recreation and Community Services	5	0.1	0.5	0.8	0.4
	Total	**69**	**10.0**	**76.3**	**0.8**	**61.1**
	Section Total (3 Time Periods)	**192**	**---**	**204.3**	**10.0**	**637.3***
	* Equals Section Weighted Score					

[a] Source: (*10-41*, p. 166).

TABLE 22

FORM S-1—SOCIAL HIGHWAY IMPACT RATING SCALE[a]

Social Highway Impact	Central Value	Desirable Impact	Undesirable Impact	Total Impact Value
	(1)	(2)	(3)	(4)
A. Inter-Metropolitan	26.4			
1. Wholesale Trade Area	(8.2)			
a. Volume Expand (2) Decrease (3)	1.9			
b. Trade Area Superordinate (2) Subordinate (3)	3.6			
c. Centralize Trade (2) Bypass Trade (3)	2.7			
2. Regional Dominance	(9.9)			
a. Cultural Dominance (2) Subservience (3)	4.5			
b. Functional Dominance (2) Subservience (3)	2.7			
c. Specialized Functions, Increase (2) Decrease (3)	2.7			
3. Communication and Transportation	(8.3)			
a. Major Economic Goods Increase (2) Decrease (3)	1.9			
b. Cultural Integrative Increase (2) Decrease (3)	4.5			
c. Administrative and Functional Headquarters Increase (2) Decrease (3)	1.9			

Social Highway Impact	Central Value	Desirable Impact	Undesirable Impact	Total Impact Value
	(1)	(2)	(3)	(4)
B. Intra-Metropolitan				
i. Metro Area	24.6			
1. Relationships Between Social Areas	(9.9)			
a. Style of Life Increase (2) Decrease (3)	3.6			
b. One Style of Life Diffuse (2) Only (3)	3.6			
c. Selective Avoidance No (2) Yes (3)	2.7			
2. One Social Area Only	(8.1)			
a. Deprivation No. (2) Yes (3)	2.7			
b. Low Resistance No (2) Yes (3)	2.7			
c. A Priori Rationalization No (2) Yes (3)	2.7			
3. Social Attributes of Metro Area	(6.6)			
a. Destruction No (2) Yes (3)	1.9			
b. Changing Balance Between Areas No (2) Yes (3)	2.8			
c. Eliminate Central Areas Information Functional No (2) Yes (3)	1.9			

Social Highway Impact	Central Value	Desirable Impact	Undesirable Impact	Total Impact Value
	(1)	(2)	(3)	(4)
ii. Metro Community	24.3			
1. Change in Members	(13.5)			
a. Social Intimacy				
Increase (2)	4.5			
Decrease (3)				
b. Dislocation				
Very High (2)	4.5			
Very Low (3)				
c. Selected Communities				
Low (2)	4.5			
High (3)				
2. Community Attributes	(10.8)			
a. Functional for Social Intimacy				
Very High (2)	3.6			
Very Low (3)				
b. Day to Day Importance				
No (2)	2.7			
Yes (3)				
c. Integrative Foci				
No (2)	4.5			
Yes (3)				
iii. Urban Man	24.7			
1. Semi-Permanent Settlement	(8.2)			
a. Individual and Family				
No (2)	3.6			
Yes (3)				
b. Interaction Patterns of Individual				
No (2)	2.7			
Yes (3)				
c. Style of Life				
No. (2)	1.9			
Yes (3)				
2. Individuals with Low Rates of Adjustment and Survival	(8.3)			
a. Eliminating Metro-community				
No (2)	4.5			
Yes (3)				
b. Decreasing Reestablishment Certain Types Metrocommunities				
No (2)	1.9			
Yes (3)				
c. Education to Successful Resistance				
No (2)	1.9			
Yes (3)				
3. Interaction Between Individuals	(8.2)			
a. Residential Segregation				
Decrease (2)	3.6			
Increase (3)				
b. Alternate Possibilities Style of Life				
No (2)	1.9			
Yes (3)				
c. Eliminating Successful Adjustment				
No (2)	2.7			
Yes (3)				

[a] Source: (*10-41*, p. 173).

TABLE 24

ROUTE RATING FORM A—APPEARANCE CONSIDERATIONS[a]

(1) Considerations	(2) 0-5 Yr. Period			(3) 6-25 Yr. Period			(4) 26-50 Yr. Period			(5)
	Desirability Rating 1-10	Weight Factor	Weighted Rating	Desirability Rating 1-10	Weight Factor	Weighted Rating	Desirability Rating 1-10	Weight Factor	Weighted Rating	Combined 50-Year Weighted Rating
Route Length from										
Local or Sectional:	8	4	32	8	2.5	20.0	......	0		52.0
A-1 Scale Relationship	5	1	5	5	1.0	5.0	......	0		10.0
A-2 Noise Factor	6	2	12	8	1.3	10.4	......	0		22.4
A-3 Barrier Factor	8	3	24	8	2.2	17.6	......	0		41.6
A-4 Changes in Area										
Route Total:										
A-5 City Planning	5	6	30	5	8	40	5	4	20	90.0
A-6 Continuity & Fit to the Entire City	9	4	36	8	4	32	......	0		68.0
A-7 Respect for Sacred Areas	8	5	40	8	5	40	......	0		80.0
A-8 Driver's Experience of the City	9	2	18	9	2	18	......	0		36.0
Section # to										
Total Section Rating										400.0
Relative Section Rating 400/5.70										70

[a] Source: (*10-41*, p. 181).

TABLE 25

ROUTE RATING FORM S—SOCIOLOGICAL CONSIDERATIONS[a]

Route from
Length
Section #
to

(1) Considerations	(2) 0-5 Yr. Period			(3) 6-25 Yr. Period			(4) 26-50 Yr. Period			(5)
	Desirability Rating 1-10	Weight Factor	Weighted Rating	Desirability Rating 1-10	Weight Factor	Weighted Rating	Desirability Rating 1-10	Weight Factor	Weighted Rating	Combined 50-Year Weighted Rating
Inter-Metropolitan Effects										
S- 1 Wholesale Trade Area	5	1.8	9.0	5	.9	4.5				13.5
S- 2 Regional Dominance	5	2.2	11.0	5	1.1	5.5				16.5
S- 3 Communication & Transportation	5	1.8	9.0	5	.9	4.5				13.5
Intra-Metropolitan Effects										
S- 4 Relationship Among Social Areas	6	2.2	13.2	8	1.1	8.8				22.0
S- 5 One Social Area Only	7	1.8	12.6	8	.9	7.2				19.8
S- 6 Social Attributes of Metro Area	6	1.4	8.4	8	.7	5.6				14.0
Metro Community Effects										
S- 7 Changes in Members	8	3.0	24.0	8	1.5	12.0				36.0
S- 8 Community Attributes	7	2.4	16.8	7	1.2	8.4				25.2
Effects on Urban Man										
S- 9 Semi-Permanent Settlement	2	1.8	3.6	3	.9	2.7				6.3
S-10 Rates of Adjustment & Survival	3	1.8	5.4	4	.9	3.6				9.0
S-11 Interaction Among Individuals	3	1.8	5.4	4	.9	3.6				9.0
Total Section Rating										**184.8**
Relative Section Rating 184.8/3.30										**56**

[a] Source: (*10-41*, p. 183)

TABLE 26

ROUTE RATING FORM E—NEIGHBORHOOD ECONOMIC CONSIDERATIONS [a]

Route Length from

(1) Considerations	(2) 0-5 Yr. Period: Desirability Rating 1-10	(2) 0-5 Yr. Period: Weight Factor	(2) 0-5 Yr. Period: Weighted Rating	(3) 6-25 Yr. Period: Desirability Rating 1-10	(3) 6-25 Yr. Period: Weight Factor	(3) 6-25 Yr. Period: Weighted Rating	(4) 26-50 Yr. Period: Desirability Rating 1-10	(4) 26-50 Yr. Period: Weight Factor	(4) 26-50 Yr. Period: Weighted Rating	(5) Combined 50-Year Weighted Rating
E- 1 Residential Property Values	6	6.0	36.0	7	3.84	26.9	8	1.12	9.0	71.9
E- 2 Residential Relocation	4	4.2	16.8	5	.96	4.8	5	.08	0.4	22.0
E- 3 Business Property Values	7	9.6	67.2	8	5.44	43.5	8	1.52	12.2	122.9
E- 4 Business Site Development	7	10.8	75.6	8	6.08	48.7	9	1.60	14.4	138.7
E- 5 Commercial Relocation	5	6.6	33.0	5	2.24	11.2	5	.08	0.4	44.6
E- 6 Opening New Markets	5	7.8	39.0	5	4.80	24.0	5	1.28	6.4	69.4
E- 7 Service to Employment Centers	6	3.0	18.0	7	2.24	15.7	8	.64	5.1	38.8
E- 8 Service to Shopping Centers	6	3.0	18.0	7	1.92	13.4	8	.64	5.1	36.5
E- 9 Service to: Churches, Clubs, Recreation and Community Services	7	4.2	29.4	8	2.88	23.0	8	.96	7.7	60.1
E-10 Relocation of Churches, Clubs, Recreation and Community Services	5	4.8	24.0	5	1.60	8.0	5	.08	0.4	32.4
Total Section Rating										637.3
Relative Section Rating 637.3/10										64

Section # to

[a] Source: (*10-41*, p. 185).

TABLE 27

RATING CALCULATION FORM C, ROUTE ________, AND ROUTE COMPARISON FORM R[a]

For Appearance Rating			
Section	Length of Section as % of Route Length	Relative Section Appearance Rating	Length Times Rating

Total Route Appearance Rating

For Sociological Rating			
Section	Length of Section as % of Route Length	Relative Section Sociological Rating	Length Times Rating

Total Route Sociological Rating

For Neighborhood Economic Rating			
Section	Length of Section as % of Route Length	Relative Section Neighborhood Economic Rating	Length Times Rating

Total Route Neighborhood Economic Rating

ROUTE COMPARISON FORM R

Considerations	Alternate Routes A	Alternate Routes B	Basic Condition
FixedValue Considerations:			
R- 1 Funds Available			
R- 2 Completion Date			
R- 3 Legality			
Monetary Considerations:			
R- 4 Construction Cost			
R- 5 Annual Maintenance Cost			
R- 6 Annual Vehicle Operating Cost			
R- 7 Travel Time Cost			
R- 8 Accident Costs			
R- 9 Vehicle-Mile Cost			
R-10 Benefit-Cost Ratio			
Desirability Considerations:			
R-11 Appearance Rating			
R-12 Sociological Rating			
R-13 Neighborhood Economic Rating			
R-14 Institutions or Prohibitions	DNA PC DTM	DNA PC DTM	DNA

Explanation:

DNA = Does not apply
PC = Prohibitive consideration
DTM = Design to Minimize

[a] Source: (*10-41*, p. 186).

cates many of the dangers that are inherent in any subjective rating system, particularly when one is trying to choose between social factors, economic factors, and transportation factors which of themselves are quite different in nature and in values.

Southeastern Wisconsin Regional Planning Commission, "Land Use Transportation Study—Forecast and Alternative Plans 1990" (*10-44*)

The study recognizes the difficulty in combining the results of the ordinary cost-benefit analysis, using the road-user approach that ends in a numerical answer of a cost/benefit ratio or rate of return, with the general social and economic consequences of transportation improvements. The two cannot be added or otherwise conveniently merged. The Southeastern Wisconsin Regional Planning Commission (SEWRPC) therefore turns to other schemes by which to evaluate their alternative plans for transportation for their seven-county region.

The method used is the "rank-based expected value" method. This method has been used in corporate and military decision making, and the prime reference is Ansoff (*10-2*).

The rank-based expected value method uses basically a system of ranking the different factors in order of their preferences, then assigning to them weighted values on a direct reverse listing of their numerical preference rank. The advantages of the ranking method are that it is generally much easier and a more sound procedure to rank different factors or rank different objectives in the order of their preference than it is to assign to them a definite weighted value or to assign to them a monetary value, either in the form of a benefit or in the form of a cost. This rank-based expected value method avoids these difficult decisions. But the method does call for a ranking of the methods by subjective judgment. Also, the objectives have to be ranked, as do the alternative plans of achieving the objectives.

The assigning of weighted values to the ranking equal to the reverse order of the ranking is arbitrary rather than objective. As a matter of fact, the method could be applied with equally appropriate results without assigning the ranking value factor. Basically, the method provides for listing the objectives to be achieved by the transportation or highway facility under study for improvement whether it be on a project basis, a route basis, a system basis, or a total transportation area basis. These objectives in the end have to be weighted as to their relative importance. This weighting is a second subjective decision. Within each major objective there is next listed the standards by which the achievement of each different transportation plan is measured with respect to the degree that the objective is achieved. Thus, each alternative transportation plan is ultimately ranked on the basis of these standards, or measures, of achievement toward the objectives set forth for the system or project in total.

A special probability factor was included in the method by the SEWRPC. This special feature is a probability factor assigned to each one of the transportation system plans, or alternatives, to indicate the relative probability of the plan being implemented. The probability factor is so assigned that the alternative plan having the highest probability of being implemented receives the highest score, and, in the end, the total system of evaluation is based on numerical factors, the highest numerical value indicating the plan of preferred acceptance. The lowest value is the plan having the least value or least acceptance when viewed in its potential of achieving the objectives set forth.

Step by Step Procedure

The procedure in applying this rank-based value system of evaluation of alternatives is described in the following steps:

1. Step 1.—Prepare a list of the specific development objectives that the proposed facility is expected to achieve. In the Wisconsin example, two sets of objectives were set forth—the first set related solely to the transportation system plan, and the second set related solely to the land-use plan. Each of these sets of objectives was analyzed separately.
2. Step 2.—Prepare a list of specific standards by which to measure the relative attainment of the objectives by each of the alternative transportation plans. Here again, if the total objectives are in two lists—(1) the transportation system plan, and (2) the land-use plan—there will be a set of measurement standards for each of these two sets of objectives.
3. Step 3.—The specific objectives are assigned preference rank numbers from 1 upward. These preference rank order numbers for the specific development of objectives are in turn assigned rank order values equal to the reversed order of their preference numbers.
4. Step 4.—For each of the development objectives the individual standards are also ranked from 1 upward according to the order of preference of these particular standards. In turn then, this ranking of the standards is assigned rank order values in the reverse order of the preference ranking. See Table 29 for this order.
5. Step 5.—Rate each of the alternative improvement plans against each of the standards, assigning to each improvement plan and to each standard a value representing the degree to which the improvement plan achieves the objective based on the particular standard being used as a measuring device. Any desirable rating value system can be used for this step. The SEWRPC used a maximum value of 3 and assigned this value of 3 to each plan that achieved the particular standard. If the standard was only partially met, a value of 2 was assigned, and if the standard was not met by community or other efforts, a value of 1 was assigned. See Table 29 (columns 4, 5, and 6) as an illustration, where the value scale ranges from a top value of 5 to a low value of 1.
6. Step 6.—After the value achievement index is assigned to each individual improvement plan for each standard under each objective, the rating is calculated for the final comparison of the alternatives for each objective. This rating is accomplished by multiplying the rank order value of each of the standards against the weighted value assigned to the improvement plan alternatives as indicated. In Table 29, this is simply a multiplication of column (3) in turn times columns (4), (5), and (6). The sum of these

TABLE 28

FORM D—DESIRE/COST RATIO [a]

1	2	3		4		5		6	
		Route A		Route B		Route C		Combined	
Costs (in thousands)	Rel. Wgt.	Numerical Value	Percentage	Numerical Value	Percentage	Numerical Value	Percentage	Numerical Value	Percentage
1. Annual Construction	XX	494	XXX	406	XXX	0	XXX	900	XXX
2. Annual Maintenance and Operation	XX	25	XXX	21	XXX	58	XXX	104	XXX
3. Totals	XX	519	51.7	427	42.6	58	5.7	1004	100.0
Desirability Ratings									
4. Appearance	1	69	XXX	60	XXX	10	XXX	139	XXX
5. Sociological	1	88	XXX	70	XXX	90	XXX	248	XXX
6. Neighborhood Economic	1	69	XXX	75	XXX	50	XXX	194	XXX
7. Totals	XX	226	38.9	205	35.3	150	25.8	581	100.0
8. Desire/Cost Ratio	XX	XXX	.752	XXX	.828	XXX	4.526	XXX	XXX
9. D/C Ratio Weighted	1	XXX	.752	XXX	.828	XXX	4.526	XXX	XXX
10. Benefit/Cost Ratio	XX	XXX	1.250	XXX	1.600	XXX	1.000	XXX	XXX
11. B/C Ratio Weighted	1	XXX	1.250	XXX	1.600	XXX	1.000	XXX	XXX
12. Feasibility Ratio	XX	XXX	2.002	XXX	2.428	XXX	5.526	XXX	XXX

[a] Source: (*10-41*, p. 191).

cross multiplications is added to produce the total at the bottom of the columns, which total represents the grand plan value (V_{po}) of each of the alternative improvement plans. Because the standards are ranked with the highest value number (5) for the No. 1 preference and because the achievement of the alternative plan in reaching the objective is also given a high number (5) for the one that has the highest achievement, the summation total (P_{po}) of the columns (4), (5), and (6) in Table 29 means that the high number represents the highest preference among the alternative plans. These numbers are then assigned a rank order value (V_{or}) with the first rank being assigned a No. 3 in case of three alternative plans, or a No. 5 in case five alternative plans are being evaluated.

7. Step 7.—The rank orders (V_{or}) at the bottom of Table 29 are transferred to Table 30 where it is seen that each of the specific objectives (five in this particular example) are assigned their rank order values of 5, 4, 3, 2, 1.

8. Step 8.—Determine the probability of implementation of each of the plans being evaluated and assign this decimal value to each alternative as indicated in Table 30.

9. Step 9.—The main field of Table 30 contains the rank order values transferred from Table 29. These rank order values are next multiplied by the rank order value of each objective as given in Table 30, and then by the probability coefficient indicated for each of the alternative plans, A, B, and C. The sums of these multiplications are then carried to the bottom of Table 30. These final values represent the evaluation of the specific alternative transportation plans against their achievement of the objectives. The order of preference is from the highest plan value to the lowest. In this particular instance plan A with a score of 19.5 is indicated as the alternative plan of first choice.

Also indicated at the bottom of Table 30 is the plan value score for each plan alternative, A, B, and C (39, 23, 28), omitting the probability factor. It is seen that the probability factor has a heavy effect on the final ranking of the plans, provided, of course, that there is some spread in the probability factors.

Summary Discussion of the SEWRPC Method

As must be the case in this type of evaluation scheme, considerable amount of subjective judgment is involved. First, the plan objectives themselves are ranked in the order of their preference. Again, the standards against which the achievement of the objective is measured are subjectively ranked. The third subjective measurement is that represented by the weighted score given each alterntive to indicate the degree to which that particular alternative plan reaches that particular standard under each objective. Not counting the probability of implementation coefficient, the total system then involves two specific subjective rankings and one weighted score that can also be interpreted as one form of subjective ranking.

The final result, however, gives a good indication of the relative value of the different alternative plans of reaching the over-all transportation objectives, but it must be understood that the final result is controlled by the three subjective ratings or rankings involved in the total process.

A comment should be made on the implementation

TABLE 29

CALCULATION OF RANK ORDER VALUES FOR EACH PLAN ALTERNATIVE FOR EACH OBJECTIVE—TRANSPORTATION DEVELOPMENT PLAN [a]

STANDARDS SUPPORTING THE OBJECTIVE			DEGREE [b] TO WHICH EACH ALTERNATIVE PLAN REACHES THE OBJECTIVES AS MEASURED IN TERMS THAT THE SUPPORTING STANDARDS ARE MET		
			ALTERNATIVE TRANSPORTATION PLAN		
PREFERENCE ORDER NO., P_o (1)	DESCRIPTION OF STANDARD (2)	RANK ORDER VALUE, V_o (3)	A (4)	B (5)	C (6)
	(*a*) OBJECTIVE NO. 1. An Integrated and Balanced Transportation System Serving the Land-Use Plan				
1	Residential land	5	4	4	3
	a. Low density	—	5	5	3
	b. Medium density	—	5	3	4
	c. High density	—	3	3	2
	d. Adequate level of service	—	4	4	4
2	Park and recreation land and open space	4	5	3	5
3	Commercial land	3	4	3	3
4	Government and institutional land	2	4	3	5
5	Industrial land	1	2	4	3
Plan value for each objective, V_{po}			62	51	57
Preference rank order based on plan value, V_{po}, P_o			1	3	2
Rank order value by objective, V_{or} (transferred to Table 30)			3	1	2
	(*b*) OBJECTIVE NO. 2. Maximum Improvement in Traffic Flow and Safety				
1	Minimize vehicle-hours of travel	3	5	4	4
2	Maximum percentage of total travel on high-capacity facilities	2	4	4	5
3	Maximum percentage of total travel on facilities of lowest accident potential	1	5	4	5
Plan value for each objective, V_o			28	24	27
Preference rank based on plan value, V_{po}, P_o			1	3	2
Rank order value by objective, V_{or} (transferred to Table 30)			3	1	2
	(*c*) OBJECTIVE NO. 3. Minimum Disruption of Desirable Existing Community Developments and Programs				
1	Maximum reservation of right-of-way	5	5	5	5
2	Minimum disruption of neighborhoods	4	4	4	5
3	Minimum relocations of people and business	3	4	5	4
4	Minimum penetration of environmental corridors	2	3	4	3
5	Minimum removal of cultural sites	1	3	3	3
Plan value for each objective, V_o			62	67	64
Preference rank based on plan value, V_{po}, P_o			3	1	2
Rank order value by objective, V_{or} (transferred to Table 30)			1	3	2
	(*d*) OBJECTIVE NO. 4. Maximum Aesthetic Quality and Visual Satisfactions				
1	Compatible geometric standards, landscapes, and area harmony	3	5	4	3
2	Maximum preservation of natural beauty and blending of design with environment	2	4	4	4
3	Minimize undesirable social effects, pollution, noise	1	4	3	4
Plan value for each objective, V_o			27	23	21
Preference rank based on plan value, V_{po}, P_o			1	2	3
Rank order value by objective, V_{or} (transferred to Table 30)			3	2	1
	(*e*) OBJECTIVE NO. 5. An Economical and Efficient Transportation System				
1	Minimize total transportation cost	3	5	3	5
2	Minimize total vehicle-miles and person-miles of travel	2	4	4	3
3	Maximum use of existing facilities	1	3	5	4
Plan value for each objective, V_o			26	22	25
Preference rank based on plan value, V_{po}, P_o			1	3	2
Rank order value by objective, V_{or} (transferred to Table 30)			3	1	2

[a] Source: Patterned after SEWRPC Table A-29 (*10-44*, p. 240), but all objectives, ranks, and values are hypothetical.

[b] The degree to which a standard is met is measured by the following scheme:
5 = fully meets the standard;
4 = standard substantially or 50 to 80 percent met;
3 = standard 10 to 50 percent met;
2 = standard could be met through community or private planning;
1 = standard cannot be met.
The SEWRPC used a scale of 3 for fully meeting the standard, 2 for partially meeting the standard, and 1 when the standard could be met by community or private planning effort.

TABLE 30

CALCULATION OF OVER-ALL PREFERENCE RANKING OF THE ALTERNATIVES

DEVELOPMENT OR PROJECT OBJECTIVE					
PREFERENCE ORDER NO., P_o (1)	BRIEF TITLE OF OBJECTIVE (2)	RANK ORDER VALUE, V_o (3)	RANK ORDER VALUES (V_{or}) FROM TABLE 29, BY ALTERNATIVE PLAN A (4)	B (5)	C (6)
1	Integrated and balanced system	5	3	1	2
2	Maximum improvement in traffic flow	4	3	1	2
3	Minimum disruption of community	3	1	3	2
4	Maximum aesthetic satisfaction	2	3	2	1
5	Economical and efficient system	1	3	1	2
Plan value, V_T			39	23	28
Preference rank without probability factor, P_T			1	3	2
Probability of implementation, p			0.5	0.8	0.6
Total plan value, V_{Tp}			19.5	18.4	16.8
Preference rank with probability factor, P_{Tp}			1	2	3

probability coefficient. This factor might be objected to on the basis that, when it is injected into the evaluation system, the transportation plans themselves are not being measured as to their public acceptability, but by their effectiveness in reaching the goals of the community or the transportation goals. Effectiveness and probability of implementation are entirely separate factors. As used by the SEWRPC, the probability factor gives weight to the probability of implementation of the plan based on what is probably the community attitude toward such a plan, and whether the plan is likely to be financed. The highest probability is assigned to the development plan that has the highest probability of being accepted by the public or by whatever authoritative groups have the responsibility of accepting or rejecting the various plans.

It could be concluded that the probability index should not be applied in the evaluation because such factor evaluates the plans not on their own particular merits in meeting the objectives of the community or transportation needs, but on the basis of what may be official opinion or community opinion for or against the plan. It could be reasoned that the plan that best serves the total community interest and objectives is the one that ought to have the highest rank regardless of whether there is a high probability of acceptance. In economic analysis of alternative proposals, one of the principles is that the matter of financing by whom, to what extent, and how is not a factor that should enter the cost-effectiveness analysis or the cost-benefit analysis. These are questions that come up at the end in the acceptance or implementation of the plan, but perhaps should not enter into the ranking of the plan as to the over-all economic and social feasibility.

The probability factor of implementing each plan alternative might be more appropriately applied if it measured the over-all degree of relative risk and uncertainty associated with each alternative rather than the degree of probable acceptance of the plan by the community.

The preference rank could be used directly instead of using the rank order values (numbers that reverse the preference order) if so desired. However, two changes in procedure would be necessary: (1) reverse the scale of 5 (highest attainment) down to 1 (lowest attainment) for the degree that the plans meet the standards, so that 1 represents the highest achievement toward reaching the goal and 5 the lowest, and (2) the probability factor would be the complement of the one proposed (i.e., the probability of not implementing the plan). If this direct ranking scheme is used the first order of preference at the end V_{Tp} of Table 30 would be the low value rather than the high value.

Tables 29 and 30 follow in principle the procedures given in Tables A-29, A-30, and 123 of the SEWRPC report, but the alternatives and objectives are hypothetical.

George E. Klein, "Evaluation of New Transportation Systems" (*10-45*)

In the forepart of this paper Klein discusses many of the factors and processes surrounding the economic evaluation of urban transportation systems. He brings out the importance of the decision process and the ultimate decision. He does present a specific method of evaluating the transportation plans for an urban area. His general scheme provides for isolation of the economic and social factors. He then endeavors to indicate what might be the minimum value index and the maximum value index (base 10 as most valuable) on a basis of considering the desirable and undesirable attributes involved. He then provides for judgmental rating of a specific factor on a specific alternative as somewhere between the very lowest rating of zero and the very highest rating of ten. He gives the objectives of the proposal improvement considerable weight in his rating process, which, of course, is logical. His total evaluation system is on a cost basis; therefore, he does not consider benefits as such, but everything in the end is assigned some dollar value of cost. Of course the factors that are highly desirable or highly favorable or highly beneficial have practically a zero cost, whereas those that are highly undesirable have a high cost.

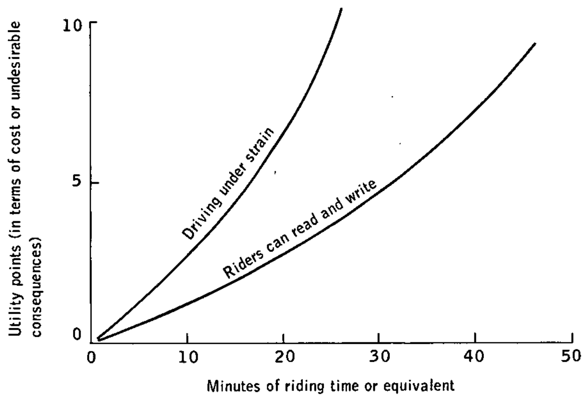

Figure 34. Waiting time when on trips. Source: (10-45, *p. 26*).

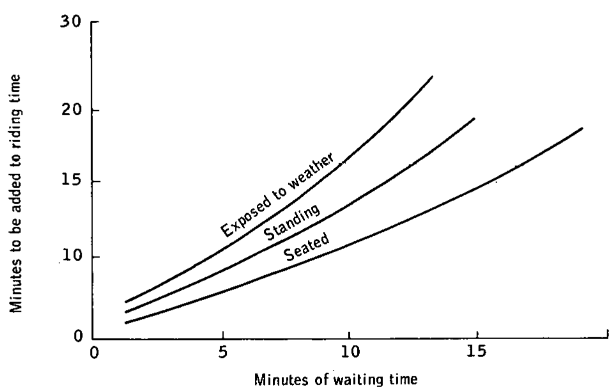

Figure 35. Waiting time when on trips. Source: (10-45, *p. 76*).

Figures 34 to 37 show his general scheme of assigning utility points to these different factors.

There is merit to Klein's separation of the different social and economic factors and then placing them on a minimum and maximum utility point scale by descriptive situations. It is doubtful, however, whether Klein's last step of putting a dollar value on his utility points is a desirable procedure. Certainly, this particular process is highly subjective, which the author recognizes, but he suggests specific dollar values for the utility points on most all of the factors he placed on his scale of utility values. The author admits, however, that his dollar values are only suggestive or illustrative in character, and that study and research would have to be conducted before particular dollar values could be expressed on a sound or reasonable dollar basis.

The utility point scale between 0 and 10 is workable and usable. The abscissa scale is usually between highly desirable and highly undesirable extremes. This also is a usable device. The subjective determination comes, however, in pinpointing the horizontal and vertical location of the particular factors on the proposed utility system under evaluation. This system probably injects, however, the minimum amount of risk or uncertainty with respect to subjective evaluations because the two end points, or the low and high values, are well fixed by describing existing situations with which the analyst would be familiar. The analyst should also be reasonably well apprised of the public's general acceptance of the extreme conditions specified as the minimum and maximum number for his utility points.

In reality, the horizontal axis becomes not a rating axis but, in effect, a ranking axis, and the vertical scale could be considered to be a weighting scheme because the weight is between 0 and 10. The proposed conversion of the utility points to dollars is simply for the purpose of being able to add all of the social and economic evaluations to the road-user cost, but a scheme of dangerous procedure.

CONCLUDING STATEMENT ON EVALUATION SYSTEMS

The foregoing review of the limited literature on the use of ranking and rating schemes for evaluating alternative proposals for highway improvements indicates that the general attempt is toward numerical ratings based on subjective

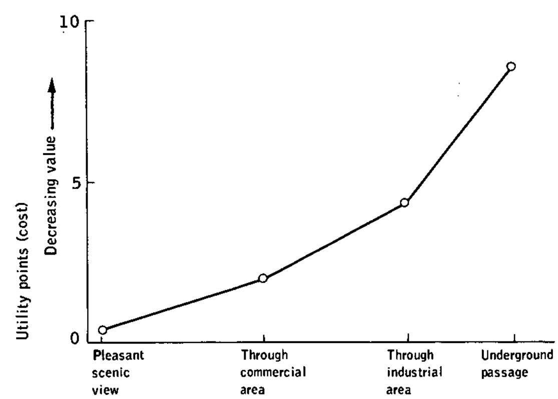

Figure 36. Scenic aspects of traveler's view. Source: (10-45, *p. 77*).

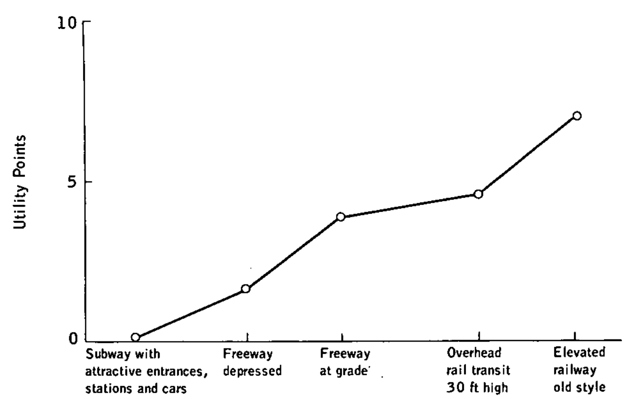

Figure 37. Aesthetics of transportation facilities. Source: (10-45, *p. 81*).

comparative values of the different factors. In addition to the assignment of numerical values, alternative schemes have been proposed of simply determining the preferred choice between pairs of alternatives, or by simply ranking factors plus and minus, favorable or unfavorable.

Except by subjective rating, there is no positive way to determine what preference should be given to road-user benefits and costs as compared to nonuser benefits and costs. Likewise, within the nonuser area there is no way, except by subjective decision, to determine the preference for design aesthetics as opposed to the dislocation of families and business organizations, as an example.

There would possibly be some value in an index device that could be used to set forth public preferences with respect to each specific project or each specific proposal. Falk (*10-14*) attempts this sort of scheme, and apparently it could be used with reasonable results, but at the sufferance of considerable monetary expense and time to collect the public's preferences for each specific highway improvement proposal.

It must be remembered that whether a consequence of a highway improvement is desirable or undesirable is a question of viewpoint and the local situation involved, including the particular goals and preferences of the community at large. The movement of families from a certain proposed highway location may be considered highly desirable, but the movement of families from another location may be considered undesirable. It follows that any proposed ranking or rating scheme has to be flexible enough to allow the use of both positive and negative evaluations for identical factors, and that the evaluations to be used must be developed by the decision maker for each specific application.

Perhaps the greatest risks are found in any system that applies dollar value to the nonmarket social and economic factors. Except by popular election wherein everyone votes, there is no way of knowing whether the public wants to suffer the construction cost of an additional mile of highway and the extra cost of operating vehicles over that mile in exchange for saving 20 acres of park area. But if such an election were the "decision maker," there is no assurance that the public would have cast intelligent and informative votes on the proposal. On such technical, social, and economic systems, the public cannot be expected to attain an informed status. Further, it can be expected that only a small percentage of the public at large will vote, but that a high percentage of the voters who are individually affected will vote. The total vote, then, will not represent the choice of the total public.

Assuming then that it is unwise and impractical to go to a public referendum for the decision, it remains the sole responsibility of the lawfully constituted decision body to make the decision. In this process of reaching a decision, can anything be gained by assigning arbitrary dollar values to the many social and economic factors in order that they may be added to the highway cost dollars and the motor vehicle running cost dollars to reduce each improvement alternative to a grand total dollar cost comparison?

The decision maker is privileged to proceed as he cares to. He may rank, rate, and price in any combination that may be of assistance to him. Ranking and rating may be appropriate in helping him see clearly the significance of the several conflicting and competing factors. Dollar pricing, however, may not prove to have any advantage. As long as subjective judgments plus individual viewpoints are the keys to the final decision when nonmarket factors are involved, perhaps a reasonable procedure is to let the decision maker use his own chosen process of reaching a decision, rather than have someone else present him with a tailor-made subjective evaluation.

Research, analysis, and discussion of this important subject will continue. In time perhaps, market value will be found for many of the factors currently classified as nonmarket and perhaps more reliable ways will be found of getting acceptable expressions of the preferences of the public.

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CHAPTER ELEVEN

MAKING THE FINAL DECISION BY MANAGEMENT[1]

Up to the time a proposed highway improvement is scheduled for contract letting, all of the studies, surveys, investigations, and conferences provide information useful in (1) making the decision whether to build a facility of any kind, and (2) determining the details of the specific design for the facility and its location.

THE DECISION SITUATION

In making the final decision relative to location, design, and other features of proposed highway improvements, including the decisions to go ahead and do something rather than to maintain the existing situation, the decision maker refers to the highway commissioner, the chief highway engineer, the city council, the board of supervisors, the state highway commission, or other constituted legal authority empowered by law to make the decisions and to spend the public's money for that specific purpose. In all such public organizations as well as in private organizations there is an individual or a body of persons empowered to make these decisions that commit resources and monies to investment in certain types of facilities.

Character of the Decision

Basically, the decision is of one or two types. The first one is a decision between doing nothing and building a highway facility, or improving an existing facility, without particular commitment as to the specifics of design. The second decision deals with the design, geometrics, details, and specifications related to the final working drawings that are used as the basis of bidding. The types of highway improvements that undergo this decision process include all forms of proposals, such as complete new highway systems, complete routes, segments of routes, altering existing routes by change in line and grade, widening a bridge, or making a spot improvement to reduce traffic accidents or to improve traffic flow. It is important to realize that this decision process applies to all forms of highway investments as contrasted to the one most people carry in mind (i.e., the center-line location of a highway).

There is no set procedure and there are formulas available by which the decision can be reached. The decision is based on what is thought to be the best solution for providing certain satisfactions in the future or the best solution to achieve certain goals of the individual or of the community.

The three major factors on which the decision must be made are: (1) What is the objective of the improvement? (2) From whose viewpoint is the objective to be obtained? and (3) What are the criteria and factors that measure the probable success of the facility in reaching the goals and in satisfying the viewpoints involved? Answers to the following three questions should aid the decision maker in answering the previous three questions: (1) Is the project or expenditure necessary? (justification), (2) Does the worth of the project exceed its cost? (evaluation), and (3) Does the importance of the project exceed other possible uses of the money? (priority).

Decision-Making Theory

In recent years the process of decision making has undergone penetrating examination to discover the nature of the process, theory involved, and procedures. Although decision making is not subject to mathematical processing, it can be aided considerably by model-making and computer analysis. The evaluation of alternatives discussed in Chapter Ten is closely related to other efforts to understand and to improve the decision-making process.

Manheim (*11-1*, pp. 3-4) points out by the following approximate wording that the decision maker has five groups of subsidiary determinations that precede the final decision:

1. What are the choices available to the decision maker?
2. What represents value to him? If he chooses a particular course of action, what will determine whether he describes the results as good or bad?
3. Having decided what represents value to him, how does the decision maker go about describing each possible alternative choice by its consequences—how does he actually associate value to each alternative?
4. The choice of an action implies that certain consequences (favorable and unfavorable) will result from the direct action of the decision maker; what circumstances beyond his control might affect the consequences to be expected from any action choice?
5. What represents a satisfactory procedure by which the decision maker can use his answer to each of the preceding four questions to select a course of action?

The basic framework offered by Manheim is to list each possible action and, opposite each possible action, list its probable consequences. The scheme is based on the implication on the part of the decision maker that in the real world there is a direct relationship between the action he may take and its corresponding consequences in the community affected. Because no decision maker can know all about the world around him, it has to be expected that his judgment of the consequences may or may not correspond to what actually is unfolded in the future. The decision maker's goal is to try to get his decisions in agreement with what the consequences would seem to indicate as the best situation for all those who will be affected.

The decision maker's model is a product of his concept of the factors involved and their consequences, together

[1] The management decision process is covered in greater detail by Winfrey (*11-3*, Chap. 23).

with his measures of effectiveness in reaching the objectives or in providing for the attainment of goals with the greatest satisfaction or the least cost. The measures of effectiveness are not goals but guides to determine to what extent individual goals are likely to be attained by a certain decision or by each of the alternatives from which the choice will be made. The decision maker also takes into consideration the uncertainties of the future—he measures the degree of reliability on which his forecast of consequences may be judged. Also, there are many types of consequences, some quantifiable and some not, that enter into the decision process. The main consequences of certain actions or certain selections of alternatives not only must be listed, they also need to be subdivided into many subconsequences. The complexity of the decision process and the difficulty of developing an analytical model are increased with an attempt to include *all* of the consequences and to measure their relative effectiveness or relative desirability.

Manheim quotes from Don K. Price to the effect that there will never be a social science strong enough that "decisions at the highest level of government may be determined by the scientific approach" (*11-1,* p. 36). However, it is realized that many scientific processes and the results of scientific approaches can be used by decision makers in the decision process. It is true, however, that the decision must be that of the decision maker, not that of someone else or the product of some mathematical model. The decision maker is responsible for the decision and, therefore, he wants to make it himself.

Several authors have commented that the decision-making scheme and the decision itself are only as good as the quality of the factual data used by the decision maker. Furthermore, the data are only as good as the manner in which they were gathered and the manner in which they are used. Good data can be misused in the decision process, and poor data can be properly used. In either case, the decision is a poor decision as far as being measured by the method used to arrive at it.

Environment of the Decision Process

The polling place is recognized as the decision point of many community proposals with reference to public works, public policies, and public finances. In highway transportation, both rural and urban, the polling place is rarely used specifically. It has been used in large-scale highway bond issues, and in bond issues for special facilities such as bridges. It has also been used in broad-scale system planning, such as financing rapid transit systems with bond issues. However, the polling place is not used to decide on a location for a transportation facility or for the elements of engineering design. It is these latter two situations that really generate public controversy and pose difficult decision-making situations.

It is well known to highway administrations that at public hearings on the location and design of specific highway projects the objectors are largely those who are personally and individually affected by the proposed highway location and design. Thus, the people who speak at public hearings are often those who would be forced to move from their residential or business location, or who would have their business potential adversely affected. The majority of the community's people usually do not attend public hearings on highway improvements because they have no sizeable personal stake in the decision and, in general, favor highway improvements. Therefore, public hearings do not succeed in getting an expression of the community preferences, and the hearing transcript becomes a record of just the objectors rather than an expression of the whole community.

In public hearings and public expressions, the short-range viewpoint is considered more often than the long-range consequences. Some of the adverse consequences of highway improvement actually occur before construction begins, some are suffered during construction, some occur immediately after construction is completed but last not more than a year, and some, both to the user and nonuser, may last many years. The decision maker needs to separate the short run from the long run and express his evaluation of the good and the bad factors accordingly.

The decision maker's task is to sift, weigh, and interpret the public opinion in such a way as to gain support for his decision. He should consider but not feel compelled to follow the desires of those who registered themselves to the contrary. It is no easy or pleasant task to sort out the purely personal factors from those of the larger community and then to select the path for the community to take.

The Setting for the Decision

The situation faced by the decision maker with respect to highway improvements is a complex of factors involving individuals, the public at large, the highway user, the land owner, and many situations and combinations of situations, all of which have a bearing on whether to build the facility and, if so, in what location and to what design. The fact that a decision must be made is further made difficult because often there are many alternative ways by which the goals could be achieved, or there could be a change in goals themselves. The most popular type of situation encountered and the one that reaches the newspapers more often than any other decision has to do with specific location of a new highway. The decision process, however, could involve the installation of traffic signals and systems, various kinds of intersection traffic controls, a bridge location, a design choice between a depressed or elevated highway, a design that involves tunneling a river or using a bridge, a design that involves a high-level bridge or low-level bridge, and many other features of over-all highway design and construction that offer a multitude of alternatives.

In the case of a location of a new highway, such as a segment of the Interstate system, there is first the choice of the so-called corridor or the general location through which the highway will be routed. This corridor is an important factor in urban areas, because often there are several corridors that could be used for the highway. Even though the corridor selection may not be too difficult to make, the exact center-line location of the highway calls for further considerations and brings into action groups of local citizens who may be affected or concerned. Following the selection of the center-line location come the factors of the geometrics of design involving vertical grades, horizontal curvature, depressed or elevated locations, and certain aesthetic aspects of the design. These factors offer many alternatives and thus they bring to light many local opinions, particularly from those whose land would be taken for the highway right-of-way, or from those people on abutting properties who might not want to be so close to a public highway. This, then, involves considerations of the viewpoint on which the ultimate decision is to be made, or the compromise of viewpoints that seems to be the best solution.

The decision involves also the major question of whether the facility should be built at all, as illustrated by the suspension of freeway construction in San Francisco, and the long-delayed decision in Washington, D.C., as to where to put Route 66 and whether to build the Three Sisters Bridge. In both communities, however, the decisions are made difficult because of the outspoken attitude of a few persons of the total community, particularly by those who are directly affected by the highway right-of-way location. In general, the community wants more highways and better highways, but not at the cost of personal expense. Thus, this personal bias of a few persons becomes a factor in the total process of making the decisions.

Role of the Decision Maker

Bearing in mind the responsibility of the decision maker in selecting that alternative for highway transportation improvement preferred to all of the alternatives considered, it has to be concluded that the decision must be a human and not a mechanical or electronic decision. Furthermore, the decision maker must reach his decision through the process of study, thinking, surveying, and testing. He should be supplied with all the facts, probabilities, descriptions of the probable consequences, economic analyses, public opinions, and other information that may have a bearing on his decision. In the last analysis the responsibility for the decision must rest on the decision maker and not on some analyst whose report he may read.

In view of the hazards and uncertainties involved in ranking and rating systems for nonuser consequences or nonmarket consequences, it is concluded that as yet there is no desirable and workable system proposed by which to rate or rank alternatives or factors of decision. Future study and research may produce improved aids to decision making, but it is doubtful that any scheme can be devised that would be a substitute for the decision-maker's judgmental analysis of the alternatives before him. The final decision should involve the community goals and the community choice of alternatives, but to achieve knowledge of what the community choice is, is a difficult process.

Other Factors

Although the rating of a single factor such as aesthetics of geometric design could be developed on the basis of its good and poor qualities, the real problem involved is the relative choice of aesthetics in preference to other factors such as user benefits, moving households, or the taking of an historical landmark. Aesthetics could be ranked on an arbitrary scalar system from 10 down to 0 as among specific alternatives of design. This is reasonably possible because the aesthetic factors could be seen and measured on the basis of their relative individual qualities. The design having no objectionable qualities (in other words, wholly aesthetically acceptable) would automatically have top ranking among the alternatives. But it must be remembered that any such ranking is the result of personal preference, and those preferences differ from individual to individual.

TOOLS AND AIDS FOR THE DECISION MAKER

In reaching a decision, the decision maker has available certain tools, aids, and assistance, such as various types of analyses, investigations, surveys, discussions, and reports. Thus, in the economic analysis work the basic purpose is to supply the decision maker with certain of the analyses, a description of the possible consequences, and costs that he may use as guides in reaching his decision.

Engineering Economy Analysis

One of the important tools that should be available to the decision maker on every proposal that requires an investment of highway funds in highway plant is the highway engineering economy analysis. As pointed out in Chapter Five, this report is primarily one involving highway cost, road-user cost, and road-user benefits and the market priceable factors to indicate whether the investment in the highway will offer net benefits commensurate with the net cost involved in highway construction and highway maintenance. Whether this report uses the equivalent uniform annual cost method, the present worth of costs method, the benefit/cost ratio method, or the rate of return method, it does indicate the relative measure of highway cost and road-user benefits.

The Socio-Economic Analysis

The road-user analysis of economy is paralleled by a similar analysis made on the over-all social and economic consequences of a proposal but dealing with those factors that are not priceable on the market. Although such factors may not always be measurable, their importance and relative desirabilities usually can be described. As set forth in Chapters Three and Nine, the socio-economic report will deal with such things as shifts in employment, population, and locations of retail trade and wholesale trade; the effects on land use; the relocation of people; the conflicts with cemeteries and parks; land-use renewals; and all environmental factors. This report will point out the socio-economic effects that may result from the proposed highway improvement, and it will divide them among individuals, areas, communities, and activities both private and public. Thus, the socio-economic report will afford the decision maker with good descriptions of the pro's and con's of the proposed highway facilities with respect to the broad-scale social and economic and environmental factors involved. The report will further point out what probably will happen to the community or the area affected if the existing situation is maintained and the new proposed highway facility is not built.

Public Responses

In the process of making many of the surveys, designs, and investigations leading up to definite proposals for highway location or highway design or the remodeling of highway facilities, sectors of the public often express themselves for or against features of the proposal or the proposal as a whole. Further, before a project is finally adopted in location or in design, public hearings may be held. Speakers at these hearings may represent either themselves, or groups of citizens, or institutions. These hearings are often attended by sizeable numbers of people, but in general only a small percentage of the people within the area affected attend the hearing, and the greater percentage of those attending are those who oppose the proposed facility, its location, or its design.

Local newspapers and television and radio also have a good deal to say for or against the highway proposals. These statements are supplemented in many cases by direct letters to the decision maker or by submission of petitions signed by local citizens and property owners who are to be affected by construction of the proposed highway facility.

Responses From the Governor and Legislators

Other tools of a decision maker are the position of the governor, mayor, or other top executives within the political jurisdiction involved, and also the response and attitude of the legislative body such as a county board, a city council, or a state legislature.

System Plan, Community Plan, or Transportation Plan

Urban areas particularly often have some sort of master plan that sets forth as of a given date the general land-use plan and transportation plan to which all improvements within the community should respond. This master plan may be an official document approved either by the legislative body, the planning commission, or an other responsible political group. It is true that by official action by the legislative body, land uses and improvements to land and to structures on the land may be permitted that do not conform to the master plan. Frequently, a zoning requirement may be waived for particular purposes on application to the proper body. These are decisions that are in accordance with the law, but, in connection with the planning and approval of highway improvements, the ultimate decision must be made with proper recognition of and coordination with an over-all community plan or transportation system plan. These adopted plans for future area growth and change are also tools for the decision maker.

Time Required for Construction, Cost of Construction, and Traffic Detours

An important factor the decision maker often must consider and weigh is the construction cost of the different alternatives as related to the total time of construction, the disruption of the normal activity of the community, and the handling of traffic during construction. This last factor can be an aggravating item to the traveling public and, if continued over any length of time, results in much inconvenience, extra costs, and unfavorable reactions.

Community Goals and Plans

Most urban communities have some sort of over-all plan or set of goals, and these should be an important factor in all decisions that affect transportation and land use. For instance, some communities desire to bring in business and industry; others would like to maintain a bedroom-type of community and a quiet neighborhood. Further, some communities are anxious to have a continuing increase in population, whereas others are not, at least not at any accelerated rate. In addition, master plans govern land use, public facilities, and transportation facilities.

Objective of the Improvement

Perhaps the most important guideline that the decision maker is to consider is what is the basic objective of the improvement? What is it supposed to accomplish? This is discussed later with reference to the process the decision maker may elect to follow.

TECHNIQUES USED BY THE DECISION MAKER

The maker of decisions on highway improvements has no recognized specific technique to use in reaching his decision. In fact, the decision is basically subjective, made by using such facts, figures, analyses, opinions, judgments, and goals as may be submitted to the decision maker or as he may be able to collect himself. Such data enable him to interpret not only what the public desires in the way of transportation facilities but also whether the proposed facilities will reach the goal in an economical and desirable manner. In addition to using these data, perhaps certain principles of game theory could be advantageously used.

The decision maker can seek counsel from professional, business, or neighborhood people, or organizations with respect to the alternatives laid before him. These counsels would be in addition to the communications, including public hearings, he already has.

Analysis and Comparisons of the Data and Reports Available

For each alternative, including the do-nothing alternative as opposed to building a highway facility, the decision maker can array the factors embodied in each of the alternatives among which he must choose. A good technique is to indicate in the array those factors that are favorable and unfavorable in the short run as well as in the long run. The time duration of the consequence, whether favorable or unfavorable, is an all-important point. In general, members of the community are more inclined to give weight to immediate goals, satisfactions, and dissatisfactions than to those of the long run. This is especially true of the individuals and groups that are directly interfered with because of the highway location. Such citizens are more inclined to consider their immediate hardship rather than their position after a year or so beyond the completion of the facility. Chapter Ten discusses several types of specific analyses and ranking and rating systems that may be used.

The technique of comparison by pairs is useful in helping the decision maker determine which of two alternatives is the more logical one from the standpoint of reaching the goals or creating more benefits or creating less adversities. This comparison can be made factor by factor within a pair of alternatives, and the factors may be checked by giving plus signs to the favorable ones and minus signs to the unfavorable ones, without attempting at the moment to rank or to quantify the degrees of goodness or badness. In this comparison by pairs the intent is to isolate the alternative or a factor within an alternative that in the end ranks the highest from the standpoint of favorable consequences in the judgment of the decision maker. Within the comparison by pairs the decision maker has the opportunity to determine worthwhile trade-offs between favorable and unfavorable factors and thus also arrive at somewhat of a balance of over-all goodness as between the pair of alternatives being considered.

A good insight as to the over-all desirability of one proposed alternative over another one may be had by listing the factors of road-user and nonroad-user character that are involved. In this listing of factors they may be grouped by the favorable, neutral, or unfavorable consequences.

It is evident that the techniques used by a decision maker in arriving at a decision are basically a process of comparing factors in a way to permit him to see those that have desirable consequences and those that have undesirable consequences, as well as those that are neutral. Once these factors are so listed, the decision maker begins then to see the predominant character of the different highway alternatives which, in turn, will lead his own subjective thinking to the alternative that in his judgment offers the best over-all attainment of the goals sought by the improvement.

One technique available to the decision maker to show relative values of factors and trade-offs is to express the worthwhileness or the degree of objection to certain features in some form of unit cost. For instance, two urban center-line locations cause the dislocation of a different number of families. Some guide as to the significance of the number of families not moved can be obtained by reducing the increase in highway construction between two alternative highway costs per family not moved. Generally speaking, the higher cost alternative would be proposed as a way to reduce the number of families to be dislocated. Pricing out the cost on a cost per family not dislocated is a good index as to whether the investment might be worth that amount per family not moved.

Guidelines and Criteria

The decision maker can make up his own list of guidelines and criteria to use in the process of reaching his decision. These factors include public policies, departmental policies, design standards, and other factors on which the public has expressed itself or factors definitely prudent to use in making the decision.

One of the important guidelines to use is the objective of the improvement; e.g., reduction of traffic congestion, increase in vehicle capacity, reduction in traffic accidents, or provision of a transportation link needed between two particular areas. Any proposed improvement alternative that does not substantially accomplish the objective sought would naturally be rated low in desirability.

For urban areas particularly, the community itself may have a policy and a goal governing its growth, its redevelopment, and its direction (e.g., choices between being a bedroom, a business, or an industrial community). The alternatives of the highway facility being considered ought to contribute to that community goal or, at least, should not restrict its attainment.

Many communities do have a master plan or an area transportation plan, or the highway department itself may have plans for improving its system of routes in the community. The alternatives being considered for which a decision is desired ought to contribute to the fulfillment of this over-all transportation plan with respect to (1) land use, (2) developing an integrated transportation system, and (3) other modes of transportation. Also, the over-all plan may provide for increasing the land area for particular purposes and/or decreasing the land area for other purposes. The specific highway facility being considered should contribute to the attainment of these goals.

In certain areas the public may have expressed itself as to its attitude for highway improvement, particularly toward freeways, expressways, and parkways. It may have declared itself for a particular level of transportation facilities, or for attaining a high degree of environmental factors related to the aesthetics of construction of all kinds within the community. In some areas with a high degree of historical background, the community may desire to retain historical landmarks and architecture, and otherwise tie itself largely to the past rather than rebuild to current fashion so far as community growth is concerned.

The decision maker needs to be aware that public goals change over time, as do public opinion and social custom. Between conception of a highway improvement and its submission to the people, there can be a marked change in public goals. These goals may also change with political administration change. The real asset is in being able to forecast what public opinion will be when the project is presented for acceptance, or, better, after it has been in use for a time.

Certain elements or certain features of highway design may correct certain community ills, or these factors may prevent the increase or development of such ills in the future. The slum clearance and remodeling of the city from the standpoint of updating its structures are often goals of a community. Highway planning and highway design that contribute to these goals is to be preferred over types of design that, in the long run, may contribute to unsatisfactory situations rather than to their cure.

Lastly, a criterion to use in the ultimate decision is toward the election of that alternative that will produce the most good for the most people. Attaining this goal, of course, means giving not much weight to desires of individuals and small groups that favor or disfavor a certain location or design of highway. Such outspoken attitudes must be carefully considered, however, but the decision in the end needs to be weighted directly in favor of the community and the people as a whole. Here again the viewpoint of the long-range objectives and long-range consequences is an important factor. It is well to bear in mind that communities continue to change, neighborhoods are rebuilt and repopulated, and the people tend to migrate.

Goals of Transportation Facilities

Transportation facilities really have three particular goals as viewed from three different positions: (1) goals of the road user, (2) goals of the land user, and (3) goals of the community at large as expressed to the community management responsible for the carrying out of the desires of the community.

Each of these goals and the people supporting them need to be considered from the standpoint of maximizing the satisfactions along these lines. For instance, the road user is interested in adequate, safe, and reliable transportation that produces a convenient trip and a comfortable ride. As a road user he is not so much concerned with the effect of the type of highway on the adjacent property or, perhaps, on the community as a whole.

The land user, on the other hand, is interested in preserving the qualities and values of his land and his land use, whether it be for business purposes or a residential neighborhood. He does not want the property to be detrimentally affected in a way that would reduce his business volume or income, nor does he want a highway to spoil his view or introduce noise and air pollution in his neighborhood.

The management of the community has the responsibility of seeing that all decisions are directed toward the attainment of the over-all community goals, including due attention to social welfare, economics, aesthetics, and community harmony. In this respect, the community management is interested in highway improvements that will help achieve the over-all goals with the minimum detrimental effects toward other goals or toward desirable factors or features existing in the community.

Although there is no direct way to measure the degree to which certain highway facilities achieve the goals of these three sectors of the community—the road user, the land user, and the community management—it is the decision maker's responsibility to reach a decision as to the location and type of highway facility to approve. He should strive to see that his solution affords the best possible combination of benefits and that combination of adversities having the least detrimental effects with respect to these three community viewpoints.

THE DECISION MAKER'S QUALITIES

A good decision maker has the knack and know-how of seeing the full conception and the full ultimate consequences of all of the factors involved in a proposed highway improvement. He not only must visualize the magnitudes and importance of these factors, he also has to be able to give them relative values in his own mind so that in the end he is satisfied that he reached the best decision and that his decision will be reasonably well accepted by the community at large, knowing, however, that certain individuals in the community will not agree with his decision.

The decision maker must have the courage to (1) reach his decision, and (2) announce his decision. There are cases of record where the decision maker lacked this courage and allowed a certain proposal to go on for years without rendering a specific decision. Thus, the community suffered either way, but suffered more because of the lack of decision than it would have had a decision been made early.

A decision maker does not necessarily have to spell out in detail all the factors and considerations and weights that he used in reaching his decision. However, he has to be able to show that he did consider all the evidence and reports and factors before him and that in his best judgment the decision he reached is the one of greatest benefit to all.

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CHAPTER TWELVE

ECONOMIC ANALYSIS THROUGH USE OF COMPUTERS

The electronic computer is now a standard instrument found in practically every educational, engineering, business, industrial, and management organization. Highway departments are using the computer extensively in engineering design, research, planning, management, and operational functions. It is not necessary, therefore, to describe the general uses of the computer in highway departments. It should be of value, however, to describe the use of computers in making economic analyses and the functions supporting such analyses.

This chapter describes some of the applications in the areas of engineering design, route location analysis, economic analyses of alternative engineering designs, and transportation system analysis as found in transportation planning. The primary purpose here is to illustrate the general practice and to indicate the types of computer programs that have been developed. No attempt is made to be all-inclusive or to furnish complete descriptions.

GENERAL MANAGERIAL APPLICATIONS

The computer is applied widely by highway departments in such processes as statistical and financial record keeping, cost accounting, payroll, planning, and construction project programming and controls; these are distinguished from technical applications (engineering design and research). Some of these specific applications cover such activities, functions, and processes as:

1. General managerial and administrative:
   a. Data banks for use in planning.
   b. Construction programming and control.
   c. Construction project fiscal control.
   d. Budget allocation and control.
   e. Work performance.
   f. Maintenance expense records and control.
   g. Information storage and retrieval.
2. Technical applications:
   a. Statistical analysis.
   b. Mathematical analysis and calculations.
   c. Design processes—structural and others.
   d. Iterative analyses.
   e. Processes requiring solution by successive trials.
   f. Systems analyses.
   g. Graphic plotting and mapping.
   h. Traffic assignment in route location and design.
   i. Model building and simulation.
   j. Economic analysis.

COMPUTER APPLICATIONS TO ECONOMIC ANALYSES

Appropriate to discussion here are applications of the electronic computer that are specifically economic analysis, engineering economy, or applications to engineering or other purposes that support economic analysis. The terms economic analysis and engineering economy analysis are rather broadly interpreted.

COMPUTER LOGIC FOR ECONOMIC ANALYSIS

A computer program for economic analysis for proposed highway improvements needs to be written for application to a range of types of improvements and for ranges in the variable factors. Further, the road-user analysis requires quite different computer programming than does the analysis of the nonuser consequences.

A casual search of the literature and of the lists of computer programs available in highway departments did not disclose any computer programs specifically for highway engineering economic analyses, but is a reasonable assumption that some organization has adapted AASHO's *Road User Benefit Analyses for Highway Improvements* ("Red Book") and other procedures to calculation by the computer.

It is unfortunate that past attention to economic analysis for highways has neglected most applications other than to route location alternatives. The need is for a generalized computer program with subprograms for specific highway design features that will permit computer analysis for all proposals for improving highway facilities, routes, and systems. Also needed is a computer program for the analysis of urban transportation systems with provision for multi-mode facilities.

Computer Program Requirements for Highway Engineering Economy Analysis

To be fully useful a computer program for analysis of highway engineering economy of two or more alternatives should provide for the following:

1. Solution for a wide selection of types of highway improvement prospects such as route location, spot accident reduction, intersection traffic control devices, interchange design and spacing, pavement type selection, bridge type selection, drainage facilities, stage construction, street widening, traffic detours during construction, pavement widening, and tunnel location and length.
2. Analysis by at least four methods: equivalent uniform annual cost, present worth of costs, benefit/cost ratio, and rate of return.
3. A choice of discount factors over a range, say, from 5 percent to 10 percent, plus provision for solving for the discount rate when using the rate of return method. The program should provide for use of the present worth of single sum, present worth of a series, sinking fund, and capital recovery factors.
4. Solution with and without a terminal value.
5. A range of analysis periods, including specific service lives by highway elements when appropriate.
6. Calculation of motor vehicle running cost by type of vehicle for ranges of speed on level tangents, vertical grades, and horizontal curves, and speed changes. Traffic accident costs should be provided for.
7. Calculations similar to those in item 6 for travel time and for travel time value.
8. Analysis for different types of highway designs.
9. Sensitivity analysis for the factors of discount rate, terminal value, analysis period, average daily traffic volume, and vehicular type mix.

Because of the wide range in choice of discount rates, the six common compound interest factors, and growth factors involved it is questionable whether the computer procedure should provide for: (1) data storage, (2) curve equation storage, or (3) individual input of the factors needed for each solution desired. The same question of procedure applies to the basic running cost data for motor vehicles by class. The preferred procedure can be indicated only by detailed study of the requirements, computer capabilities, applications, and manual alternatives.

Computer Program Requirements for Nonuser Consequences

With one exception, it is doubtful that a computer program would be useful in analysis of the nonuser consequences. Generally, such consequences will be unquantified and unpriced so that little calculation is possible. Further, because of the many variable factors and difficulties of describing them, they almost have to be handled by descriptive methods.

The one situation where a computer may be applied to advantage is in reducing a ranking or a rating system to an order of alternative preference and in making a sensitivity analysis of the ranking or rating factors. Although a numerical ranking or rating procedure is not recommended in Chapter Ten, for general use, it might be used by the decision maker when he supplies the specific ranking or rating values for the social, economic, and community factors involved.

Advantages of Using Computers

Applications of computer technology to economic analysis of highway projects and operations offer advantages over hand computations: (1) less time required, (2) higher reliability of accuracy, (3) more alternative designs are apt to be studied, and (4) the sensitivity analysis for the variable factors can be made easily. The analysis of all probable choice locations and their subalternative design options provides a good source of answers to the public questions regarding the preferred designs. These answers are more apt to be developed with computer analysis than by hand computations.

The probabilistic nature of those variables that can take a range of values rather than a single value can be controlled with a computer. This control may be approached through the application of sensitivity analysis whereby values in the range can be tested for their effect on the relative ranking of the alternatives under consideration. Break points may be identified: points past which one alternative would be preferred over another if there were a strong probability that that point on the range would be exceeded.

Different assumptions concerning average daily traffic, analysis period, service lives, discount rates, and values of travel time can be immediately tested for their significance when programmed for the computer. Significant variables crucial to the decision between alternatives so identified means the estimates for those variables can be sharpened with more precise estimates. Such analyses lend themselves to digital representation and statistical analysis via the computer (*12-25*).

The difficulty of performing rapid accurate cost estimation on which to base an economic analysis may be overcome by the computer. Once computer models for various cost elements of the construction and operation of highways have been programmed, tested, and validated, accurate outputs reflecting the consequences of alternative solutions can be generated quickly (*12-25*).

Computer applications can improve on present hand methods by increasing (1) the number of alternatives the engineer will study, and (2) the quality of answers he receives. The expansion of computer applications in highway economic analysis depends on how soon good numeric evaluations in dollar or other terms can be found for consequences of highway improvements related to engineering location and design variables and how adequately the correlation can be defined as a step to modeling the interactions for computer analysis.

A highway economic study should consist of identifying all the relevant cost-producing and gain-producing variables in proposals for highway facility improvement at a particular level of sensitivity and measuring each of these costs for each of several designs using computer models of the sort described in this chapter. Different programs are required depending on the form of the input data and the relevant cost factors identified. The costs and gains can be calculated for each alternative. From these figures, equivalent uniform annual cost, present worth, benefit/cost ratio, or the rate of return can be generated.

Goble (*12-8*) stresses the advantage of man-machine communication in computer application to structural design and other highway design activities. Such communication with the analyst at the computer console has great advantage in economic analysis. The analyst could test out the key factors for their sensitivity and, also, modify design input factors within the main alternatives under analysis. The technique of man-machine communication is advancing rapidly. Its use in economic analysis of improvements proposed for highways has considerable merit.

Having the mass of routine calculative detail handled by computer programs frees the engineer for his main task: creative design-oriented thinking that requires his judgment, imagination, intuition, and experience. This is the engineer's unique contribution that makes the difference between finding the "best" solution over just a "good" one. No computer can replace man in this capacity.

The social and economic consequences of highway improvements have not yet been adapted to the computer in a way that useful summaries can be had of the advantage over manual tabulations and descriptions.

PROGRAMS DEVELOPED AT MIT [1]

The Civil Engineering Department of the Massachusetts Institute of Technology has had under development, since 1957, a number of programming systems and computer-oriented methods of analysis that are applicable to the location and design of highways, and specific engineering subanalyses, including the economy of design.

Going under the general heading of ICES (Integrated Civil Engineering System), the computer application consists of a series of programs useful for performing a variety of component analyses. The eventual goal is an omnibus program capable of performing a system analysis for an integrated route location study. The information flow for such a system is shown in Figure 38.

Details of a complete system are still being worked out. At present, several subsystem analyses have been successfully applied by a number of users. They fall under the

[1] Detailed information on the ICES programs can be obtained from: Civil Engineering Systems Laboratory, MIT, 1-163, Cambridge, Mass. 02139.

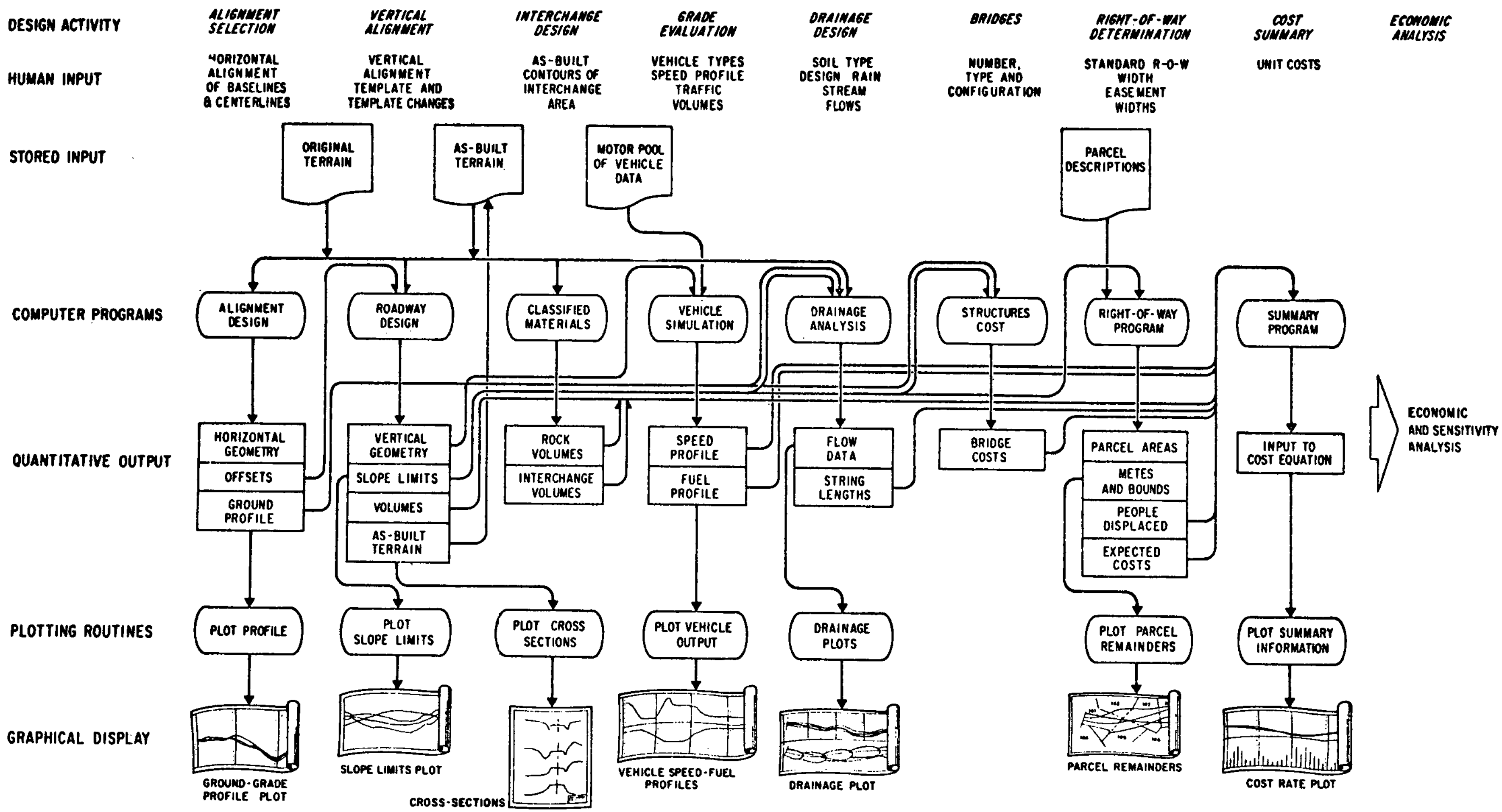

Figure 38. Information flow for an integrated route location evaluation system using a computer with additional disk memory. Source: (12-31, *p. 93*).

title ROADS (Roadway Analysis and Design System), a subsystem of ICES. Other ICES subsystems applicable to the highway location and design problem are COGO, for coordinate geometry calculations, and BRIDGE, for bridge design, both of which involve principles of economy.

The latest version of the Massachusetts Institute of Technology system is described by Roberts and Suhrbier (*12-31*). The component parts and capabilities are briefly summarized here to point out the main features, approaches, and capabilities of the system.

Digital Terrain Model (DTM)

Digital Terrain Model (DTM) applies to both location and design systems. It is a statistical sample of the continuous surface of the ground within a "band of interest" or potential highway corridor. The input consists of a number of selected points with known X, Y, and Z coordinates. X represents the distance along a base line; Y represents the distance along a cross section or scan line normal to the base line; and Z represents the elevation of the terrain point. The data take-off from topographic maps can be done either by hand or using the Digital Terrain Data Recorder, a device for digitizing data directly from maps to cards, paper, or punched tape.

1. *Location system* begins with the "alignment design phase" that inputs the edited terrain deck, location geometry, and offset data for alternative alignments. The output consists of tabular listings of location geometry and a graphic ground profile plot.

The "roadway design phase" inputs the alignment and the design phase output cross section to produce a table of vertical geometry, slope intercepts and volumes, and graphic slope stakes plot and mass haul diagram (*12-31*, pp. 17-32). Figure 39 is a flow chart showing the foregoing procedures.

2. *Design system* is intended to function in both the preliminary engineering and final design phases.

The design system starts with the same terrain data as the location system. The design system has an "alignment design phase" similar to that in the location system, with a few simplifying modifications.

The "roadway design phase" uses the more refined data of the original terrain model rather than the approximations of the location system. The intent is to provide a more exact description of the typical roadway cross section. The output of these two phases consists of tabular and graphic profile and slope stake and mass haul plots.

The "materials classification phase" comes into play when it is necessary to compute rock volumes for removal and cut and/or fill quantities for interchange areas. A Materials Classification/Volumes Program is employed for these purposes.

Structures Cost

Rapid estimation of the cost of structures (bridges) for use in economic analysis in the early stages of highway location analysis is provided for.

The program produces construction costs estimates from formulae incorporating such parameters as structure length and width, number and type of spans, skew angle, vertical clearance, and foundation conditions.

Although the result provided for by this program is not appropriate for estimating the cost of a single bridge at the design stage, it forms a good estimate of the cost of all structures in a large project (*12-31*, pp. 49-51).

Drainage Analysis Program

A subphase of the computer program organizes and extends the output of the DTM Design System into a form useful for drainage analysis. The output is a station-by-station summary of the direction in which runoff water will flow at five points on the completed roadway cross section: two slope intercept points, two hinged points, and center line. For presentation, the information can be plotted in both horizontal and vertical form with arrows showing the direction of water flows. The program also outputs string length accumulations of ditch for a given flow direction.

The information generated by this program can be used by the engineer to: (1) identify points where inlets, cross ditches, or downspouts should be located, (2) locate possible culverts and compute their lengths, (3) indicate interceptor ditches, and (4) show where guardrail may be required.

Right-of-Way Parcel Evaluation System

Cost of property for right-of-way acquisition is estimated by a special program. Actually, two programs were developed for this purpose. Because of data and computational difficulties they are felt to be less accurate than estimates developed manually. Hand evaluations will therefore usually be the preferred method.

1. The *zone cost approach* divides the area of interest into uniform cost zones. Then, the area and cost of each zone falling within the right-of-way limits is computed. Mathematical description of irregularly shaped zones was found difficult, even where approximated by rectangles of various sizes. "Data point" information for each zone includes the location of the rectangles' lower boundary and the type and cost of land on a square-foot basis. This information and the right-of-way limits are input. Output consists of the accumulated area and cost of different land types.

Problems of the method arise from the difficulty of: (1) accurately including improvements in land value data, (2) determining and distributing severance damage, and (3) coordinating location and right-of-way sections to minimize the expense of data gathering.

2. The *Parcel Evaluation System* attempts to improve accuracy of the estimate of rights-of-way cost by evaluating land on a parcel-by-parcel basis.

The basic input is a master file of data for all properties in the area of interest. The coordinates of the metes and bounds of each parcel are recorded along with a parcel number, owner's name and address, property address, number of residents, number of employees, type of property, assessed value of land and buildings, the frontage value, and property width.

Three programs make up the Parcel Evaluation System. The first relates the right-of-way limits to the land model;

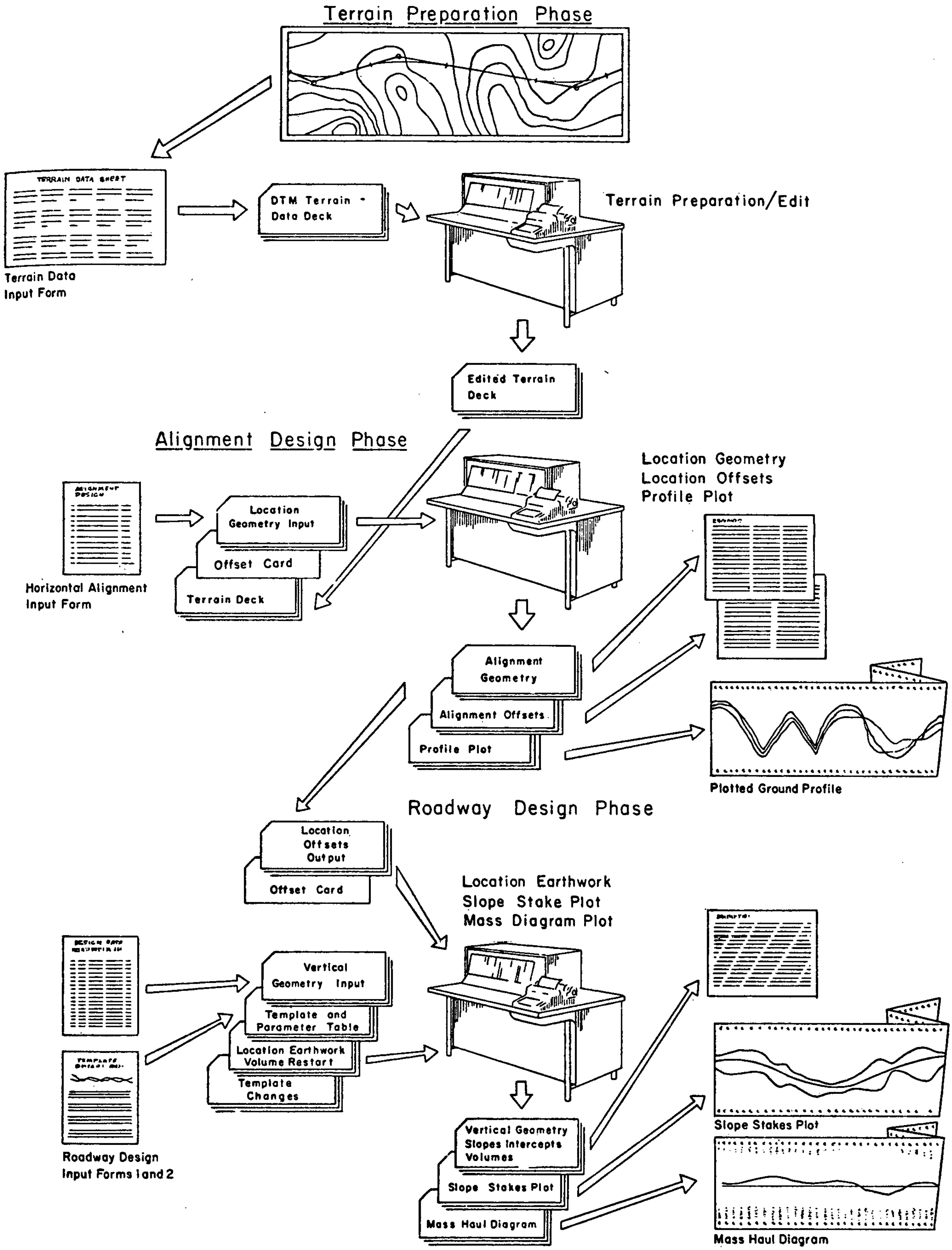

Figure 39. Location system flow chart. Source: (12-31, *p. 27*).

the second computes the area of each parcel lying within and outside of the right-of-way; and the third computes the associated costs.

Output consists of certain descriptive information and the following cost data by parcel: total assessed value, market value, area taken, and expected costs. Output also includes a summary of residents displaced, workers displaced, assessed value of property taken, and expected cost of property to be taken.

Difficulties of this method include the problem of tying all deed descriptions to a grid system and the expense of collecting and organizing the mass of data required. As in the zone cost approach there is no easy way to account for physical improvements.

Vehicle Simulation and Operating Cost System

The user cost side of the economic analysis is handled by use of a computerized vehicle simulation program. The vehicle simulation and operating cost system models or simulates the operation of a vehicle over a specified highway alignment and determines the associated costs in this movement.

Vehicle running costs vary directly with vehicle road speeds, engine revolutions per minute, vehicle tractive effort, and percentage of full engine load. These in turn are directly related to highway design characteristics, including the vertical alignment, superelevation, pavement type, and operational restrictions on speed. The system programs take these design characteristics and a description of the vehicle and calculate the consequences of these characteristics on engine performance. The consequences are then converted into associated costs.

System inputs include vehicle data, control data (such as wind speed, pavement type, unit fuel price, unit value of travel time, and traffic volumes), desired speed profile data, vertical alignment data, horizontal alignment data, and a full vehicle performance table. Output includes the clock time and speed at which the vehicle passes each station on the alignment, along with information on the cost and amount of fuel consumption. A table, output at the end of each run, summarizes all pertinent vehicle cost information.

The resulting figures on time and fuel consumption, when added to oil, tire, maintenance and repair, and depreciation cost figures, produce the average vehicle trip cost. These costs computed for a standard car, a small truck, and a large truck are then multiplied by the traffic volumes for vehicles of each type predicted to use the facility per annum to determine the total annual road-user cost.

Congestion effects cannot be directly accounted for by the system but can be handled indirectly by lowering the speed profile to produce longer travel time and higher fuel consumption and increasing the volume level in future years to match anticipated traffic increases.

Annual Highway Maintenance Cost Program

Highway maintenance cost for a "basic mile" was determined. It was modified to account for variance in actual conditions from the "basic mile." The modifying factors include pavement age, widths, and type; traffic volume; and soil conditions. Tables of these factors under various conditions have been developed and placed in a computer program that calculates an estimate of the highway maintenance cost.

Economic Analysis

When highway capital and maintenance costs and nonuser costs for all alternative alignments have been computed, they are totaled and summarized for each alignment according to the formula:

$$TAC = ACC + AUC + AMC \tag{11}$$

in which

TAC = total annual transportation cost ($);
ACC = annual highway capital cost ($);
AUC = annual road-user time and running cost ($); and
AMC = annual highway maintenance cost ($).

It should be mentioned that traffic accident costs and road-user comfort and convenience and nonuser social, political, economic, and aesthetic factors are omitted from the analysis because of the lack of adequate estimates and models.

Choice is made on the basis of the alternative having the least equivalent uniform annual transportation cost. The program could be modified to use the benefit/cost ratio or rate of return methods. Unless the traffic volume is substantially the same for each mutually exclusive set of alternatives, the annual cost solution will not indicate the most favorable choice.

PURDUE UNIVERSITY GENERALIZED COMPUTER-AIDED ROUTE SELECTION SYSTEM

A direct application of the computer to highway economic analysis is presented by Turner (*12-38;* see also *12-39* and *12-40*). Turner developed numerical surface analysis procedures applied in connection with minimum path analysis procedures. The procedures provide for conversion of the land characteristics into numerical values expressed in the equivalent of topography or contour maps. These values are converted into utility surfaces and combined when desirable.

The technique provides for a series of analyses, each succeeding one covering a narrower land path until a specific highway alignment is reached. The sequence is region, band (5 to 10 miles wide), corridor (2 to 5 miles wide), route (0.5 to 1 mile wide), and alignment (specific route location).

The following route-independent factors are first used to generate preliminary alternative routes: topography, soil, geology, foundation condition, land use and value, and travel demand.

These factors are used in expressing the values in terms of: (1) earthwork cost, (2) pavement cost, (3) right-of-way acquisition cost, and (4) service benefit factors.

The route-dependent factors include: user costs and benefits, aesthetics, social factors, economic considerations, and specific design factors such as grade line and elevations.

These factors play their stronger roles when the analysis reaches the route and alignment stages.

The process places stress on man-to-machine communication and sensitivity of the factors involved in alternative route locations. The graphic printouts are an important part of the machine-to-man communication. The contour maps make possible quick evaluation of results and afford a sound basis for successive trials and modifications of the factors of route location and engineering design.

The following described computer programs indicate some of the applications to phases of highway operations that are related to economic analysis. No attempt was made to assemble all such programs.

PROGRAMS RELATED TO HIGHWAY DESIGN AND MANAGEMENT SYSTEM PLANNING

Computer programs have been developed to specific structural and other applications of highway design and transportation planning that relate to economy.

Texas Flexible Pavement Design

Noteworthy for its incorporation of engineering economy analysis is a program covering flexible pavement design prepared by the Texas Transportation Institute for the Texas Highway Department (*12-32*).

The program write-up describes it in these terms (*12-32*, pp. 1-2):

> . . . a recommended procedure for the design of flexible pavements. The procedure takes into account both physical and cost variables, and provides a means for making design decisions based on probable overall long range costs, including costs to traffic, rather than on initial construction costs alone.
>
> Physical variables are treated in terms of how they affect the serviceability-time curve of the pavement. Means for evaluating them in any given locality are presented.
>
> Cost variables considered are the following: initial construction, routine maintenance, periodic seal coating, overlay construction, road-user costs due to traffic delays during overlay construction, and terminal value of the pavement. All future costs, discounted to present value, are added to initial construction costs to form the overall annual or present worth cost.
>
> Because of the number of variables involved, and the need to investigate all possible designs meeting selected criteria, initial attempts to prepare the usual curves or nomograms for the designer's use were quickly abandoned. The solution of the design equations, and the search for the least-cost design, are made in a computer. The computer program, and a brief description of what it contains, are included in this report.
>
> In writing the computer program, the attempt was made to provide for ease of change, so that as new findings are made in flexible pavement research, they can be incorporated into the program with a minimum of effort. Meanwhile, the program is recommended as an aid not only to the design engineer but also to the research engineer in establishing where emphasis should be placed in pavement research.

Ranking of Alternative Freeway Locations

The study by Consoer, Townsend and Associates (*12-6*) made use of a computer program for rank-ordering several potential freeway locations by their fulfillment of plan objectives. (See Chapter Ten.)

The problem confronting the analysts was to order the "quality of . . . alternative plans . . . to be measured by degree of fulfillment of . . . objectives." To accomplish that task, they assign

> . . . a value to each objective in order of its performance, and rank each alternate plan under each objective in order as they fulfill the objective. (For these rankings, the higher number represents the higher rank.) A value for each plan is then calculated by summing the products of each alternative plan rank under each objective and the objective value.
>
> . . . . .
>
> The procedure is summarized as follows:
> 1. Rank objectives in order of importance.
> 2. Rank alternative plans in order of fulfillment of objectives.
> 3. Calculate alternative plan value as the sum of objective values times alternative plan ranks.
> 4. Best plan has the highest plan value (*12-6*, p. 73).

When the method incorporates a large number of objectives, "the total number or permutations of objective values soon becomes too large to permit calculation of alternative rank for all possibilities of objective values" (*12-6*, p. 77).

To overcome this limitation and enable a large number of "objectives to be included in the systems for analysis," a computer program was written to perform the calculations. The program provides for (*12-6*, p. 77):

> 1. A random selection of objective values between specified limits.
> 2. A summation of values used for each objective.

The report concludes concerning the computer program (*12-6*, pp. 77-78):

> As the calculations were iterated, the sums of objective values became closer together. In the analyses performed with 15 objectives without restraint of objective values, we found that the probability ratios stabilized after the sum of objective values was within about 5 percent of each other. To reach this value, about 1,500 iterations were required. All calculations with and without restraint were run through not less than that number of iterations.

Critical Path Method

A computer system developed by the Bureau of Public Roads generates critical path method reports.

> The Critical Path Method (CPM) is a management technique used for planning, scheduling, and monitoring the progress of a project. A project is defined as any undertaking that has a definite beginning and to which work is applied leading to a definite completion. In nearly all cases, a project is made up of many operations. These operations are called activities. Activities are physical work items or restraints on other operations necessary for the completion of the project (*12-37*, p. 1).

A manual (*12-37*) prepared by the Bureau

> . . . contains computer programs which will provide some of the necessary reports for applying CPM to a project. The system or series of programs covers the scheduling calculations for any unit of time, calendar dating the schedule on a working day basis and plotting the calendar dated schedule on a working day basis. While other programs can be developed, these are sufficient for scheduling and monitoring purposes (*12-37*, p. 4).

The CPM computer system consists of the following three programs (*12-37,* p. iii):

1. CPM Calculations Program: "Used for doing the arithmetic calculations associated with the scheduling of a project. The results from this program become the information necessary for use by the other programs."
2. CPM Calendar Dating Program: "Used for either scheduling or monitoring purposes. The output is a calendar dated report of the starts and finishes."
3. CPM Time-Sequence Plot Program: "Used for the monitoring of the project. The report produced by the program is in the form of a bar chart showing the duration and total float of each activity on a calendar day scale."

The CPM computer programs have a place in the list of computer applications for engineering economy. Economy is achieved through laying out projects by a sequence of operations with definite time intervals for completion, thereby limiting cost-producing delays.

Preconstruction Engineering

The State of Washington Department of Highways has formulated the "Washington Automated Control System (WAX)," a critical path scheduling system for the control of preconstruction engineering activities.

According to a paper on the system presented to the AASHO Committee on Electronics, "this system uses the critical path method of scheduling precontract engineering activities for the best utilization of resources, both manpower and financial" (*12-4,* p. 1).

A brief description of the system follows (*12-4*):

> The arrow diagram for the critical path was developed from a basic premise that preconstruction engineering activities are grouped into five general stages: the Reconnaissance Report; the Design Report; the Access Report; the Preparation of Plans, Specifications, and Estimates, including Right-of-Way Acquisition; and the Advertising Period. These stages are identified in the data system to assist in report production. A basic network for a design project—reconnaissance through advertising—together with alternative networks for a complex Federal Aid Project, could result in a schedule with as many as 670 Activities.
>
> . . . .
>
> [T]he system provides for the generation of an initial schedule for review and revision by the District personnel and as many prefinal schedules for review and revision by both District and Headquarters personnel as are necessary to produce a schedule that is mutually satisfactory.
>
> For scheduling, the system further provides for the use of this mutually approved or deadline schedule for monitoring progress of the schedules and for retrieving information for planning work loads.
>
> For control, the system finally provides for the updating of the schedule and the production of a new current schedule on a biweekly basis.

A page of the WAX CPM output is shown in Figure 40.

AASHO COMPUTER PROGRAM LISTINGS RELATED TO DESIGN

A number of special computer programs are available for analyzing various design problems where there are alternative choices available. Most such programs have an engineering economy dimension in that they include some provision for comparing the various feasible design alternatives on a cost basis to determine the least cost solution. Although they do not deal in cost, others gear design to actual conditions to deter "overbuilding and underbuilding," as a result of applying uniform solutions.

Many of the currently available programs are listed in the *AASHO Computer Program Index* (*12-3*) published periodically by the AASHO Subcommittee on Electronics. Table 31 gives the various categories of application for which computer programs are available.

The following references excerpted from the *AASHO Index* reveal the variety of programs that are applicable to analyses of alternatives leading to the most economical choice.

Bridge Design

Ohio Highway Department (*12-3,* p. 78): "Bridge Optimum." A process to obtain the minimum cost design for a continuous plate girder of uniform depth.
Computer: IBM 360/50.
Language: FORTRAN.

Montana Highway Department (*12-3,* p. 54): "Hydraulics of Bridge Waterways." (A modified version of BPR program HY-4.) This program computes slope of channel, normal stage, and backwater for up to 99 trial constrictions.
Computer: IBM 360/30/64K.
Language: FORTRAN IV F.

Culvert Design

Ohio Highway Department (*12-3,* p. 78): "Culvert Design." Generates most economical type and size of culvert for a given set of hydrological conditions.
Computer: IBM 1410.
Language: FORTRAN.

Oklahoma Highway Department (*12-3,* p. 54): "Design and Analysis of Roadway Culverts." A combined program to handle box culverts, circular pipes, and pipe-arches in one execution. (Adapted from BPR HY-Series.)
Computer: IBM 360/40-65K.
Language: FORTRAN E.

Economic Impact

Missouri Highway Department (*12-3,* p. 45): "Four-Quarter Moving Averages." Economic trends of retail sales by geographic area to show impact of highway relocation.
Computer: IBM 1620-60K.
Language: SPS.

NEW PROJECT PREFINAL DISTRICT
DUE DATE 07 MARCH 1968

WASHINGTON STATE HIGHWAY COMMISSION
CPM REPORT DATE 26 FEBRUARY 1968

PROJECT		PROJECT DESCRIPTION											PROGRAM 7
33084BA		SR 112 S-0217CLALLAM BAY TO CLALLAM RIV											
				CURRENT SCHEDULE				DEADLINE SCHEDULE					
I - J	ACTIVITY DESCRIPTION	RESPON. UNIT	DUR-ATION	EARLY START	EARLY FINISH	TOTAL FLOAT	DUR-ATION	EARLY START	EARLY FINISH	LATE FINISH	LAG		
483 484	REVU PRLM CONTRACT SIGN PLANS	LOC	5	30SEP68	07OCT68	88	5	18JUN68	25JUN68	12DEC68			
485 486	REVU PRLM CONTRCT ILLUMN PLANS	LOC	5	30SEP68	07OCT68	88	5	18JUN68	25JUN68	12DEC68			
085 088	REVIEW HYDRO STUDIES	DES	5	02OCT68	09OCT68		5	25JUN68	02JUL68	02JUL68	69-		
498 120	APPRAISE & NEGOTIATE FOR SITE	R/W	3	02OCT68	07OCT68	83	3	20MAR68	25MAR68	05DEC68			
498 135	RESTRAINT	HR/W		02OCT68	02OCT68	75		20MAR68	20MAR68	19NOV68			
486 487	PREP ESTMIMATE DATA	TRAFF	10	07OCT68	22OCT68	88	10	25JUN68	10JUL68	27DEC68			
486 480	PREP SPECIFICATIONS	TRAFF	10	07OCT68	22OCT68	88	10	25JUN68	10JUL68	27DEC68			
088 105	PREPARE PS&E DATA FOR DRAINAGE	PE-13	20	09OCT68	08NOV68	30	20	02JUL68	31JUL68	18OCT68			
093 096	PREPARE R/W TRUE COST ESTIMATE	R/W	10	09OCT68	24OCT68	40	10	05JUL68	19JUL68	18OCT68			
095 100	REQUEST UP-DATE TITLE EVIDENCE	TITLE	28	09OCT68	21NOV68	23	1	17JUL68	18JUL68	21OCT68			
095 500	SUB PRL PL-UTL CLALLAM CO PUD	PE-13	1	09OCT68	10OCT68	47	1	17JUL68	18JUL68	16OCT68			
109 114	REVIEW R/W PLANS/PROFILES	LOC	1	09OCT68	10OCT68		1	17JUL68	18JUL68	18JUL68	59-		
109 138	PREPARE PS&E PLANS/PROFILES	PE-13	10	09OCT68	24OCT68	61	10	17JUL68	31JUL68	20NOV68			
109 501	RESTRAINT CLALLAM CO PUD	PE-13		09OCT68	09OCT68	53		17JUL68	17JUL68	23OCT68			
117 480	PREP FENCING PLANS	PE-13	5	09OCT68	17OCT68	63	5	10JUL68	17JUL68	15NOV68			
114 118	REV&APPR R/W PLANS/PROFILES	HRWAC	10	10OCT68	25OCT68		10	18JUL68	01AUG68	01AUG68	59-		
500 501	OBTN PLNT DATA CLALLAM CO PUD	PE-13	5	10OCT68	18OCT68	47	5	18JUL68	25JUL68	23OCT68			

Figure 40. Sample output from the Washington Automated Control System. Source: (12-4, *p. 735*).

TABLE 31

CATEGORIES OF COMPUTER APPLICATIONS BY HIGHWAY DEPARTMENTS [a]

MAJOR	INTERMEDIATE	MINOR
1. Planning	1. Programming	
	2. Highway inventories	
	3. Loadometer	
	4. Traffic control	1. Accident studies
		2. Traffic permits
	5. Traffic studies	1. O&D studies
		2. Traffic assignments
		3. Traffic counting
	6. Other studies	
2. Engineering	1. Location and survey	
	2. Design	1. Hydraulics
		2. Soils and materials
		3. Road design and earthwork
		4. Structures
		5. Geometrics
	3. Right-of-way	
	4. Construction	
	5. Maintenance	
3. Financial management	1. Budget and encumbrances	
	2. Cost accounting	
	3. Payroll and personnel	
	4. General accounting	
4. Administration and management	1. Management report	
	2. Bid letting	
	3. Inventories	
	4. Motor vehicle and driver's license	
5. Data processing service programs		

[a] Source: (*12-3,* p. 6).

Long-Range Planning

Missouri Highway Department (*12-3,* p. 3): "Long Range Planning (Supplementary)." This program package stores road data on tape for easy access, produces percentage deficiency from design standards and cost of upgrading road segments.

Computer: IBM 1410-40K.

Language: COBOL.

Project Priority

Idaho Highway Department (*12-3,* p. 1): "Improvement Priority Evaluation." Computes benefit/cost ratio for project priority evaluation.

Computer: UNIVAC SS-90.

Language: X-6.

Roadway Design

Pennsylvania Department of Highways (*12-3,* p. 52): "Roadway Design." Grade profile, template generation, and cut/fill areas and volumes.

Computer: BURROUGHS 5500/32K.

Language: FORTRAN.

Travel Time

Washington State Highway Department (*12-3,* p. 33): "Route Analysis." Given speed zones, finds zone to zone time measurements, computes time ratio of existing and proposed routes, volume assignment, and travel times.

Computer: IBM 1620.

Language: SPS.

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12-2. ALEXANDER, C., and MANHEIM, M. L., "The Design of Highway Interchanges: An Example of a General Method for Analyzing Engineering Design Problems." *Hwy. Res. Record No. 83* (1965) pp. 48-87.

12-3. AMERICAN ASSOCIATION OF STATE HIGHWAY OFFICIALS, *AASHO Computer Program Index.* Subcommittee on Electronics, Washington, D.C. (Nov. 15, 1968).

12-4. BULLEY, W. A., *Washington's Automated Control System (WAX), Olympia: State of Washington*

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CHAPTER THIRTEEN

RESEARCH NEEDS RELATED TO ECONOMIC ANALYSIS

The research studies listed in this chapter relate specifically to the needs for input data and concepts and procedures for economic analysis. There is no attempt to cover the broad scale of research needs as related to the total aspects of highway transportation. The economic analysis is one of the activities leading to preparing material for ultimate consideration by the decision maker in determining whether the highway facility should be constructed; and, if it should be constructed, to what specific location and design.

These listings of research studies have not been correlated with research now under way. At the time a research program is considered that might involve one of the items in this list, the current situation would be investigated, so that new research would not duplicate work under way or recently finished.

The listing of the 55 specific research needs under the eight general topics does not represent a research program or major research projects made up of studies or subphases. Rather, the intent is to call attention to the need for specific information to improve economic analysis. It is assumed that any agency undertaking research in these areas would design a research program or project to cover such subjects as would logically fit together in a research effort. Many of the separate listings should be combined into projects of wider scope if adopted as a research program.

The greatest need in the field of economic analysis for highways is for input data required for solution of specific applications, not for analytical procedures. It is noted, however, that some procedural and conceptual studies are suggested.

The input data involve the following general subject areas:

TOPIC FOR RESEARCH	NO. OF STUDIES SUGGESTED
A. Motor vehicle running cost	11
B. Travel time and personal preferences	4
C. Motor vehicle performance in traffic	7
D. Traffic accidents	14
E. Social and economic effects	8
F. Community factors	3
G. Highway construction and maintenance	2
H. Analysis concepts and procedures	6
Total	55

The research studies listed are classified by these subject areas. The listings are not in order of time or priority of importance. No attempt is made to estimate the dollar cost of the research effect required to produce the desired results.

The normal sources of research activity and funds to perform the research include the following agencies:

1. State and other highway departments.
2. Educational institutions.
3. Research institutions and foundations.
4. National Cooperative Highway Research Program.
5. Federal Highway Administration.
6. Federal Mass Transit Administration.
7. Federal Department of Housing and Urban Development.
8. Private industry.
9. Trade associations and foundations.

The whole area of economic analysis could be materially improved through giving the subject specific attention in connection with programs of research, data collection, observations of traffic performance, and planning operations. Numerous examples are to be found in past studies of traffic performance, traffic accidents, vehicle operating cost, transportation planning studies, and highway maintenance where a small amount of additional effort would have produced much information useful in economic analysis of highway improvements.

The Federal Highway Administration and the highway departments should be encouraged to give the needs of economic analysis attention in their total research and planning efforts on projects that have other objectives, but on which data necessary to economic analysis could be gathered.

RESEARCH NEEDED IN SUPPORT OF ECONOMIC ANALYSIS OF HIGHWAY TRANSPORTATION IMPROVEMENTS

Group A. Motor Vehicle Running Cost

A-1. Title: Additional Field Work on Motor Vehicle Running Costs Following Final Reporting of NCHRP Projects 2-5, 2-5A, and 2-7.

Objectives and Situation: It is desirable to review critically the final reports on NCHRP Projects 2-5, 2-5A, and 2-7 to determine what additional field work on fuel consumption, oil consumption, tire wear, vehicle maintenance, and vehicle depreciation needs to be done to complete a reasonable scope of empirical performance of vehicles.

These contracts have moved ahead to their present status without a critical review of the total areas of information that should be collected with respect to type of vehicle, traffic condition, and the geometrics of highway design on which field tests should be conducted. It is highly desirable that all of the accomplishments in this series of NCHRP contracts be reviewed critically as a basis for developing a work program to fill the gaps and in order that the necessary extrapolations and interpolations can be made to cover adequately vehicles, traffic, and highways.

A-2. Title: Reduction and Organization of the NCHRP Projects 2-5, 2-5A, and 2-7 Data to a Form for Direct Application to Economic Analysis.

Objectives and Situation: The objective is to take the specific data, interpolate and extrapolate them, and make other adjustments, such that full tables covering all conditions of operation and highway elements will be available for direct use for economic analysis.

It is desirable that the completed data from these NCHRP contracts be assembled in tables covering the full range of speeds, grades, curves, and other elements of highway design as will be necessary to make the data generally applicable. This task will be a sizeable one but it is a necessary step before the full value of the field research can be realized.

The work will involve assignment of the running cost factor of fuel, tires, oil, vehicle maintenance, and vehicle depreciation to vehicle speed and speed changes for highway design factors of distance, horizontal curves, vertical plus and minus grades, and roadway surface type. Also, the assignments will involve several classes of vehicles.

A-3. Title: Assignment of Vehicle Maintenance Expense to Vehicular Speed and to Elements of Highway Design.

Objectives and Situation: The expenses of repairs, servicing, and general maintenance of motor vehicles no doubt are related to the speed the vehicle is driven and to the elements of highway design. The objective of this study is to determine a method of assigning the maintenance cost to speed and highway design and also to make the direct assignments wherein the basic maintenance expense is available.

The maintenance expense of a vehicle is as much a part of the running cost of that vehicle affected by highway design and traffic conditions as is the consumption of fuel, tires, and oil, which expense items can be measured fairly well by running test vehicles under the situations considered. The over-all maintenance and repair expense of an average vehicle, though, cannot be determined by operating a test vehicle. It is essential that some assignment of maintenance expense be made, however, to speed and speed changes and to the elements of highway design in order that the economy studies of highway design can include all of the motor vehicle running costs that are affected by highway design and traffic conditions.

A-4. Title: Assignment of Motor Vehicle Depreciation Expense to Vehicle Speed and to Elements of Highway Design.

Objectives and Situation: The objective of this study is to develop methods for assigning and to assign the depreciation expense of vehicles to the elements of speed and to the highway design elements (distance, vertical grades, horizontal curves, roadway surface type) in a form that would be usable in economic analysis.

In the end, a vehicle goes to the scrap pile. At that time the cost new, less its scrap value, is the total depreciation expense that is chargeable to the past operation of the vehicle. The speed of the vehicle, the highway design, and the traffic action under which the vehicle operates have a bearing on how the depreciation expense should be allocated. A vehicle will be driven more total miles in its lifetime when driving conditions are comparably easy on the vehicle. Further, the total mileage on which to allocate depreciation being a function of the obsolescence and styling of a vehicle, the vehicle that is driven a minimum of miles per year will not have nearly as many total vehicle-miles in its life as will a vehicle that is driven high annual mileages. Perhaps a relationship exists between the total annual miles and the total life miles of a vehicle with respect to the speed it is driven and to the conditions of the highway over which it is operated.

A-5. Title: Running Cost of Motor Vehicles When Operating Over Rolling Grades.

Objectives and Situation: It is desirable to determine the over-all running cost of vehicles operating in an area of basically rolling grades; that is, grades that frequently change plus to minus in relatively short distances so that it is difficult to determine their running cost in a reliable manner by using specific percentages of plus and minus grades.

Ordinarily, the running costs of vehicles are developed and put into tables in the form of running cost per mile for a certain class of vehicle operating up or down given specific percentages of grades. These running costs are reliable for the longer length of grades; but, where the vehicle is continuously going up and down in rolling country, it is questionable as to how well the particular published tables apply. It is desirable, therefore, to do field test work to measure the fuel consumption for operation over rolling grades. Also, tire wear and oil consumption should be measured. In the end, tables should be calculated so that the running cost could be used directly on a vehicle-mile basis for operation over rolling grades. The index might be one of total rise and total fall per mile, but perhaps some other scheme can be developed.

A-6. Title: Running Cost of Motor Vehicles When Simultaneously Operating on Combined Vertical Gradients and Horizontal Curves.

Objectives and Situation: It is desirable to determine the motor vehicle running costs for vehicles operating on combined grades and horizontal curves. So far the field work (with minor exception) has been limited to determining fuel consumption, tire wear, and oil consumption on vertical grades separately from horizontal curves and vice versa.

Often, particularly in mountainous country, highway design combines simultaneously a gradient and a horizontal curve. It is desirable to see whether the running costs of the vehicles under this combined condition are the sum of the separate operations on grades and horizontal curves, or whether there is an adjustment factor to apply. The work applies especially to the excess vehicle running cost on grades and the excess cost on curves above operating on level tangents.

A-7. Title: Motor Vehicle Running Cost on Urban Streets.

Objectives and Situation: To enlarge on the scarce data available it is desirable to determine the motor vehicle running cost of different classes of vehicles operating over different types of urban streets.

In urban streets there is a high degree of speed changes and a fairly low limit on maximum speed. It is difficult to determine motor vehicle running cost in urban areas on a specific speed and speed change basis because generally the vehicle is continuously changing speed, including making many stops. It is desirable to determine the running cost of vehicles in normal operation over urban streets, including residential areas, business areas, and downtown areas, in such a form that the running cost can be expressed in terms of key indices, such as type of highway design, ADT, or stops per mile. This type of table of running cost will facilitate the economic analysis for general purposes. It would not replace, however, the specific analysis for conditions where speed, speed changes, grades, and curvature can be itemized.

A-8. Title: Running Cost and Time of Travel Under Congested Conditions of Traffic.

Objectives and Situation: It is desirable to determine the running cost and travel time of traffic under congested conditions—more specifically under the morning and peak-hour traffic in urban areas and on special facilities for week-end, vacation, or recreational type of traffic. These costs probably could be determined from observations of the speed and speed change distributions of the traffic under congested conditions. One analysis that is available indicates that, in urban areas under congested conditions, a vehicle may spend 25 percent of its total travel time with an idling motor, awaiting the opportunity to move ahead.

A-9. Title: Annual Travel Time Consumption by ADT's and Highway Type.

Objectives and Situation: There is need to prepare over-all yearly travel time for highways by design type, geographic conditions, and for different ADT's.

As now generally practiced, the travel time for each project is calculated by use of the operating speeds for traffic adjusted for speed changes and other special factors. It would facilitate analysis to have available over-all tables of general application of the travel time under specific conditions of traffic volume, highway design, and route geometrics. The calculations would be based on speed distribution and speed change distribution by hourly traffic volumes.

A-10. Title: Annual Running Cost of Motor Vehicles Based on Average Daily Traffic and Average Hourly Traffic for Different Highway Types.

Objectives and Situation: For convenience of the analyst in making highway engineering economy studies, it is desirable to have the annual total motor vehicle running cost expressed specifically for traffic volumes and for different highway types. Therefore, it is desirable to explore what can be done in developing the tables or curves for this application.

Ordinarily, although each highway improvement or each highway route varies considerably in how it affects motor vehicle running cost, for many different types of analyses, particularly preliminary analyses, it is feasible and reasonable to express the total running cost of vehicles for a year as related to the traffic volumes for each general type of highway. Such tables would shorten the ordinary analytical procedure and make adaptation to computer calculations more feasible than it is now.

A-11. Title: Road Weight of Motor Vehicles by Classification Types.

Objectives and Situation: The weight and weight distribution of all vehicles on the highway should be determined and made available for economic analyses, taxation studies, and other applications.

With the exception of the heavier trucks, which are weighed in most every state every summer, there is a distinct lack of road weights of vehicles in the light truck, passenger car, and bus classifications. In economic analysis, the weight of the vehicle is a good index to its running cost and over-all traffic behavior. It is therefore desirable to conduct a visual vehicular classification count of all the vehicles on typical types of highways, both urban and rural, and at the same time to weigh the passenger cars, buses, and light vehicles in much the same way that the states weigh trucks. This information would be helpful in determining the typical vehicle on which running cost and performance data should be gathered and made available in tables for economic analyses.

Group B. Travel Time and Personal Preferences

B-1. Title: Value of Travel Time.

Objectives and Situation: Although substantial progress has been made in determining the value of time for commercial vehicles and for passenger automobiles, considerable work is still advisable. What is lacking is variations in travel time value attributable to geographical areas, trip purposes, highway designs, and other factors. Two of the elements not yet thoroughly investigated relate to the minimum amount of time that is of value to highway travelers, and the value of time as available in different hours of the day as well as for specific types of trips. (The Federal Highway Administration has a contract under way that will cover passenger car travel time value as related to trip purpose and family income.)

B-2. Title: Highway Cost Required to Produce Reductions in Travel Time.

Objectives and Situation: In the earlier work done by the Stanford Research Institute for the Bureau of Public Roads, the concept of the cost of time as expressed in terms of highway costs required to produce specific reductions in travel time was developed. This idea was explored and a manual was written by SRI by which to apply the method to a variety of situations in order that values of the cost of time could be determined by highway departments. The work has not yet been undertaken by any state, but it is hopeful that the states will do so. The Federal Highway Administration is planning to distribute a procedural manual on this subject.

B-3. Title: Value of and Quantification of Item of Personal Preference of the Road User.

Objectives and Situation: The highway traveler puts considerable weight on comfort, convenience, mental strain, physical strain, privacy, security, and the noise factor encountered in driving different classes of highways at different times of the day. So far, these items have not been successfully quantified or priced, and often they have not been identified. It is desirable that a systematic research be undertaken to determine the character of these items of personal preference and show how they can be identified, quantified, and priced so that they can be positively taken into consideration in the studies of highway economics and desirability of alternative highway improvements.

B-4. Title: Yearly Average Vehicle Occupancy Rates by Ages of Occupants for Rural and Urban Driving by Highway Types.

Objectives and Situation: For use in calculating the gross value of travel time and for wages lost in traffic accidents, additional information is needed on the age of vehicle drivers and passengers, their occupation, and economic status. These data need to be known by time of day for the year and by highway type and location.

Group C. Motor Vehicle Performance in Traffic

C-1. Title: Instrumentation for Counting, Classifying, and Speed Recording of Traffic at Roadside Stations.

Objectives and Situation: At present, permanent traffic counting stations operated by the state highway departments are counting vehicles by the hour, but are not classifying the vehicles or recording vehicle speed. It is desirable to develop instrumentation by which at these permanent recorder stations, and others on a temporary basis, the total traffic stream for the year can be identified as to type of vehicle, the numbers of each type of vehicle, and the speed at which the counting station is passed. On the development of this instrumentation, the desirable data to use in economy studies with respect to the speed and vehicle classification would be more readily available; furthermore, it is possible that the total operation could be conducted far more economically than by the present system. The recorder data could be fed directly into electronic computers and processed without manual effort being applied.

C-2. Title: Instrumentation for Recording Speed, Speed Changes, and Distance of a Test Vehicle in Traffic.

Objectives and Situation: To aid in collecting traffic performance data under specific situations there is need for an electronic instrument that will record the speed, distance, vertical grade, and horizontal curve, second by second, as a test vehicle drives in traffic. Also to be indicated, by manually operated buttons, would be special situations encountered with reference to highway design factors and traffic conditions. This recording instrument should be designed for direct feed as input data to a plotting computer so that a speed profile can be obtained and summaries can be made without need for manual calculations or recordings.

C-3. Title: Traffic Performance With Respect to Speed Distribution and Speed Changes Related to Specific Conditions of Traffic and Highway Design.

Objectives and Situation: Vehicle speed and changes in speed are the important factors in comparing vehicle running costs on alternative proposals for highway improvements. Yet, little is known about how speed and speed changes are affected by highway design, traffic controls, and traffic characteristics. Research of an extended nature is proposed to assemble the desired performance data. A few illustrative situations for which the speed data are wanted are:

Pavement width
Shoulder width
Pavement plus shoulder width
Minus grades and plus grades
Plus grades with and without uphill truck lanes
Horizonal curves
Combined grades and horizontal curves
Intersections by traffic control scheme
Interchanges
Divided highways under congestion on grades
In a specific urban community as a whole when new types of highway facilities are open
By basic type under conditions of changing hourly traffic volumes
Wet and flooded pavements
Overtaking and passing
With and without highway lighting
During an accident in the general area

C-4. Title: Speed Distribution of Traffic on a Yearly Basis.

Objectives and Situation: The literature is deficient in its reporting of the speed and speed distribution of different classes of vehicles on anything but a spot basis for a few hours. It is desirable that the speed distribution for a full year be determined for many kinds of traffic conditions and many types of highway designs. This information could be collected in the field by the installation of special types of electronic equipment to count and record the speed of the traffic by types of vehicles in the traffic stream.

C-5. Title: Economy of Wide Bridges and Pavements Based on Traffic Volume, Traffic Speed, and Speed Changes.

Objectives and Situation: With the present high standards of wide pavements, wide shoulders, and wide bridges, considerable construction money is being put into the widening of pavements, shoulders, and bridges. The economics of this widening are not fully understood because data are not available as to exactly how the traffic will behave after the changes are made with respect to its behavior ahead of the change in highway geometry. The accident rate also should be observed. This work could be achieved by taking before and after measurements of the behavior of traffic on current widening projects, and on old narrow bridges compared to new full roadway width bridges of different lengths.

C-6. Title: Adverse Travel Time, Adverse Travel Distance, and Vehicle Running Cost Caused by Certain Types of Highway Facilities.

Objectives and Situation: Certain types of highway designs and certain types of traffic controls result in adverse travel (increase in travel as compared to the before condition) by the motor vehicles, excess travel time, and other extra cost consequences. Although the ultimate net advantage may be positive for these kinds of highway facilities, nevertheless the adversities should also be identified, quantified, and priced. As a way of illustrating what is in mind, consider the following: one-way traffic, access control, reversible traffic flows, no turns, truck prohibitions, and peak-hour restrictions on movements of vehicles.

C-7. Title: Rerouting, Travel Time, and Running Cost Effects of Construction and Maintenance Operations on Highway Traffic.

Objectives and Situation: The Bureau of Public Roads has issued to the states a manual on how to conduct studies of the handling of traffic through construction or detouring of traffic during construction and heavy maintenance operations. The objectives are to determine what it costs the contractor, what it costs the state, and what it costs the traveling public in connection with such detours or by handling traffic through construction. These observations should result in better information to determine how best to handle traffic during construction and maintenance operations and how to determine the reasonableness of contract bids on proposed construction in which the traffic must be taken care of through the construction site.

Group D. Traffic Accidents

D-1. Title: Before and After Accident Rates and Costs for Spot Improvements and TOPICS [1] Improvements, Together with the Cost of the Highway Alterations Intended to Reduce the Accidents Rates or to Improve the Traffic Flow.

Objectives and Situation: Evaluation of the economy of the spot accident reduction program and the TOPICS traffic improvement program is handicapped by the absence of before and after data of costs, traffic flow, speeds, accidents, and other data. It is proposed to have the states report the full data on a substantial number and variety of such improvements with the before and after information to make possible reliable analyses of the economy effected. These analyses would be available as guides to the selection of each year's improvement programs.

D-2. Title: Effects on Traffic Accidents of the Following Types of Highway Improvements: (1) Conversion to One-Way Traffic, (2) Installation of Lighting, (3) Change in Vertical Grades, (4) Changes in Horizontal Curve, (5) Intersection by Design Type and Traffic Control, (6) Interchanges by Design Type, (7) Reversible Traffic Flows, and (8) Other Types.

Objectives and Situation: There is need for accident rates and accident costs as related to specific types of highway design changes and traffic control changes. Research on this need can be accomplished by analysis of available records, before and after studies, and simulation and model analyses.

D-3. Title: Traffic Accident Rate for Commercial Vehicles.

Objectives and Situation: Although reports are available that indicate something of the frequency and severity of truck traffic accidents, little is known about the relative accident rate or the cost of the accidents as attributed to specific classifications of commercial vehicles and trucks. Generally, heavy trucks have a better accident record on the basis of vehicle-miles of travel than do passenger cars; however, some evidence exists that lighter-weight trucks and middle-weight trucks may have a higher accident rate than tractor-trailer combination vehicles. A detailed study of the accident records of the commercial vehicles by weight and axle classification is needed.

D-4. Title: Accident Records and Accident Rate Correlation with Speed, Average Hourly Volume, and Highway Type.

Objectives and Situation: In spite of the volume of accident data available, there is still need for further analyses of traffic accidents with respect to speed, average hourly volume, and highway type. These studies should be made with specific attention to collecting information necessary to economic analysis of highway improvements.

D-5. Title: Relation of the Involvement Rate to Accident Rates.

Objectives and Situation: There are two ways to report traffic accidents: (1) by involvement (i.e., the number of vehicles involved), and (2) by accidents, without reference to the number of vehicles involved. Both forms of compilation of the data are desirable because they serve different statistical analyses and different economic and financial applications. Little is known, however, as to the over-all correlations between involvement rates and accident rates

[1] Traffic Operations Program to Increase Capacity and Safety.

for particular types of highways, types of accidents, and according to other descriptive characteristics of accidents. The proposal is to analyze accidents and reports to develop the ratio of involvements to accidents for highway types, traffic volume, and type of accident.

D-6. Title: Accident Frequency and Cost by Severity, by Highway Design, and by Traffic Volume.

Objectives and Situation: In spite of a large amount of study devoted to traffic accidents, there is still a lack of reliable figures for frequency, or rate, or accidents by severity class and by highway design and traffic conditions. This study is fairly well covered at the moment in the FHWA's Interstate Highway System Accident Study, but it needs to be extended to all rural highways and urban highways, roads, and streets. In proposed highway improvements, the accident factor has often been neglected in the economic analysis because of lack of accident frequencies and accident cost data. This situation could be improved by a systematic study such as was started under NCHRP Project 2-3 by the Cornell Aeronautical Laboratory.

D-7. Title: Annual Costs of Accidents by ADT and Highway Type.

Objectives and Situation: Reports on traffic costs are usually presented in one of two ways: (1) type of accident on certain kinds of highways, or (2) in total cost for an area or a highway system for the year. In connection with economic analysis, it would be highly desirable if tables of average annual costs of accidents could be compiled on the basis of ADT by specific types of highways and geographical location. Sufficient information now is available to price out the accidents, but difficulty may be encountered in determining the relative frequency of accidents under the specific highway designs, highway types, and ADT's for which it is desirable to prepare the information.

D-8. Title: Cost to Traffic in the General Area of Traffic Accidents But Not Involved in Such Accidents.

Objectives and Situation: Traffic accidents frequently cause considerable rerouting, speed changes, and time delays for traffic in the general vicinity. These costs to the traveling public are one result of traffic accidents and should be accounted for in the studies of the cost of traffic accidents. Little has been done in this field, but it is reasonable to believe that the total cost is significant. Some experimentation will be required to determine the best ways of collecting the field data on the traffic behavior. It would be necessary to get measurements of traffic performance from the moment of the accident for the duration of time until the traffic regained its normal performance.

D-9. Title: Off-Site, Indirect, and Other Costs of Accidents Not Normally Reported.

Objectives and Situation: The cost-of-accident studies in Massachusetts, Utah, New Mexico, Illinois, and Washington, D.C., have included only such costs as were directly involved in the accident, such as property damage, cost of injuries, hospitalization, and court costs. In addition to these specific costs, many others are occasioned by people not directly involved in the accident but who are related to the individuals concerned, either as relatives, friends, or associates in work. In addition, there is a considerable amount of additional expense at home, in travel, in court appearances, accident reporting, and other activities, including those costs incurred by public officials. Before the total cost of traffic accidents can be known (i.e., the cost to society as a whole) these expenses and costs and time consumptions that involve others as well as those directly associated with the accident need to be systematically studied.

D-10. Title: Wages Lost and Extra Wages Paid as a Result of Traffic Accidents.

Objectives and Situation: Most past accident cost studies (Utah, New Mexico, Illinois, and Washington, D.C.) have reported wages lost by traffic accident injuries by the product of the work time lost and the wage rate. No data were reported on whether the injured person actually was paid or not paid for the off-duty time, or on whether extra help was hired or overtime was paid to others. It is proposed to collect data on the total concept of wages paid and wages not paid and changes in wage payments because of traffic injury accidents.

D-11. Title: Insurance Compensation Received from Traffic Accident Injuries.

Objectives and Situation: The objective is to determine the recovery rate of traffic accident costs from each type of insurance by accident types, and including any compensation paid for lost work time. Traffic accident data do not report the total insurance settlements—recovery of costs and compensations paid—other than those directly covered by a motor vehicle accident policy. The purpose of this proposal is to study the effects of the whole of insurance coverage involved in traffic accidents.

D-12. Title: Relation of Traffic Accidents to Construction and Maintenance Operations, Including Detours.

Objectives and Situation: The traffic accident rate and traffic accident costs need to be determined as related to highway construction and highway maintenance operations. The accident costs desired are those that relate to the traveling public and to their relationship to highway operations.

The objective is to study primarily the accidents to the traveling public and their effects on accidents to construction workers and property. These studies should attempt to determine whether traffic should be removed from the site of highway operations or whether it would be desirable to carry the traffic through the construction site.

D-13. Title: Wage and Salary Earnings and the Cost of Sustaining a Person in Society, by Age, Trade, and Profession.

Objectives and Situation: In connection with a traffic fatality or a permanent disability, it has been proposed to arrive at the economic cost by a discounted time study of the probable earnings of the individual fatality or permanent disability for the remainder of expected life and that the present worth of these earnings be reduced by the present worth of sustaining that individual in his working position, including training and education and other special expense. As economic theory, this approach has considerable merit. Lacking, however, in its application are the detailed tables of earnings and of subsistence costs that are necessary for such calculations. However, the necessary working tables probably could be prepared with available statistics from the Bureau of the Census, the Labor Department, and others.

D-14. Title: Maximum Costs the Public Should Incur to Reduce or to Eliminate a Type of Accident of Specific Severity.

Objectives and Situation: In connection with all major efforts to reduce the traffic accident rate and to reduce the severity of accidents, little attention has been paid to what maximum expense society can afford to reduce a personal injury in severity, to reduce the severity of a permanent disabling injury, or to eliminate a traffic fatality. There must be some upper limit beyond which public funds should not be devoted to such type of accident prevention work. This study would result in guidelines that could be used by all public officials in the decision process on all highway improvements directed specifically toward the improvement of the safety record.

Group E. Social and Economic Effects

E-1. Title: Correlation of Local Economic Impact with the Origin and Destination of Traffic and with Total ADT.

Objectives and Situation: In most of the past economic impact studies of highway improvements, little attention was paid to the origin and destination of the traffic on the before and after basis for correlating the O&D of the traffic and total ADT with the effects on roadside and community activities and retail trade. It seems reasonable that highway-oriented retail trade might be more severely affected by highway relocation or by urban bypass construction if a high percentage of the traffic was through traffic or with origins and destinations outside of the local community. Further, the higher the percentage of the traffic that is of local origin and destination, the higher is the probability for a small effect on retail trade along the older route in the case of a relocation or of a bypass of an urban area. This type of information would be an aid in forecasting the severity of the economic impact for all types of proposed highway improvements wherein the origin and destination of the traffic is available.

E-2. Title: Shifts in Retail Trade as Caused by Highway Improvements.

Objectives and Situation: It is desirable to know in advance the probable ultimate effects on each type of business establishment that is required to move or that may be forced out of business by decreased trade after highway improvements are open to the traveler. This study should be related to the time element to determine over time what happens to the business volume as well as to its location. One additional item should be studied: Within an urban area in which an urban freeway is constructed, how much of the relocated business stays within the urban area or downtown area, how much goes out of business completely, and how much of the business moves to a suburban location? Associated with this study should be the cost to the business by way of lost trade, cost of moving, and cost of reestablishing the business.

E-3. Title: Total Cost and Total Benefit Associated with the Relocations of People and Business.

Objectives and Situation: Although it is well known that the families and business establishments required to relocate because of highway improvements suffer considerable costs, systematic studies seem to be missing that would give information on the total cost and benefits over time of the moving of people and business. Such information is desirable in connection with knowing how to compensate such people and also as to what may be their benefits and costs before and after moving.

E-4. Title: Ultimate Social and Economic Effects and Attitudes of Relocated People.

Objectives and Situation: Before the real economic and social effects of highway improvements can be determined for those individual families and people, as well as business, that are relocated, it is desirable to conduct studies for one, two, three, and up to ten years after these people have been forced to move. Such factors as their attitudes toward society, their economic position, and their social position should be determined for the relocatees and also for a group residing near the highway improvement but who were not forced to relocate. This study should collect the information on the amount of time relocatees had occupied the location at the time of taking and how long until it was to a second move.

E-5. Title: Benefits and Costs to Society of Not Moving a Household or a Business to Provide Rights-of-Way.

Objectives and Situation: Much effort in highway design and location in urban areas has been toward not moving people and businesses on the basis that the goal should be to move the fewest people and businesses. On the other hand, the highway construction cost and the future motor vehicle running cost incurred to avoid moving people and business are often high priced per person or business not moved. It would greatly aid the decision maker if he had some basis of determining what it is worth to society not to move an individual, a family, and a business.

E-6. Title: Value of Aesthetics of Highway Design and of Landscape.

Objectives and Situation: It is generally considered that the highway should be designed to contribute to the aesthetics of the neighborhood, and should be suitably designed and landscaped to blend in with the local environment and not to be criticized for being ugly. There may be no way that these aesthetic items could be actually identified, quantified, and priced, but it is worthwhile to make a scientific and planned study of them. At least, such a study would be desirable to point out what the decision maker could look at and how he might consider the aesthetic factors in his process of determining the highway alternative that should be constructed.

E-7. Title: Effects of Highway Design and Traffic Changes on Air Pollution in the Area.

Objectives and Situation: Because the highway design and location affect the fuel consumption of motor vehicles through grades, horizontal curves, speed, speed changes, and basic highway type, it is desirable that these factors be measured as to their contribution to air pollution. If this study can be performed, some of the social cost in this respect could be determined and a better basis could be afforded for choosing one proposed alternative location and design over others.

E-8. Title: Effects of Interchange Land Area Development on Interchange Traffic and Control, to Conserve Interchange Traffic Demand.

Objectives and Situation: Interchanges represent the access points to a superior system of transportation. As such, they are analogous to depots on the railroads or ports for shipping: they are likely points of intensive development designed to take advantage of the system's accessibilities. Insofar as the trip-generating land uses occurring at interchanges cause traffic demand to exceed interchange capacity, there is a negative effect on the system that develops congestion and bottlenecks. Economy of design and of use of interchange will be enhanced by studies of land-use development and means of controlling the development. Improvements in traffic forecasting will result.

Group F. Community Factors

F-1. Title: Effects on Local Activities During Highway Construction Operations.

Objectives and Situation: In urban areas particularly, highway construction operations currently have considerable effect on local activities, including retail business, wholesale business, social exchange, recreation, and general travel. If these effects are known, they could be used in the decision process of choice of alternatives as well as the rate of completing the construction. If the cost to the local community is high, perhaps the public should pay premium prices to work the contractor extra shifts to complete the work in a shorter time.

F-2. Title: Ultimate Disposition and Timing of Disbursement of the Money Property Owner Received From Payments for Rights-of-Way Takings and Damages.

Objectives and Situation: It is generally thought that the total cost of right-of-way and the damages paid to individuals are wholly and totally a direct cost to the community. Further, in the case of real estate taxes, many people believe that the land taken from the tax roles as private land and turned to public highways results in a direct loss of tax income. In this connection, little consideration is given to the fact that this money may be reinvested locally in real estate and business that is taxable and to the fact that these reinvestments may actually restore all of the losses to the tax base as well as values thereto. As a means of obtaining information in this respect, a study is proposed of the actual flow over a time period of that money paid to local landowners for the taking of their lands in connection with highway improvements. The real estate tax base, the real estate tax income, and the tax rate would be studied on a before and after basis for a five-year period.

F-3. Title: Flood Damages Related to Runoff and Backup Resulting From Highway Operations.

Objectives and Situation: In connection with the design of all drainage structures (i.e., culverts and bridges) the economic design depends on the probable future damage to private property that may be caused by backup water or rapid runoff as a result of highway improvements. It is in order to study individual locations to determine the damages to private land and to the public highway that result from the flooding of land related to highway facilities. This item in the economic analysis for the proper waterway or rate of flow through the highway facilities is a critical issue, because of the lack of good information on probable damage costs.

Group G. Highway Construction and Maintenance

G-1. Title: The Service Lives of Components of Highways.

Objectives and Situation: For the past several years some of the states have been keeping detailed records of the rate of constructing highways and the rate that highway pavements are resurfaced, abandoned, or reconstructed. As a result of these data, reasonably good information exists on the average service lives of different types of highway surfaces. Little has been done, though, with respect to the length of service of bridges, culverts, earthwork, and right-of-way. It is proposed that the state highway departments inaugurate studies to determine the service life of each of the main components of a complete highway.

G-2. Title: Expense of Maintaining Highways with Respect to Particular Aspects of Highway Design, Traffic Control, and ADT.

Objectives and Situation: Although the expense of maintaining highways, including the services to traffic, is a record kept by all highway departments, there is a scarcity of facts that relate the maintenance expense to specific features of traffic use of the highway. It is desirable to set up studies to better indicate the effect on maintenance expense of such items as: (1) average daily traffic, (2) traffic speeds, (3) peak-hour volumes, (4) access control, (5) type of highway median, (6) horizontal curves, and (7) vertical grades.

Group H. Analysis Concepts and Procedures

H-1. Title: Development of Computer Programs for Economic Analysis.

Objectives and Situation: The electronic computer is used extensively in certain phases of economic analysis and of system planning. No one, however, has made a systematic analysis of when it is advisable to use computer programs and when hand calculations might be profitable. Now that tentative detailed motor vehicle running costs are available in the proper form for economic analysis and the assembly of accident cost data to use in economic analysis is being approached, there is need for a systematic study of the application of computer services to this form of analysis. The study would require the cooperation of people knowledgeable in the performance of computers and computer programming and someone thoroughly familiar with the procedures for economic analysis, with particular reference to analysis methods and the input data required for every kind of proposed highway improvement.

H-2. Title: Rise and Fall Method versus Rolling Grade Method versus Specific Grade Method in Economic Analysis.

Objectives and Situation: Most of the engineering economy studies of highway design will apply a factor for the motor vehicle running cost on plus and minus grades at individual specific unit costs. Two alternatives to this procedure exist: (1) an over-all rise and fall method could be used, such as that given in *HRB Research Report No.*

9-*A;* and (2) an index to the degree of rolling grades could be used, provided that the running costs of the vehicles were first determined for a range of rolling grades. Rolling grades are here defined as a continuation of plus and minus gradient of rather short length, as contrasted to the type of grades found in mountainous countries where a straight uniform grade of, say, 3 percent might continue for one, two, or three miles. In the rolling country of southern Iowa or in the Ozark area rolling grades predominate on the highway systems.

H-3. Title: Economic Analysis of Interchange Spacing and Design.

Objectives and Situation: The spacing of interchanges and the particular design of an interchange offer a special type of problem subject to economic analysis. This problem is highly complex, extremely important, and is deserving of special attention by a team of experts in highway design, in traffic assignment in urban areas, and in the procedure for economic analysis. This team could produce a satisfactory procedure for determining the over-all economy of interchange design and spacing.

H-4. Title: Role of Income Tax as Related to Highway Improvements and Consequences.

Objectives and Situation: So far in economic analysis of highway improvements no consideration has been given to how such improvements and their use might affect income tax returns—local, state, and national. It may not be desirable to ignore the effect on income tax because the total highway operation does affect materially the income taxes paid, both through the original highway construction, maintenance operations, and in the motor vehicle running costs as an item of retail and wholesale trade.

H-5. Title: Ranking, Rating, Quantifying, and Pricing Social and Economic Factors, and Goals.

Objectives and Situation: Further study is desirable of how to deal with the social, economic, community, and personal preference factors that are not priceable, not quantifiable, or quantifiable but not priceable. The literature reports several schemes, but appears far from arriving at a satisfactory system. Applications should be worked out for single projects, route improvements, highway systems, and urban areas. Both project evaluation and project formulation should be studied. The ultimate objective is to serve the decision maker to greatest advantage.

H-6. Title: Reinvestment Rate in Economic Analysis by the Rate of Return Solution.

Objectives and Situation: Some of the economists who have written on the subject of economic analysis believe that the rate of return solution automatically assumes that all returns involved are reinvested at the rate of return solved for in that particular analysis. Other individuals do not accept this basic assumption and believe that how the money is reinvested is not a part of the analysis and that the rate of return from the project is independent of how the money is reinvested. Further, there is no discussion about the rate of return on reinvestment of the returns on the project in other methods of solution. A thorough investigation of the concept of the reinvestment of returns from an adopted alternative would contribute to the knowledge of economic analysis.

CHAPTER FOURTEEN

ILLUSTRATIVE ECONOMIC ANALYSIS OF A HYPOTHETICAL INTERSTATE HIGHWAY LOCATION PROPOSAL

As an aid to a better understanding of the material in this report and to illustrate some of the analytical procedures, an illustrative economic analysis is presented. This analysis applies to a set of four realistic, but hypothetical, mutually exclusive alternatives of an Interstate route location project. The solution illustrates many of the details and procedures of solution that are encountered in route location and in project design activities. To give the problem a greater resemblance of reality, a specific situation is described. All numerical values and factors of design and traffic are assumed, but their magnitudes are within a realistic reasonable range.

THE LOCATION SETTING

I-666 (Fig. 41) is a major route on the Interstate system that connects an important Atlantic oceanport with important industrial areas to the northwest and north. The ultimate connection to these industrial areas is I-888, now completed for its full length. I-666 was placed on the Interstate system at the express request of the Department of Defense as a connection from the Middle Atlantic port areas to the industrial areas farther to the north and northwest.

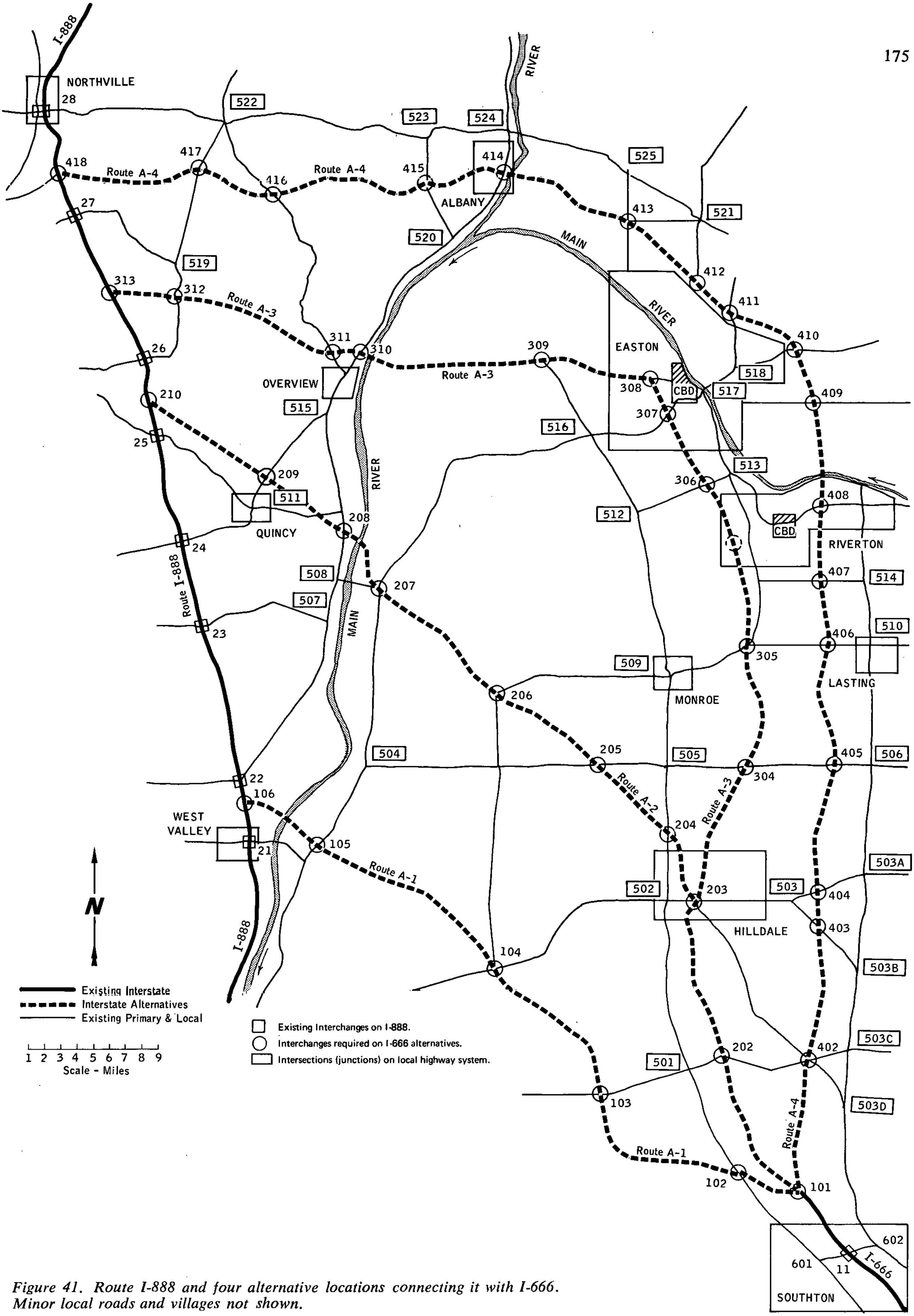

Figure 41. Route I-888 and four alternative locations connecting it with I-666. Minor local roads and villages not shown.

I-666 is about 70 percent completed in its total length. The critical section for which the location is not yet approved is that between the end of the completed section near Southton to some point on I-888 (Fig. 41). Four major location alternatives are under consideration. Minor variations in routing along these major locations are unimportant to the analysis at hand. Because of the defense and military values of I-666, the original concept was to locate I-666 primarily on the basis of a transportation facility to serve the objective of the route—a defense highway. In support of this concept, the northwest end section —that section making the connection with I-888 from Southton—was to follow the more direct routing from Southton to I-888 along the path represented by Alternative A-1. After the highway department had made considerable advancement with the preliminary engineering along Alternative A-1, strong pressures developed to locate this extension of I-666 northward from Southton and then westerly along a routing that would serve directly the urbanized areas along the general routing of Alternatives A-3 and A-4.

In view of these expressions of concern from the urban areas, and because of the possibility of serving future local needs, the state highway department enlarged its geographical area of study to include serving the urban areas directly with the I-666 extension to its connection with I-888 much farther north than originally considered.

The economic analysis presented here is assumed to result from the studies, surveys, and engineering developments on design completed by the highway department prior to making its final recommendations and prior to any public hearings. But the highway department did receive a heavy load of statements and communications supporting the urban routing.

A few statements that should bear on the final decision as to the routing of the I-666 connection between Southton and I-888 are as follows:

1. A route through the urban area changes the objective of this segment of I-666 from a defense and Interstate highway function to a highway to serve the local urban interests.

2. Not all of the available 42,500 miles of the authorized Interstate system have been allocated. This situation means that if one of the longer (A-3 or A-4) alternatives is chosen, there is less mileage by 58.501 miles on the system for other routes, the needs for which could be greater or lesser than the need for the longer routing for I-666.

3. From the viewpoint of the state and of the urban communities involved, the urban routing of the I-666 extension would be to their financial advantage. The 90 percent federal financing for this urban route would relieve the local funding for such routes as will be ultimately needed to serve the general urban areas between Southton and Northville.

4. The urban alternative routing (A-4) adds up to 15.842 miles of distance between Southton and Northville over that required by Alternative A-1 and 20.595 miles more than A-2. As of 1970 some 650 vehicles a day make the full through trip between Southton and Northville.

As Figure 41 shows, there are many other possibilities for routing of the extension of I-666 to I-888. These possibilities were investigated by the highway department, with the result that the chief engineer of highway location and design decided that Alternatives A-1, A-2, A-3, and A-4 could be used as a sound basis of determining the preferred general location of the extension of I-666 from both the user and nonuser viewpoints. In the final design process variations from the center-line location chosen can be made as advantageous changes come to the attention of the designers.

THE SOLUTION [1]

Presented herein is an economic analysis of most of the factors, user and nonuser, involved in locating the extension of I-666 to I-888. The road-user analysis, basically a highway engineering economy study of the four alternative locations, is presented first. Sufficient explanation, procedures, and results are offered so that it is possible for anyone to make his own analysis and arrive at approximately the same numerical findings.

The solution for the highway engineering (road-user) economy must be on an area or system basis, because the four alternative routes to be compared fulfill different objectives but yet are mutually exclusive (only one of the four alternatives or other routing will be constructed). Under these conditions, the equivalent uniform annual costs of the Interstate routes or the equivalent solution of present worth of costs cannot be used; the traffic volumes are widely different, the mileages are unequal, and the total highway construction cost varies accordingly. Considering all consequences to whomsoever they may accrue, the only logical procedure is to investigate the before and after transportation costs and benefits within the whole geographical area affected. The area analysis procedure is used in this solution.

Because construction of an Interstate route section of I-666 to connect I-666 at Southton with I-888 somewhere between West Valley and Northville has been ordered by competent authority, no objective is to be gained by calculating its road-user economy as compared to the existing travel between Southton and Northville or within the area as a whole. The analysis for economy, therefore, can be restricted to comparing the four alternatives, A-1, A-2, A-3, and A-4, in pairs with each other, and including the effects of each alternative on the total area traffic affected.

Following the economic analysis for the road-user economy as affected by each of the four alternatives, the social, community economic effects, and environmental values are discussed.

[1] Acknowledgment is made to Charles W. Dale of the Federal Highway Administration for the detailed arithmetic calculations and for his general contributions to the concepts and procedures used in this solution.

Because the urban alternatives A-3 and A-4 are designed to meet the needs for area traffic along the urban corridors, it is a necessary factor in the economic analysis to include supplementary highway construction during the 20-year analysis period required to provide a reasonable level of total highway service for the entire area, regardless of which alternative is chosen for the I-666 extension. This provision in the analysis is met by supplementary major highway construction in 1970, 1975, 1980, and 1985. This supplementary construction depends on the traffic capacity that is furnished by the I-666 extension, and is a maximum with Alternative A-1 and a minimum with Alternative A-3. In other words, the economic analysis, in keeping with the principle of considering all consequences to whomsoever they may accrue, is placed on a system basis, or area basis. Under this basis, the Interstate route plan becomes part of an area plan, rather than just a plan for the extension of I-666. Regardless of where I-666 is located, there will be major effects on the transportation within the rural and urban areas. These effects need to be considered under the doctrine of considering all consequences.

GENERAL PROCEDURE OF ANALYSIS

As Figure 41 shows, the interchanges on each of four alternative locations for I-666 and for I-888 are numbered. Further, intersections of local roads and highways are numbered where there is need to reference them as being affected by the I-666 extension.

Traffic volume and classification by class of vehicle for 1970 and 1990 are given for each section of Interstate and affected highways. From these traffic volumes and vehicle classification, together with the mileages between interchanges or intersections, the following road-user factors were calculated: running cost per year, accident costs per year, and travel time in hours for both 1970 and 1990. For the area-affected routes, these items were calculated for 1970, 1975, 1980, 1985, and 1990 to correspond to the supplementary construction. This general scheme facilitated calculating the road-user costs and travel time as well as in making the traffic volume forecasts for all the affected routes without and with each of the four alternative locations for the I-666 extension.

INPUT DATA

Tables 32 to 42 give the basic data pertaining to the design of the four alternative locations for the I-666 extension. In sequence, these tables give (Table 32) the construction cost of the alternative routes and the cost of the supplementary construction by years for each alternative routing; (Table 33) mileage and location of the supplementary construction; (Table 34) the annual operating and maintenance expense of highways as related to traffic ADT; (Table 35) the horizontal curves by segments of I-888 and alternative routes between interchanges; (Table 36) the plus and minus grades between interchanges; (Table 37) the 1970 and 1990 ADT by vehicle classification for the four I-666 alternative locations and for travel on I-888; (Table 38) the rural and urban mileage and the ADT for the segments of area routes that are affected by the I-666 extension and for sections of I-666 that are located on existing rights-of-way; (Table 39) the speeds for each of the five classes of vehicles when operating on vertical grades; (Table 40) the speed changes for each class of vehicle for 1970 and 1990; (Table 41) the area motor vehicle running expense for passenger cars and for all vehicles combined; and (Table 42) the traffic accident frequency rates and costs for general highways by access control and accident severity.

These tables provide most of the information from which the highway costs and the road-user costs and travel time are calculated for the four alternatives of the I-666 extension, I-888, and the general area traffic that is affected by the I-666 extension. The cost of speed changes and the tables of discount factors were taken from Winfrey (*14-1*).

Table 43 gives the calculated vehicle-miles by average speeds for the years 1970, 1975, 1980, 1985, and 1990 for the area-affected routes. Table 44 gives the area-affected route vehicle-miles by the five-year intervals for rural, suburban, and urban areas and by degree of access control. These vehicle-mile tables were used in calculating area running cost, travel time, and accident costs.

RESULTS

Table 45 gives the solution in terms of equivalent uniform annual cost at 7 percent and 10 percent vestcharge rates and for an analysis period of 20 years. The road-user costs and travel time given are based on the data in Tables 46, 47, and 48.

There is a significant difference in the total equivalent uniform annual transportation cost between the four alternative locations of the extension of I-666, including the area-affected traffic. The value of time at $0, $1, and $2 per hour does not change the ranking of the economy of the four alternatives, which ranking, lowest cost to highest cost, is: A-2, A-1, A-3, and A-4.

The road-user running and accident costs and travel time are higher for Alternatives A-3 and A-4 than for either A-1 or A-2. Although the equivalent uniform annual highway costs of capital and annual operation and maintenance expense increase in each step from $7,783,000 for A-1 to $10,794,000 for A-4 (calculated at 7 percent vestcharge rate), the only reduction in the road-user costs is found in Alternative A-2 when compared to A-1. Thus, only one benefit/cost ratio can be calculated—that comparing A-2 to A-1:

Benefit/cost ratio, A-2 compared to A-1, without travel time (at 7 percent vestcharge):

$$\frac{(55{,}731 - 53{,}155) - (2{,}295 - 2{,}218)}{5{,}889 - 5{,}565} = \frac{2{,}576 - 77}{324} = 7.7$$

TABLE 32

RIGHT-OF-WAY AND CONSTRUCTION COSTS ($1,000)

Cost Element	Alternative A-1	Alternative A-2	Alternative A-3	Alternative A-4
Interstate Route I-666 Extension to I-888				
Right-of-way	754	2,939	3,016	3,796
Structures	15,224	11,958	25,836	21,477
Grading and Drainage	11,065	12,688	21,920	29,120
Pavement and Appurtenances	9,085	11,770	16,320	20,300
SUBTOTAL	36,128	39,355	67,092	74,693
Area System Streets and Highways Improvements				
Right-of-way	3,696	2,405	921	2,408
Structures	18,169	16,963	5,957	2,766
Grading and Drainage	16,582	13,119	4,106	6,059
Pavement and Appurtenances	15,742	11,803	3,760	7,583
SUBTOTAL	54,189	44,290	14,744	18,816
GRAND TOTAL	90,317	83,645	81,836	93,509
Supplementary Area Improvements By Years				
1970	3,050	3,610	-	-
1975	18,338	20,690	2,170	2,170
1980	20,000	20,000	-	16,646
1985	12,801	-	12,574	-
TOTAL	54,189	44,290	14,744	18,816

TABLE 33

SUPPLEMENTARY AREA CONSTRUCTION

Year Built	Route Section	Interchange Identification	Miles Rural	Miles Urban	Miles Total	New or Old ROW
With Alternative A-1						
1970	A	104-502-203	10.3	1.9	12.2	old
1975	B	24-511	4.5	0.9	5.4	old
1975	C	509-305	3.7	1.4	5.1	old
1975	D	305-306-307-517	15.4	2.7	18.1	new
1980	E	517-411-414	16.8	5.7	22.5	new
1985	F	101-202-203	13.6	1.3	14.9	new
With Alternative A-2						
1970	G	206-509	9.6	1.0	10.6	old
1975	B	24-511	4.5	0.9	5.4	old
1975	H	511-209	1.3	0.8	2.1	old
1975	J	203-503-503A	6.3	4.3	10.6	old
1975	C	509-305	3.7	1.4	5.1	old
1975	D	305-306-307-517	15.4	2.7	18.1	new
1980	E	517-411-414	16.8	5.7	22.5	new
With Alternative A-3						
1975	B	24-511	4.5	0.9	5.4	old
1985	E	517-411-414	16.8	5.7	22.5	new
With Alternative A-4						
1975	B	24-511	4.5	0.9	5.4	old
1980	C	509-305	3.7	1.4	5.1	old
1980	C	305-306-307-517	15.4	2.7	18.1	new

TABLE 34

HIGHWAY OPERATING AND MAINTENANCE EXPENSES (DOLLARS/MILE/YEAR)

Average Daily Traffic Volume	Interstate		Primary	
	Rural	Urban	Rural	Urban
0	3,900	8,700	1,900	3,900
1,000	4,230	8,910	2,090	4,025
2,000	4,600	9,160	2,250	4,150
3,000	4,960	9,480	2,420	4,275
4,000	5,380	9,810	2,620	4,425
5,000	5,850	10,210	2,860	4,600
6,000	6,300	10,660	3,100	4,800
7,000	6,810	11,190	3,360	5,025
8,000	7,380	11,730	3,650	5,275
9,000	8,000	12,360	4,000	5,550
10,000	8,840	13,000	4,400	5,875
11,000	9,440	13,810	4,720	6,200
12,000	10,200	14,670	5,170	6,600
13,000	11,100	15,610	5,640	7,025
14,000	12,030	16,680	6,140	7,500
15,000	12,940	17,700	6,690	7,925
16,000	13,920	18,750	7,240	8,425
17,000	14,850	19,830	7,810	8,900
18,000	15,780	20,880	8,390	9,400
19,000	16,700	21,900	8,950	9,900
20,000	17,600	22,920	9,500	10,400
25,000	-	-	-	12,600
30,000	-	-	-	14,190
35,000	-	-	-	16,125

A-2 compared to A-1, with travel time valued at \$2 per vehicle-hour (at 7 percent vestcharge):

$$\frac{(111{,}033 - 102{,}015) - (2{,}295 - 2{,}218)}{5{,}889 - 5{,}565} = \frac{9{,}018 - 77}{324}$$

$$= 27.6$$

This analysis indicates that Alternative A-2 is of much greater transportation economy than each of the other three alternatives when viewed from the effects on the transportation in the community as a whole. This answer of transportation economy is without consideration of the social and community economic effects.

Although the conclusions with respect to transportation economy are unchanged by the 10 percent vestcharge rate (Table 45) as compared to the 7 percent rate, it is significant that the equivalent uniform annual highway capital costs are materially increased, the highway operation and maintenance costs are slightly decreased, and the road-user costs and travel time are materially decreased. The results of decreased equivalent uniform annual cost (*EUAC*) of the highway annual expenses and of the road-user costs and travel time come from the effect of the higher vestcharge rate in discounting more heavily the annual cash flows between 1970 and 1990 for highway maintenance expense, motor vehicle running costs, accident costs, and travel time hours. Considering that the ADT in 1990 is about 2.5 times that in 1970, it is seen that the 10 percent rate would effectively reduce the calculated equivalent uniform costs over the 20-year analysis period, as compared to a 7 percent rate.

ADVERSE TRAVEL OF THROUGH TRAFFIC AS COMPARED TO TRAVEL ON THE SHORTEST DISTANCE ALTERNATIVE

The total travel distance from Southton to Northville on the four alternative locations of the extension of I-666 are:

ALTERNATIVE	DISTANCE (MILES)	MILES GREATER THAN THAT ON A-2
A-1	91.957	4.753
A-2	87.204	—
A-3	104.125	16.921
A-4	107.799	20.595

This extra distance of travel is significant to the 650 ADT in 1970, increasing to 1,625 ADT in 1990. As analyzed in Table 45, this adverse travel is included in the road-user costs and travel time as though it were fully productive. Separate calculations produced the following results for the running cost and travel time for these through ADT vehicles on the four alternatives:

TABLE 35

MILEAGE OF HORIZONTAL CURVES ON EACH ALTERNATIVE ROUTE

Section Between Interchanges From – To	Total Miles	Miles of each horizontal curve by degrees of curve (a): Tangent	Degree of curve: 1	2	3	4	5	Total Curves
Alternative Route A-1								
101-102	4.079	3.539	0.540	-	-	-	-	0.540
102-103	10.828	9.215	0.969	0.284	0.360	-	-	1.613
103-104	10.985	7.376	0.388	1.362	1.324	0.535	-	3.609
104-105	13.799	12.294	1.126	0.379	-	-	-	1.505
105-106	5.250	4.407	0.625	0.218	-	-	-	0.843
TOTAL	44.941	36.831	3.648	2.243	1.684	0.535	-	8.110
Alternative Route A-2								
101-202	9.927	7.777	1.430	0.720	-	-	-	2.150
202-203	10.074	7.043	1.307	1.572	0.152	-	-	3.031
203-204	4.694	2.815	-	0.174	0.497	0.735	0.473	1.879
204-205	6.006	5.040	0.966	-	-	-	-	0.966
205-206	7.719	6.942	0.777	-	-	-	-	0.777
206-207	9.788	8.207	1.581	-	-	-	-	1.581
207-208	4.648	3.226	0.854	0.568	-	-	-	1.422
208-209	5.649	4.992	-	-	0.322	0.335	-	0.657
209-210	8.695	8.695	none	-	-	-	-	none
TOTAL	67.200	54.737	6.915	3.034	0.971	1.070	0.473	12.463
Alternative Route A-3								
101-302	9.927	7.777	1.430	0.720	-	-	-	2.150
302-303	10.074	7.043	1.307	1.572	0.152	-	-	3.031
303-304	9.115	5.575	0.834	1.208	1.498	-	-	3.540
304-305	7.839	6.400	0.625	0.426	0.388	-	-	1.439
305-306	10.420	8.307	0.890	1.043	0.180	-	-	2.113
306-307	4.999	4.677	0.322	-	-	-	-	0.322
307-308	2.350	1.896	0.454	-	-	-	-	0.554
308-309	8.012	6.520	1.492	-	-	-	-	1.492
309-310	12.613	8.358	2.206	1.178	0.871	-	-	4.255
310-311	1.755	0.666	0.739	-	0.350	-	-	1.089
311-312	10.320	9.100	0.415	0.805	-	-	-	1.220
312-313	3.950	3.514	0.436	-	-	-	-	0.436
TOTAL	91.374	69.833	11.150	6.952	3.439	-	-	21.541
Alternative Route A-4								
101-402	8.243	6.766	1.023	0.454	-	-	-	1.477
402-403	8.404	5.695	2.387	0.322	-	-	-	2.709
403-404	2.153	1.717	0.436	-	-	-	-	0.436
404-405	8.006	6.472	0.871	0.663	-	-	-	1.534
405-406	7.603	7.281	0.322	-	-	-	-	0.322
406-407	4.000	3.697	0.303	-	-	-	-	0.303
407-408	4.730	4.730	none	-	-	-	-	none
408-409	6.511	6.170	0.341	-	-	-	-	0.341
409-410	3.408	2.745	0.663	-	-	-	-	0.663
410-411	4.800	4.611	0.189	-	-	-	-	0.189
411-412	2.569	2.209	0.360	-	-	-	-	0.360
412-413	5.781	5.781	-	-	-	-	-	none
413-414	8.443	7.070	0.563	0.810	-	-	-	1.373
414-415	5.054	4.200	0.341	0.171	0.342	-	-	0.854
415-416	9.840	6.729	1.107	1.236	0.188	0.580	-	3.111
416-417	4.935	3.316	0.801	0.818	-	-	-	1.619
417-418	8.962	7.442	1.520	-	-	-	-	1.520
TOTAL	103.442	86.631	11.227	4.474	0.530	0.580	-	16.811
Interstate Route I-888								
21-106	2.344	1.746	0.394	0.204	-	-	-	0.598
106-22	1.304	1.304	none	-	-	-	-	none
22-23	11.037	7.443	1.081	1.620	0.431	0.462	-	3.594
23-24	5.464	4.088	0.962	0.414	-	-	-	1.376
24-25	7.000	4.642	0.612	1.082	0.460	0.204	-	2.358
25-210	2.207	1.474	0.733	-	-	-	-	0.733
210-26	2.682	0.949	0.412	0.980	0.341	-	-	1.733
26-313	4.571	3.455	0.905	0.211	-	-	-	1.116
313-27	5.643	2.623	0.961	0.822	0.342	0.681	0.214	3.020
27-418	2.751	2.411	0.340	-	-	-	-	0.340
418-28	4.357	2.427	0.404	1.210	0.316	-	-	1.930
TOTAL	49.360	32.562	6.804	6.543	1.890	1.347	0.214	16.798

(a) Mileage for each integral degree includes the range from 0.5 degrees less to 0.5 degrees more than the integral indicated.

TABLE 36

MILES OF AVERAGE VERTICAL GRADES FOR EACH ALTERNATIVE ROUTE (GRADES SUMMARIZED BY INTEGRAL CLASSES)

Section Between Interchanges	Total Miles	Miles of each specific vertical Grade[a]										
		Less than 0.5%	Minus Percent					Plus Percent				
			1	2	3	4	5	1	2	3	4	5
Alternative Route A-1												
101-102	4.079	4.079	-	-	-	-	-	-	-	-	-	-
102-103	10.828	2.186	-	0.278	-	-	-	3.123	1.872	1.106	2.263	-
103-104	10.985	-	-	2.500	6.220	-	-	-	-	1.193	1.072	-
104-105	13.799	4.038	8.180	1.581	-	-	-	-	-	-	-	-
105-106	5.250	1.353	1.596	-	-	-	-	-	1.225	0.500	0.205	0.371
TOTAL	44.941	11.656	9.776	4.359	6.220	-	-	3.123	3.097	2.799	3.540	0.371
Alternative Route A-2												
101-202	9.927	9.234	-	-	-	-	-	0.693	-	-	-	-
202-203	10.074	5.581	-	2.006	-	-	-	2.487	-	-	-	-
203-204	4.694	-	-	0.600	0.496	-	0.720	-	-	-	-	2.878
204-205	6.006	3.031	1.980	0.402	-	-	-	0.593	-	-	-	-
205-206	7.719	4.063	0.517	1.657	-	-	-	0.925	0.557	-	-	-
206-207	9.788	-	5.964	1.434	1.882	-	-	-	0.508	-	-	-
207-208	4.648	1.815	0.437	-	0.462	0.127	-	-	1.326	0.481	-	-
208-209	5.649	0.953	1.786	-	-	-	-	2.147	-	-	0.763	-
209-210	8.695	2.744	0.941	0.818	-	-	-	1.955	1.398	-	0.839	-
TOTAL	67.200	27.421	11.625	6.917	2.840	0.127	0.720	8.800	3.789	0.481	1.602	2.878
Alternative Route A-3												
101-302	9.927	9.234	-	-	-	-	-	0.693	-	-	-	-
302-303	10.074	5.581	-	2.006	-	-	-	2.487	-	-	-	-
303-304	9.115	-	4.027	1.964	-	-	-	0.915	1.232	-	0.977	-
304-305	7.839	2.658	-	1.470	0.880	-	-	1.487	0.373	0.366	0.180	0.425
305-306	10.420	2.059	4.338	-	0.896	0.150	-	1.977	1.000	-	-	-
306-307	4.999	3.165	0.381	0.299	-	-	-	-	1.154	-	-	-
307-308	2.350	1.371	-	-	-	-	-	0.979	-	-	-	-
308-309	8.012	2.872	0.561	-	-	-	-	1.439	0.496	0.928	-	1.716
309-310	12.613	1.000	3.563	2.083	3.877	1.488	-	0.602	-	-	-	-
310-311	1.755	-	-	0.931	-	-	-	-	-	-	0.824	-
311-312	10.320	0.871	2.307	0.915	-	-	-	3.132	3.095	-	-	-
312-313	3.950	-	0.678	-	-	-	-	1.724	1.000	0.548	-	-
TOTAL	91.374	28.811	15.855	9.668	5.653	1.638	None	15.435	8.350	1.842	1.981	2.141
Alternative Route A-4												
101-402	8.243	4.598	2.090	0.350	-	-	-	-	1.205	-	-	-
402-403	8.404	-	1.341	-	-	-	-	4.921	0.949	-	0.748	0.445
403-404	2.153	-	-	-	-	-	-	-	-	2.153	-	-
404-405	8.006	3.434	2.598	0.464	0.286	-	-	-	0.608	-	0.616	-
405-406	7.603	2.431	-	0.644	-	1.670	1.858	-	1.000	-	-	-
406-407	4.000	1.597	-	1.000	1.000	-	-	-	0.403	-	-	-
407-408	4.730	1.774	1.653	-	-	-	-	0.956	-	-	0.347	-
408-409	6.511	2.600	2.725	-	-	-	-	-	1.186	-	-	-
409-410	3.408	0.687	-	0.869	-	-	-	1.852	-	-	-	-
410-411	4.800	2.368	-	-	-	-	-	-	2.432	-	-	-
411-412	2.569	0.871	1.057	-	-	-	-	0.641	-	-	-	-
412-413	5.781	4.565	1.216	-	-	-	-	-	-	-	-	-
413-414	8.443	1.672	1.311	-	-	0.721	-	1.456	0.892	-	-	2.391
414-415	5.054	-	0.218	1.434	0.503	-	-	0.228	-	-	1.011	1.660
415-416	9.840	2.613	0.559	1.190	0.518	1.323	-	-	0.778	1.911	0.948	-
416-417	4.935	1.828	0.835	-	-	-	-	-	0.593	1.679	-	-
417-418	8.962	-	1.551	1.798	1.020	-	-	2.040	-	1.597	0.956	-
TOTAL	103.442	31.038	17.154	7.749	3.327	3.714	1.858	12.094	10.046	7.340	4.626	4.496
Interstate Route I-888												
21-106	2.344	1.692	-	-	-	-	-	0.672	-	-	-	-
106-22	1.304	1.304	-	-	-	-	-	-	-	-	-	-
22-23	11.037	3.359	1.852	2.228	0.460	-	-	1.218	1.920	-	-	-
23-24	5.464	1.422	-	0.403	-	-	-	3.639	-	-	-	-
24-25	7.000	1.210	1.262	1.000	-	-	-	-	1.670	1.858	-	-
25-210	2.207	0.871	-	1.106	-	-	-	2.207	--	-	-	-
210-26	2.682	-	1.678	-	-	-	-	-	0.705	-	-	-
26-313	4.571	-	-	-	-	-	-	0.989	1.904	-	-	-
313-27	5.643	1.644	-	-	-	0.544	-	0.743	1.000	0.655	1.053	0.548
27-418	2.751	2.207	-	-	-	-	-	-	-	-	-	-
418-28	4.357	-	0.802	-	-	-	0.518	2.620	0.417	-	-	-
TOTAL	49.360	13.689	5.594	4.737	0.460	0.544	0.518	12.088	7.616	2.513	1.053	0.548

(a) Mileage of each integral grade includes the range from 0.5% less to 0.5% more than the integral indicated. In the actual analysis grades to the nearest 0.1% were used in calculating the running costs.

TABLE 37

1970 AND 1990 ADT FOR FOUR ALTERNATIVES, INCLUDING TRAVEL ON I-888 AND EXISTING I-888

	1970 ADT						1990 ADT					
Section From-To	Pass. Cars	Comm. Del.	12K SUT	40K 2-S2	50K 3-S2	Total	Pass. Cars	Comm. Del.	12K SUT	40K 2-S2	50K 3-S2	Total
Alternative Route A-1												
101-102	4,202	203	205	416	221	5,247	9,202	445	449	911	484	11,491
102-103	790	38	38	78	42	986	1,730	83	83	171	92	2,159
103-104	790	38	38	78	42	986	1,730	83	83	171	92	2,159
104-105	790	38	38	78	42	986	1,730	83	83	171	92	2,159
105-106	1,255	60	61	124	66	1,566	2,748	131	134	272	145	3,430
I-888 With Alternative Route A-1												
21-106	4,613	222	225	457	243	5,760	10,102	486	493	1,001	532	12,614
106-22	4,908	237	239	486	259	6,129	10,749	519	523	1,064	567	13,422
22-23	3,304	159	161	327	174	4,125	7,236	348	353	716	381	9,034
23-24	3,320	160	161	329	175	4,145	7,271	350	353	721	383	9,078
24-25	2,758	133	134	273	145	3,443	6,040	291	293	598	318	7,540
25-26	4,741	229	231	469	250	5,920	10,383	502	506	1,027	548	12,966
26-27	4,889	236	238	484	258	6,105	10,707	517	521	1,060	565	13,370
27-28	5,024	242	245	497	265	6,273	12,158	586	593	1,203	641	15,181
Alternative Route A-2												
101-202	4,337	209	211	429	229	5,415	9,498	458	462	940	502	11,860
202-203	6,804	328	331	674	358	8,495	14,901	718	725	1,476	784	18,604
203-204	4,967	317	278	135	111	5,808	13,163	840	737	358	294	15,392
204-205	1,059	51	52	105	56	1,323	2,563	123	126	254	136	3,201
205-206	943	45	46	93	50	1,177	2,065	99	101	204	110	2,579
206-207	951	46	46	94	50	1,187	2,083	101	101	206	110	2,601
207-208	1,713	83	83	170	90	2,139	3,751	182	182	372	197	4,684
208-209	1,187	57	58	118	63	1,483	2,600	125	127	258	138	3,248
209-210	3,328	160	162	329	175	4,154	3,328	350	355	721	383	9,097
I-888 With Alternative Route A-2												
21-22	4,598	222	224	455	242	5,741	10,070	486	491	996	530	12,573
22-23	2,577	124	125	255	136	3,217	5,644	272	274	558	298	7,046
23-24	2,592	125	126	257	137	3,237	5,676	274	276	563	300	7,089
24-25	2,108	102	103	209	111	2,633	4,617	223	226	458	243	5,767
25-210	3,446	166	168	341	182	4,303	7,547	364	368	747	399	9,425
210-26	5,251	253	256	520	277	6,557	11,500	554	561	1,139	607	14,361
26-27	5,569	268	271	551	293	6,952	12,196	587	593	1,207	642	15,225
27-28	5,717	275	278	566	301	7,137	13,835	666	673	1,370	728	17,272
Alternative Route A-3												
101-302	4,337	209	211	429	229	5,415	9,498	458	462	940	502	11,860
302-303	6,804	328	331	674	358	8,495	14,901	718	725	1,476	784	18,604
303-304	5,127	247	250	508	270	6,402	11,228	541	548	1,113	591	14,021
304-305	5,127	247	250	508	270	6,402	12,407	598	605	1,229	653	15,492
305-306	6,056	336	322	373	227	7,314	14,656	813	779	903	549	17,700
306-307	10,595	676	593	289	237	12,390	28,077	1,791	1,571	766	628	32,833
307-308	11,605	741	650	316	259	13,571	30,753	1,964	1,723	837	686	35,963
308-309	8,293	461	441	511	310	10,016	20,069	1,116	1,067	1,237	750	24,239
309-310	2,758	133	134	273	145	3,443	6,040	291	293	598	318	7,540
310-311	1,860	90	91	184	98	2,323	4,073	197	199	403	215	5,087
311-312	1,893	91	92	187	100	2,363	4,146	199	201	410	219	5,175
312-313	1,966	95	96	195	104	2,456	4,306	208	210	427	228	5,378
I-888 With Alternative Route A-3												
21-22	4,598	222	224	455	242	5,741	10,070	486	491	996	530	12,573
22-23	2,577	124	125	255	136	3,217	5,644	272	274	558	298	7,046
23-24	2,592	125	126	257	137	3,237	5,676	274	276	563	300	7,089
24-25	2,108	102	103	209	111	2,633	4,617	223	226	458	243	5,767
25-26	3,725	180	181	369	196	4,651	8,158	394	396	808	429	10,185
26-313	3,873	187	189	383	204	4,836	8,482	410	414	839	447	10,592
313-27	5,717	275	278	566	301	7,137	12,520	602	609	1,240	659	15,630
27-28	5,851	282	285	579	308	7,305	14,159	682	690	1,401	745	17,677

TABLE 37 (*continued*)

Section From-To	1970 ADT Pass. Cars	Comm. Del.	12K SUT	40K 2-S2	50K 3-S2	Total	1990 ADT Pass. Cars	Comm. Del.	12K SUT	40K 2-S2	50K 3-S2	Total
Alternative Route A-4												
101-402	6,611	319	322	655	348	8,255	14,478	699	705	1,434	762	18,078
402-403	4,008	193	195	397	211	5,004	8,778	423	427	869	462	10,959
403-404	3,852	186	188	381	203	4,810	9,322	450	455	922	491	11,640
404-405	3,910	188	190	387	206	4,881	8,563	412	416	848	451	10,690
405-406	4,177	201	203	413	220	5,214	9,148	440	445	904	482	11,419
406-407	4,827	233	235	478	254	6,027	10,571	510	515	1,047	556	13,199
407-408	5,597	311	297	345	210	6,760	13,545	753	719	835	508	16,360
408-409	8,021	387	391	794	423	10,016	19,411	937	946	1,921	1,024	24,239
409-410	8,867	427	432	878	467	11,071	23,498	1,132	1,145	2,327	1,238	29,340
410-411	6,824	329	332	676	360	8,521	16,514	796	803	1,636	871	20,620
411-412	7,179	399	381	442	269	8,670	17,373	966	922	1,070	651	20,982
412-413	4,275	206	208	423	225	5,337	10,346	499	503	1,024	545	12,917
413-414	3,463	167	169	343	183	4,325	7,584	366	370	751	401	9,472
414-415	1,993	96	97	197	105	2,488	4,365	210	212	431	230	5,448
415-416	1,993	96	97	197	105	2,488	4,365	210	212	431	230	5,448
416-417	2,045	99	100	203	108	2,555	4,479	217	219	445	237	5,597
417-418	2,106	101	102	208	111	2,628	4,612	221	223	456	243	5,755
I-888 With Alternative Route A-4												
21-22	4,598	222	224	455	242	5,741	10,070	486	491	996	530	12,573
22-23	2,577	124	125	255	136	3,217	5,644	272	274	558	298	7,046
23-24	2,592	125	126	257	137	3,237	5,676	274	276	563	300	7,089
24-25	2,108	102	103	209	111	2,633	4,617	223	226	458	243	5,767
25-26	4,046	195	197	401	213	5,052	8,861	427	431	878	466	11,063
26-27	4,195	202	204	415	221	5,237	9,187	442	447	909	484	11,469
27-418	4,449	214	217	441	234	5,555	10,767	518	525	1,067	566	13,443
418-28	6,178	298	301	612	326	7,715	14,951	721	728	1,481	789	18,670
I-888 Existing Situation												
21-106	4,598	222	224	455	242	5,741	10,070	486	491	996	530	12,573
106-22	4,598	222	224	455	242	5,741	10,070	486	491	996	530	12,573
22-23	2,577	124	125	255	136	3,217	5,644	272	274	558	298	7,046
23-24	2,592	125	126	257	137	3,237	5,676	274	276	563	300	7,089
24-25	2,108	102	103	209	111	2,633	4,617	223	226	458	243	5,767
25-210	4,165	201	203	412	219	5,200	9,121	440	445	902	480	11,388
210-26	4,165	201	203	412	219	5,200	9,121	440	445	902	480	11,388
26-313	4,271	206	208	423	225	5,333	9,353	451	456	926	493	11,679
313-27	4,271	206	208	423	225	5,333	9,353	451	456	926	493	11,679
27-418	4,405	212	215	436	232	5,500	9,647	464	471	955	508	12,045
418-28	4,405	212	215	436	232	5,500	9,647	464	471	955	508	12,045

	ALTERNATIVE			
ITEM	A-1	A-2	A-3	A-4
Year 1970:				
Motor vehicle running cost ($)	1,251,881	1,194,742	1,421,845	1,510,400
Traffic accidents ($)	41,087	36,091	38,115	41,310
Travel time (hr)	371,581	349,872	416,393	449,599
Year 1990:				
Motor vehicle running cost ($)	3,279,109	3,097,553	3,701,463	3,820,404
Traffic accidents ($)	99,272	81,586	87,125	112,987
Travel time (hr)	931,533	878,874	1,044,242	1,093,695

In view of the original objective of I-666 as a defense highway, these adverse costs to the through trips may have some significance in the decision process.

The results of the solution to the transportation economy of the four alternative locations of the I-666 extension are presented as they came out on the first trial; in other words, no changes have been made to adjust for seemingly unrealistic results. No doubt a more careful and studied analysis would alter the results slightly one way or other. After the researchers had been through the analysis once and had been forced to make many decisions on selection of data, magnitude of factors, and procedures, they noticed a few items where refinements of the analysis could be improved. However, such refinements probably would not alter the relative standing among the four basic alternatives, or the basic procedures illustrated.

TABLE 38

MILEAGE AND AVERAGE DAILY TRAFFIC FOR 1970 AND 1990 FOR AREA ROUTES AFFECTED BY I-666 EXTENSION; ALSO FOR I-666 ON EXISTING ROW

Section No.	From-To by Route Intersections	Rural/Urban	Miles	Average Daily Traffic: Existing	A-1	A-2	A-3	A-4
			1970 - Existing and With I-666 Extension					
I-1	601-102-501-204	R	20.8	3,500	3,100	1,200	1,500	1,800
		U	7.5	7,000	6,300	2,300	2,700	3,000
I-2-a	204-505-509	R	9.7	3,600	2,400	3,200	2,400	2,000
		U	0.9	7,000	5,700	6,300	5,700	3,900
-b	509-305	R	3.2	4,000	2,700	3,600	2,700	2,200
		U	1.3	7,500	5,000	6,600	5,000	4,200
I-3-a	305-517	R	7.9	16,100	12,900	9,700	11,300	12,900
		U	8.4	24,100	19,300	14,500	16,900	19,300
-b	517-521	R	5.5	14,100	11,300	8,500	9,900	11,300
		U	3.5	22,000	17,600	13,200	15,400	17,600
I-4-a	521-524	R	13.3	3,700	4,400	2,200	3,800	2,200
I-4-b	524-28	R	32.0	3,100	3,700	1,800	3,200	1,800
II	602-503B-402-403	R	23.2	6,900	6,400	2,800	2,800	5,000
		U	2.2	13,800	12,500	5,500	5,500	10,000
III	503A-506-514-Riverton	R	9.3	2,600	2,600	2,400	1,900	900
		U	3.7	5,200	5,200	5,100	3,800	1,700
IV	23-507-207-516-Easton	R	34.3	700	800	900	700	800
		U	5.7	2,100	2,400	2,500	2,200	2,400
V	21-105-504-505-506	R	41.7	1,000	300	500	400	400
VI	22,507-310-414	R	42.9	3,900	4,700	5,100	4,500	4,200
VII	25-511-208	R	10.7	4,700	4,600	3,300	4,200	4,700
		U	2.3	9,500	9,400	6,800	8,700	9,500
VIII	509-512-309	R	20.1	2,200	2,100	2,000	1,300	1,600
		U	1.3	4,700	4,600	4,500	2,600	3,500
IX	Overview-311-522	R	17.7	5,000	4,800	4,000	2,000	4,500
X-1	104-502-203	R	11.2	1,000	1,500	900	900	1,000
		U	2.4	4,000	5,000	3,300	3,300	4,200
X-2	203-404-503A	R	6.3	2,500	3,000	2,100	2,100	2,600
		U	4.4	2,700	3,400	2,400	2,400	2,800

SAMPLE SPECIFIC CALCULATIONS TO ILLUSTRATE PROCEDURES

This section illustrates the procedures and handling of the data in the process of calculating the highway costs and the road-user costs and travel times for travel on I-888 and on the area-affected routes, with and without each of the four I-666 alternative extensions. Only sample calculations are presented, but these are sufficiently extensive to illustrate the important procedures, concepts, and assumptions. The general procedure was to calculate the highway capital costs for the route as a whole, rather than by sections. The motor vehicle running cost, accident cost, and travel time were calculated for each location alternative by route section for 1970 and 1990. These road-user costs and travel times were then spread uniformly over the 20 years for the route as a whole, using the appropriate gradient discount factor. The supplementary construction capital costs were spread uniformly forward 20 years from the year of construction, then the equal annual amounts between the date of construction (1975, 1980, or 1985) and 1990 were brought back to 1970 on a discounted present worth basis.

Because the supplementary construction alters the highway operating and maintenance expense, it was necessary to calculate the maintenance expense for the area routes affected for 1970, 1975, 1980, 1985, and 1990, then to calculate their present worth at 1970. This total 1970 present worth was then spread over the 20-year period to 1990. The same procedure was applied to the area road-user costs and travel time. By this procedure, all of the highway cost factors and the road-user factors were reduced to an equivalent uniform amount over 1970 to 1990. The supplementary highway construction was in effect given a terminal value at 1990 proportional to the remainder of a 20-year service period.

TABLE 38 (*continued*)

Section No.	From-To by Route Intersections	Rural / Urban	Miles	Average Daily Traffic: Existing	A-1	A-2	A-3	A-4
				1990 - Existing and With I-666 Extension				
I-1	601-102-501-204	R	20.8	7,650	6,800	2,650	3,300	3,950
		U	7.5	15,300	13,800	5,050	5,900	6,550
I-2-a	204-505-509	R	5.3	9,550	6,350	8,500	6,350	5,300
		U	5.3	18,550	15,100	16,700	15,100	10,350
I-2-b	509-305	R	2.2	10,600	7,150	9,550	7,150	5,850
		U	2.3	19,900	13,250	17,500	13,250	11,150
I-3-a	305-517	U	16.3	42,600	34,200	25,700	29,900	34,200
I-3-b	517-521	U	9.0	37,300	29,900	22,500	26,200	29,900
I-4-a	521-524	R	13.3	8,100	9,650	4,800	8,300	4,800
I-4-b	524-28	R	32.0	6,800	8,100	3,950	7,000	3,950
II	602-503D-402-403	R	23.2	15,100	14,000	6,150	6,150	11,000
		U	2.2	30,200	27,400	12,000	12,000	21,900
III	503A-506-514-Riverton	R	9.3	6,900	6,900	6,450	5,050	2,400
		U	13.7	13,800	13,800	13,500	10,100	4,500
IV	23-507-207-Easton	R	34.3	1,850	2,100	2,400	1,850	2,100
		U	5.7	5,550	6,350	6,600	5,850	6,350
V	21-105-504-505-506	R	41.7	2,400	700	1,200	950	950
VI	22-507-310-414	R	42.9	9,400	11,400	12,300	10,900	10,150
VII	25-511-208	R	10.7	10,300	10,100	7,200	9,200	10,300
		U	2.3	20,800	20,600	14,900	19,050	20,800
VIII	509-512-309	R	10.1	5,800	5,550	5,300	3,450	4,250
		U	11.3	12,450	12,200	11,900	6,900	9,300
IX	Overview-311-522	R	17.7	12,100	11,600	9,700	4,850	10,900
X-1	104-502-203	R	6.8	2,400	3,650	2,200	2,200	2,400
		U	6.8	9,700	12,100	8,000	8,000	10,150
X-2	203-404-503A	R	4.4	6,050	7,250	5,100	5,100	6,300
		U	6.3	6,550	8,200	5,800	5,800	6,800
				1970 - Route Sections Having I-666 Extension on Existing ROW				
A-2	204-207	R	25.0	3,000	2,750	0	2,500	2,850
A-3	308-311	R	21.5	6,300	6,300	6,200	0	6,000
		U	2.5	12,600	12,500	12,300	0	11,000
A-4	402-405	R	20.0	5,000	4,700	4,300	4,000	0
				1990 - Route Sections Having I-666 Extension on Existing ROW				
A-2	204-207	R	25.0	7,300	6,700	0	6,800	6,900
A-3	308-311	R	15.5	15,250	15,250	15,000	0	14,500
		U	8.5	30,500	30,250	29,750	0	26,600
A-4	40-2-405	R	20.0	12,100	11,350	10,400	9,700	0

TABLE 39

VEHICLE OPERATING SPEED ON PLUS AND MINUS HIGHWAY GRADES FOR FIVE CLASSES OF MOTOR VEHICLES [a]

MINUS GRADES (mph)						PLUS GRADES (mph)				
PC	CD	SUT	2-S2	3-S2	Grade Range (%)	PC	CD	SUT	2-S2	3-S2
65	60	55	50	50	0 - 0.24	65	60	55	50	50
65	60	55	50	50	0.25 - 0.74	65	60	55	50	50
65	60	55	50	50	0.75 - 1.24	65	60	52½	47½	47½
65	60	52½	47½	47½	1.25 - 1.74	65	60	50	45	45
65	60	52½	47½	45	1.75 - 2.24	65	57½	47½	42½	40
65	57½	47½	42½	40	2.25 - 2.74	65	57½	45	37½	35
62½	57½	45	37½	35	2.75 - 3.24	62½	55	40	32½	30
62½	55	40	32½	30	3.25 - 3.74	62½	55	35	27½	25
60	55	35	27½	25	3.75 - 4.24	50	52½	30	25	22½
60	52½	32½	25	22½	4.25 - 4.74	60	52½	27½	22½	20
57½	52½	30	22½	20	4.75 - 5.24	57½	50	25	20	17½
57½	50	27½	20	17½	5.25 - 5.74	57½	47½	25	17½	15
55	47½	25	17½	15	5.75 - 6.24	55	45	22½	17½	15
55	45	22½	17½	15	6.25 - 6.74	52½	42½	22½	15	12½
52½	42½	22½	17½	15	6.75 - 7.24	50	40	20	15	12½

(a) Passenger car, commercial delivery, single-unit truck, 4-axle tractor-semitrailer (40 kips), and 5-axle diesel tractor-semitrailer (50 kips).

I. Example Calculation of Capital Costs

A. Alternative A-1 of I-666 Extension

Construction cost of 1970 = $36,128,000
Analysis period = 20 years
Vestcharge rate (discount rate) = 7 percent
Solve for equivalent uniform annual cost.
EUAC = 36,128,000 (*CR*, 7%, 20 yr) = $3,410,000

B. Supplementary Construction for Alternative A-1

1970 construction: *EUAC* = 3,050,000 (*CR*,7%,20 yr) = $287,899

For the 1975, 1980, and 1985 construction the procedure is to first spread the capital cost for each year forward 20 years by using the capital recovery factor. The second step is to find the present worth as of the year of construction of the uniform annual amounts from the date of construction to 1990. The third step is to move this calculated present worth of the services back to 1970 as a single sum.

1975 construction = $18,338,000:
EUAC = 18,338,000 (*CR*,7%,20 = 0.094393)
= 1,730,979
PW (1975) = 1,730,979 (*SPW*,7%,15 = 9.1079)
= 15,765,584
PW (1970 = 15,765,584 (*PW*),7%,5 = 0.712986)
= 11,240,638
EUAC = 11,240,638 (*CR*,7%,20 = 0.094393)
= $1,061,038

1980 construction = $20,000,000:
EUAC = 20,000,000 (*CR*,7%,20 = 0.094393)
= 1,887,860
PW (1980) = 1,887,860 (*SPW*,7%,10 = 7.023582)
= 13,259,540
PW (1970) = 13,259,540 (*PW*,7%,10 = 0.508349)
= 6,740,474
EUAC = (*CR*,7%,20 = 0.094393) = $636,254

1985 construction = $12,801,000:
EUAC = 12,801,000 (0.094393) = 1,208,325
PW (1985) = 1,208,325 (*SPW*,7%,5 = 4.100197)
= 4,954,370
PW (1970) = 4,954,370 (*PW*,7%,15 = 0.362446)
= 1,795,691
EUAC = 1,795,691 (0.094393) = $169,501

Total *EUAC* of all supplementary construction for A-1:

1970 =	$ 287,899
1975 =	1,061,038
1980 =	636,254
1985 =	169,501
Total	$2,154,692 or $2,155 thousand

Alternative A-1 capital cost plus supplementary capital cost for the area = $3,410 plus $2,155 = $5,565 thousand.

II. Example Calculation of EUAC of Highway Operating and Maintenance Annual Expense

A. Alternative A-2

VALUE	YEAR	RURAL	URBAN	TOTAL
Miles	1970	46.426	20.774	67.200
	1990	38.707	28.493	67.200
ADT	1970	2.100	5.000	—
	1990	3.300	14.000	—
O&M expense	1970	4,650	10,200	—
per mile ($)	1990	5,100	16,650	—
Total yearly expense ($)	1970	215,809	197,406	413,215
	1990	211,895	474,408	686,303

Assume a straight-line (gradient) increase in highway operating and maintenance expense, 1970 to 1990. The first step is to find the gradient growth—the yearly increase or slope of the gradient.

(686,303 − 413,215) ÷ 20 = $13,654 per year increase above the base amount of $413,215. The equivalent uniform annual O&M expense is therefore $413,215 + 13,654 (the gradient uniform factor). See Winfrey (*14-1*, p. 776).

$$EUAC = 413{,}215 + 13{,}654\ (GUS,7\%,20 = 8.316307) = \$526{,}766$$

B. I-888 and Affected-Area Routes

The procedure for calculating the *EUAC* of highway operating and maintenance expense is the same as that for Alternative A-2, as illustrated.

III. Route Section 305 to 306

Figure 42 shows the detailed calculations of running cost, travel time, and accident cost for Route section 305 to 306 of Alternative A-3. The unit running costs are from Winfrey (*14-1*, App. A).

IV. Calculation of the EUAC for Motor Vehicle Running Cost, Accident Cost, and Travel Time—Interstate Routes

A. Alternative A-1—Running Cost

The calculation uses the gradient factor for the 20 years from 1970 to 1990. See Table 46 for the 1970 and 1990 amounts.

$$EUAC = [(3{,}053{,}631 - 1{,}322{,}340) \div 20](GUS,7\%,20) + 1{,}322{,}340 = \$2{,}042{,}241$$

B. Alternative A-1—Accident Cost

$$EUAC = [(97.097 - 44{,}506) \div 20](GUS,7\%,20) + 44{,}506 = \$66{,}378$$

C. Alternative A-1—Travel-Time Hours

$$(EUAH = [(870{,}418 - 396{,}219) \div 20]GUS,7\%,20) + 396{,}219 = 593{,}399 \text{ hours}$$

D. I-888

The same procedure is applied to I-888.

V. Calculation of Road-User Costs and Travel Time for Affected-Area Routes

Because of the effects of the supplementary construction in 1970, 1975, 1980, and 1985, the running cost, accident cost, and travel-time hours for the affected-area traffic were calculated for 1970, 1975, 1980, 1985, and 1990 with and without each alternative A-1 to A-4. The reduction of these five-year-interval amounts to equivalent uniform annual amounts over 1970 to 1990 requires special attention to the separate years. A sample calculation follows for the area motor vehicle running cost with Alternative A-1.

A. Affected-Area Traffic Running Cost and Travel Time with Alternative A-1

The full detail of the area-affected traffic is not given, but Table 38 gives the basic data. Missing is the mileage of suburban traffic and the ADT for 1975, 1980, and 1985. The first calculations were those to produce for each affected street and highway section the vehicle-miles of travel, by year and by average speed groups. See Table 43.

The street and highway sections were also classified at the same time by rural, suburban, and urban character. The vehicle-miles were then totaled as given in Table 44 for the calculation of accident costs.

For Alternative A-1 for 1970, the affected-area running costs and travel-time hours were calculated as follows using Tables 42 and 43:

Average Speed (mph)		
50	(229,987,000 vehicle-miles)($0.0427)	= $9,820,445
40	(156,256,000) (3.62)	= 5,656,467
35	(245,134,000) (3.74)	= 9,168,012
25	(50,370,000) (3.35)	= 1,687,395
	Total	$26,332,319

The travel time hours:

229,987,000 ÷ 50 =	4,599,740
156,256,000 ÷ 40 =	3,906,400
245,134,000 ÷ 35 =	7,003,829
50,370,000 ÷ 25 =	2,014,800
Total for 1970	17,524,769

B. Traffic Accident Costs for 1970 for the Area-Affected Traffic with Alternative A-1

The accident rates per 100,000,000 vehicle-miles and the cost per accident are given in Table 42. The calculation of the cost of accidents is straight multiplication of (vehicle-miles) (accident rate) (cost per accident):

TABLE 40

SUMMARY OF SPEED CHANGES BY MAGNITUDE AND NUMBER FOR FIVE VEHICLE CLASSES IN 1980 AND 1990

1970 TRAFFIC (c)						1990 TRAFFIC(c)				
Pass. Car	Comm. Del.	SUT	2-S2	3-S2	Route Section (a),(b)	Pass. Car	Comm. Del.	SUT	2-S2	3-S2
		I-888 Without Any Alternatives A-1 to A-4								
		55-40g	50-30g	50-30g	22-23	(Actually same as 1970)				
		55-45g	50-40g	50-40g	24-25	- 1990 Costs And Time Attributed				
		55-45g	50-40g	50-40g	25-210	to Speed Changes On I-888 Were				
65-55g	60-45g	55-25g	50-15g	50.15g	313-27	Calculated by Multiplying 1970				
65-55g	60-45g	55-25g	50-20g	50-15g	418-28	Figures by 2.19 -				
		I-888 With Alternatives A-1 to A-4								
					21-106	65-55t	60-50t	55-45t	50-40t	50-40t
		Same as above								
					22-23			55-40g	50-30g	50-30g
					24-25			55.45gt	50-40g	50-40g
					25-210			55-45g	50-40g.	50-40g
					210-26	65-55t	60-50t	55-45t	50-40t	50-40t
					313-27	65-55gt	60-50t	55-45t	50-40t	50-40t
							60-45g	55-25g	50-15g	50-15g
					418-28	65-55gt	60-50t	55-45t	50-40t	50-40t
							60-45g	55-25g	50-20g	50-15g
		I-888 Additional With Alternative A-1								
		Same as above			106-22	65-55t	60-50t	55-45t	50-40t	50-40t
		I-888 Additional With Alternative A-3								
		Same as above			26-313	65-55t	60-50t	55-45t	50-40t	50-40t
		I-888 Additional With Alternative A-4								
		Same as above			27-418	65-55t	60-50t	55-45t	50-40t	50-40t
		Alternative A-1								
		55-45g	50-40g	50-40g	101-102	65-55t	60-50t	55-45gtt	50-40gtt	50-40gtt
		55-40g	50-30g	50-25g	102-103			55-40g	50-30g	50-25g
65-55g	60-50g	55-25g	50-20g	50-15g	104-105	65-55g	60-50g	55-25g	50-20g	50-15g
		Alternative A-2								
					101-202	65-55t	60-50t	55-45t	50-40t	50-40t
					202-203	65-55tt	60-50tt	55-45tt	50-40tt	50-40tt
	60-50g	55-25g	50-20g	50-15g	203-204	65-55t	60-50gt	55-45tt	50-40tt	50-40tt
								55-25g	50-20g	50-15g
			50-40g	50-40g	204-205				50-40g	50-40g
		55-45g	50-35g	50-35g	206-207			55-45g	50-35g	50-35g
		55-35g	50-30g	50-25g	207-208			55-35g	50-30g	50-25g
	60-50g	55-30g	50-25g	50-20g	208-209		60-50g	55-30g	50-25g	50-20g
65-55g	60-50g	55-35g	50-30g	50-25g	209-210	65-55gt	60-50gt	55-45t	50-40t	50-40t
								55-35g	50-30g	50-25g

CLASSIFICATION	1970 VEH-MI (1,000)	ACCIDENTS PER 100,000,000 VEH-MI			COST PER ACCIDENT ($)		
		FATAL	INJURY	PROP. DAMAGE	FATAL	INJURY	PROP. DAMAGE
No access control							
Rural	352,663	7.08	107.6	217	9,090	2,225	233
Suburban	116,654	4.41	191.7	289	7,955	1,826	202
Urban	178,850	3.88	171.5	350	6,821	1,427	171
Full access control							
Rural	33,580	2.81	64.2	84	9,090	2,225	233

TABLE 40 (*continued*)

1970 TRAFFIC (c)						1990 TRAFFIC (c)				
Pass. Car	Comm. Del.	SUT	2-S2	3-S2	Route Section(a),(b)	Pass. Car	Comm. Del.	SUT	2-S2	3-S2
		Alternative A-3								
					101-302	65-55t	60-50t	55-45t	50-40t	50-40t
					302-303	65-55t	60-50t	55-45t	50-40t	50-40t
		55-40g	50-30g	50-30g	303-304	65-55t	60-50t	55-45t	50-40t	50-40t
								55-40g	50-30g	50-30g
65-55g	60-50g	55-25g	50-25g	50-20g	304-305	65-55gt	60-50gt	55-45t	50-40t	50-40t
								55-25g	50-25g	50-20g
65-55g	60-50g	55-35g	50-25g	50-25g	305-306	65-55gt	60-50gt	55-45t	50-40t	50-40t
								55-35g	50-25g	50-25g
65-55t	60-50t	55-45gt	50-40gt	50-40gt	306-307	65-55tt	60-50tt	55-45tt	50-40gtt	50-40gtt
		55-45t	50-40t	50-40t	307-308	65-55ttt	60-50ttt	55-45ttt	50-40ttt	50-40ttt
	60-50g	55-30g	50-20g	50-20g	308-309	65-55tt	60-50tt	55-45tt	50-40tt	50-40tt
								55-30g	50-20g	50-20g
		55-30g	50-25g	50-25g	309-310			55-30g	50-25g	50-25g
		55-45g	50-40g	50-40g	311-312			55-45g	50-40g	50-40g
		55-45g	50-35g	50-35g	312-313			55-45g	50-35g	50-35g
		Alternative A-4								
		55-45g	50-40g	50-40g	101-402	65-55t	60-50t	55-45gt	50-40gt	50-40gt
	60-50g	55-30g	50-20g	50-20g	402-403	65-55t	60-50gt	55-45t	50-40t	50-40t
								55-30g	50-20g	50-20g
		55-40g	50-30g	50-25g	403-404	65-55t	60-50t	55-45t	50-40t	50-40t
								55-40	50-30g	50-25g
					404-405	65-55t	60-50t	55-45t	50-40t	50-40t
		55-30g	50-25g	50-20g	405-406	65-55t	60-50t	55-45t	50-40t	50-40t
								55-30g	50-25g	50-20g
			50-40g	50-40g	406-407	65-55t	60-50t	55-45t	50-40gt	50-40gt
		55-40g	50-30g	50-30g	407-408	65-55t	60-50t	55-45t	50-40t	50-40t
								55-40g	50-30g	50-30g
					408-409	65-55tt	60-50tt	55-45tt	50-40tt	50-40tt
65-55t	60-50t	55-45tt	50-40tt	50-40tt	409-410	65-55tt	60-50tt	55-45gtt	50-40gtt	50-40gtt
					410-411	65-55t	60-50t	55-45t	50-40t	50-40t
					411-412	65-55t	60-50t	55-45t	50-40t	50-40t
					412-413	65-55t	60-50t	55-45t	50-40t	50-40t
	60-50g	55-30g	50-20g	50-20g	413-414		60-50g	55-30g	50-20g	50-20g
			50-40g	50-40g	414-415				50-40g	50-40g
		55-35g	50-25g	50-25g	415-416			55-35g	50-25g	50-25g
		55-35g	50-30g	50-30g	417-418			55-35g	50-30g	50-30g

(a) Interchange to interchange.
(b) Only sections listed in which speed changes occurred in either 1970 or 1990.
(c) First figure is the initial speed in mph; second figure is the speed after the decrease; g denotes a speed change caused by geometrics; t denotes a speed change caused by traffic. Each letter or repetition represents a separate speed change.

The results of multiplying are:

CLASSIFICATION	COST OF ACCIDENTS ($) FATAL	INJURY	PROP. DAMAGE	TOTAL
No access control				
Rural	226,964	844,310	178,310	1,249,584
Suburban	40,924	408,340	68,100	517,364
Urban	47,334	437,700	107,042	592,076
Full access control				
Rural	8,577	47,967	6,572	63,116
Total	323,799	1,738,317	360,024	2,422,140

VI. Calculation of Equivalent Uniform Running Cost, Traffic Cost, and Travel Hours for 1970 to 1990 for the Area-Affected Traffic

Because the area traffic is affected by the supplementary construction, it is necessary to compute the present worths for 1970 to 1990 in five-year bands using 1970, 1975, 1980, 1985, and 1990 data, then spread the total of the present worths over the 20-year period. An example follows for the running cost of the area-affected traffic under Alternative A-1. See Table 41 for the basic running costs (and also, accident costs and travel hours). The procedure is to assume a straight-line (gradient) increase within each five-year period, then compute the present worth at 1970, total the separate present worth, then spread to an equivalent uniform annual amount to 1990.

TABLE 41

MOTOR VEHICLE RUNNING COSTS (CENTS/MILE) USED IN THE CALCULATIONS

Area, Facility, and Speed	Passenger Cars					All Vehicles				
	1970	1975	1980	1985	1990	1970	1975	1980	1985	1990
A. General area traffic affected by I-666[a]										
1. On a 30-mph facility:										
20-mph average speed	2.99	3.01	3.06	3.08	3.11	3.86	3.89	3.95	3.98	4.01
25-mph average speed	2.60	2.62	2.66	2.68	2.70	3.35	3.38	3.43	3.46	3.48
2. On a 45-mph facility:										
30-mph average speed	3.10	3.12	3.17	3.20	3.22	4.00	4.03	4.09	4.12	4.15
35-mph average speed	2.90	2.92	2.97	2.99	3.01	3.74	3.77	3.83	3.86	3.88
40-mph average speed	2.81	2.83	2.88	2.90	2.92	3.62	3.65	3.71	3.74	3.77
3. On a 60-mph facility:										
45-mph average speed	3.43	3.46	3.51	3.54	3.56	4.42	4.46	4.53	4.56	4.60
50-mph average speed	3.31	3.34	3.39	3.41	3.44	4.27	4.30	4.37	4.40	4.44

B. Interstate routes with vehicle classification by ADT

Running cost at uniform speed on grades and horizontal curves from Winfrey (14-1, App. A).

(a) 1970 passenger car running costs from Schneider (14-2). Other costs by the researchers.

TABLE 42

TRAFFIC ACCIDENT RATES AND COSTS USED IN THE SAMPLE SOLUTION

Location and Facility	Fatal Accident	Nonfatal Injury Accident	Property Damage Only Accident	All Accidents
Traffic Accident Rate per 100 Million Vehicle-Miles[a]				
Urban:				
Full access control	1.69	53.2	131	186
Partial access control	4.08	98.6	394	496
No access control	3.88	171.5	350	526
Suburban:				
Full access control	3.52	48.8	85	137
Partial access control	4.40	82.4	253	340
No access control	4.41	191.7	289	485
Rural:				
Full access control	2.81	64.2	84	151
Partial access control	4.78	72.3	134	211
No access control	7.08	107.6	217	332
Direct Cost Per Accident ($), (b) Cars and Trucks Combined				
Urban	6,821	1,427	171	319
Suburban	7,955	1,826	202	414
Rural	9,090	2,225	233	509

(a) Source: U.S. Bureau of Public Roads; in Winfrey (14-1, Table 15-11, p. 405).

(b) Source: Illinois Division of Highways; in Winfrey (14-1, Table 15-2, p.388).

TABLE 43

ANNUAL VEHICLE-MILES OF AFFECTED TRAVEL BY FACILITY TYPE AND AVERAGE SPEED FOR FOUR ALTERNATIVES AND EXISTING HIGHWAYS BY FIVE-YEAR INCREMENTS FROM 1970 TO 1990 (1,000's)

Year	Facility Type	Average Speed (mph)	Existing	A-1	A-2	A-3	A-4
1970	60	50	236,484	229,987	175,328	158,556	193,978
	45	40	138,043	156,256	125,633	130,853	112,639
	45	35	284,700	245,134	204,400	156,950	205,130
	30	25	59,130	50,370	30,660	42,158	25,550
	All	-	718,357	681,747	536,021	488,517	537,297
1975	60	50	292,665	471,696	376,987	226,543	273,062
	45	40	170,861	193,284	137,755	132,097	107,382
	45	35	361,350	123,918	118,625	200,020	260,793
	30	25	75,722	64,474	39,245	53,963	32,704
	All	-	900,598	853,372	672,612	612,623	673,941
1980	60	50	258,194	700,621	423,495	161,723	520,594
	60	45	101,496	-	132,725	117,110	109,303
	45	40	171,018	86,803	57,472	162,723	77,066
	45	35	197,747	192,282	175,185	45,260	91,652
	30	25	340,311	28,558	-	236,789	23,798
	30	20	53,545	53,545	49,976	40,160	17,849
	All	-	1,122,311	1,061,809	838,853	763,765	840,262
1985	60	50	209,620	874,130	487,082	275,306	571,320
	60	45	235,438	-	166,120	146,577	136,805
	45	40	212,073	110,007	116,701	125,003	177,198
	45	35	246,098	239,295	218,270	56,648	114,712
	30	25	434,262	36,442	-	302,162	30,368
	30	20	68,328	68,328	66,773	51,247	22,776
		-	1,405,819	1,328,202	1,054,946	956,943	1,053,179
1990	60	50	259,394	1,089,407	611,104	337,569	716,257
	60	45	290,357	-	207,222	182,843	170,654
	45	40	262,892	139,117	146,193	156,024	220,326
	45	35	58,193	57,152	41,566	-	-
	45	30	247,324	239,904	229,658	70,664	143,095
	30	25	69,642	46,428	-	46,428	38,690
	30	20	570,678	87,053	81,249	403,829	29,018
	All		1,758,460	1,659,061	1,316,992	1,197,357	1,318,040

TABLE 44

ANNUAL VEHICLE-MILES OF AFFECTED TRAVEL BY TYPE OF ACCESS CONTROL AND LOCATION FOR FOUR ALTERNATIVES AND EXISTING HIGHWAYS BY FIVE-YEAR INCREMENTS FROM 1970 TO 1990 (1,000's)

		No Access Control			Full Access Control			
YEAR	HIGHWAY	RURAL	SUBURBAN	URBAN	RURAL	SUBURBAN	URBAN	TOTAL
1970	Existing	374,527	128,480	215,350	-	-	-	718,357
	A-1	352,663	116,654	178,850	33,580	-	-	681,747
	A-2	277,601	94,900	140,160	-	23,360	-	536,021
	A-3	289,409	46,720	152,388	-	--	-	488,517
	A-4	306,617	73,730	156,950	-	-	-	537,297
1975	Existing	463,526	161,388	275,684	-	-	-	900,598
	A-1	338,492	146,343	42,048	139,609	-	186,880	853,372
	A-2	326,614	118,625	39,245	18,068	29,901	140,160	672,612
	A-3	329,116	58,926	195,057	29,524	-	-	612,623
	A-4	348,026	92,601	200,896	32,418	-	-	673,941
1980	Existing	545,152	183,303	393,856	-	-	-	1,122,311
	A-1	426,235	31,116	82,103	284,375	-	237,980	1,061,809
	A-2	282,892	182,748	49,976	106,675	-	216,562	838,853
	A-3	383,336	67,664	276,951	35,814	-	-	763,765
	A-4	347,327	117,790	41,647	95,518	-	237,980	840,262
1985	Existing	497,400	405,829	502,590	-	-	-	1,405,819
	A-1	432,328	38,946	104,770	289,747	158,731	303,680	1,328,202
	A-2	331,156	250,135	66,773	102,492	28,041	276,349	1,054,946
	A-3	285,149	155,251	353,409	163,134	-	-	956,943
	A-4	323,052	257,145	53,144	116,158	-	303,680	1,053,179
1990	Existing	617,344	214,627	926,509	-	-	-	1,758,460
	A-1	299,837	-	421,967	357,234	193,123	386,900	1,659,061
	A-2	413,992	80,336	310,907	124,699	-	387,058	1,316,992
	A-3	357,127	85,850	555,900	198,480	-	-	1,197,357
	A-4	404,713	133,491	251,611	141,325	-	386,900	1,318,040

TABLE 45

SUMMARY OF CALCULATED EQUIVALENT UNIFORM ANNUAL HIGHWAY AND ROAD-USER COSTS AS RELATED TO THE FOUR ALTERNATIVE EXTENSIONS OF I-666 (ALL VALUES IN 1,000's)

Route or Cost Element	Calculated at 7% Vestcharge Rate for I-666 Extension Alternative				Calculated at 10% Vestcharge Rate for I-666 Extension Alternative			
	A-1	A-2	A-3	A-4	A-1	A-2	A-3	A-4
A. Highway Capital Cost ($):								
1. Route I-666 extension	3,410	3,715	6,333	7,054	4,244	4,623	7,881	8,773
2. Supplementary area construction:								
1970	288	341	-	-	358	424	-	-
1975	1,061	1,197	126	126	1,195	1,348	141	141
1980	636	636	-	530	654	654	-	544
1985	170	-	167	-	160	-	157	-
3. Total	5,565	5,889	6,626	7,710	6,611	7,049	8,179	9,458
B. Highway Operation and Maintenance Cost ($):								
1. Route I-666 extension	203	527	1,210	1,262	203	515	1,181	1,228
2. Route I-888	332	318	329	303	325	312	321	297
3. Area-affected routes	1,397	1,238	1,234	1,271	1,367	1,214	1,211	1,248
4. I-666 extensions on existing ROW	286	212	135	248	278	205	133	238
5. Total	2,218	2,295	2,908	3,084	2,173	2,246	2,846	3,011
C. Total EUAC, All Highways ($):	7,783	8,184	9,534	10,794	8,784	9,295	11,025	12,469
D. Motor Vehicle Running Cost ($):								
1. I-666 extension	2,042	8,100	19,147	18,598	1,972	7,815	18,434	17,915
2. I-888, I-666 to interchange 28	8,156	5,111	3,544	1,385	7,872	4,929	3,419	1,330
3. I-888, interchange 21 to I-666 ext.	458	3,697	4,621	6,285	439	3,575	4,463	6,068
4. Area-affected routes	42,022	33,379	29,922	33,297	40,279	31,979	27,891	31,891
5. Total	52,678	50,287	57,234	59,565	50,562	48,298	54,207	57,204
E. Traffic Accident Cost ($):								
1. I-666 extension	67	214	435	490	64	208	421	472
2. I-888, I-666 to interchange 28	229	137	88	39	229	133	86	37
3. I-888 interchange 21 to I-666 jct.	13	113	142	188	13	109	138	181
4. Area-affected routes	2,744	2,399	2,465	2,519	2,691	2,331	2,424	2,462
5. Total	3,053	2,868	3,130	3,236	2,997	2,781	3,069	3,152
F. Total Road-User Cost Without Travel Time ($):	55,731	53,155	60,364	62,801	53,559	51,079	57,276	60,356
G. Travel Time (Hr):								
1. I-666 extension	593	2,331	5,491	5,321	574	2,253	5,299	5,139
2. I-888. I-666 to interchange 28	2,137	1,300	965	341	2,157	1,353	932	329
3. I-888, interchange 21 to I-666 ext.	119	1,031	1,253	1,730	116	981	1,212	1,674
4. Area-affected routes	24,802	19,768	19,622	19,397	23,902	19,001	19,896	18,752
Total	27,651	24,430	27,331	26,789	26,749	23,588	27,339	25,894
H. Total Road-User EUAC of Travel Time ($):								
1. At $1.00 per hr.	83,382	77,585	87,695	89,590	26,749	23,588	27,339	25,894
2. At $2.00 per hr.	111,033	102,015	115,026	116,379	53,498	47,176	54,678	51,788
I. Total Transportation EUAC (highway plus road-user) ($):								
1. Without travel time	63,514	61,339	69,898	73,595	62,343	60,374	68,301	72,825
2. With travel time at $1.00 per hr.	91,165	85,769	97,229	100,384	89,092	83,962	95,640	98,719
3. With travel time at $2.00 per hr.	118,816	110,199	124,560	127,173	115,841	107,550	122,979	124,613

For 1970 to 1975:

$$PW = [(34{,}189 - 26{,}332) \div 5](GPW,7\%,5)^{1} + 26{,}332(SPW,7\%,5) = \$126{,}425$$

For 1975 to 1980:

$$PW = \{[(44{,}296 - 34{,}189) \div 5](GPW,7\%,5) + 34{,}189(SPW,7\%,5)\}(PW,7\%,5) = \$116{,}878$$

The last term $(PW,7\%,5)$ is to bring the present worth at 1975 of the 1975 to 1980 costs back to 1970.

For 1980 to 1985:

$$PW = \{[(55{,}793 - 44{,}296 \div 5](GPW,7\%,5) + 44{,}296(SPW,7\%,5)\}(PW,7\%,10) = \$106{,}058$$

[1] See Winfrey (*14-1*, p. 781).

TABLE 46

MILEAGE, AVERAGE DAILY TRAFFIC, AND ROAD-USER COST FOR I-666 ALTERNATIVES A-1 TO A-4 FOR 1970 AND 1990

Route Section[a]	Distance (Mi)	YEAR 1970 ADT	YEAR 1970 Running Cost ($)	YEAR 1970 Travel Time (Hr)	YEAR 1970 Accident Cost ($)	YEAR 1990 ADT	YEAR 1990 Running Cost ($)	YEAR 1990 Travel Time (Hr)	YEAR 1990 Accident Cost ($)
Alternate Route A-1									
101-102	4.079	5,247	444,585	126,293	14,714	11,491	1,131,225	279,281	32,117
102-103	10.828	986	216,376	67,406	7,339	2,159	473,871	147,619	16,018
103-104	10.985	986	209,796	71,010	7,446	2,159	459,563	155,511	16,248
104-105	13.799	986	282,565	80,850	9,355	2,159	618,823	177,062	20,378
105-106	5.250	1,566	169,018	50,660	5,652	3,430	370,149	110,945	12,336
SUBTOTAL	44.941	1,441[b]	1,322,340	396,219	44,506	3,155[b]	3,053,631	870,418	97,097
106-28	47.016	5,023	5,242,602	1,471,065	162,317	11,210	12,247,942	3,297,868	339,838
TOTAL	91.957	3,272[b]	6,564,942	1,867,284	206,823	7,273[b]	15,301,573	4,168,286	436,935
Alternate Route A-2									
101-102	9.927	5,415	1,090,216	318,920	36,977	11,860	2,496,171	700,176	77,335
202-203	10.074	8,495	1,806,419	503,031	42,499	18,604	4,296,586	1,107,101	94,721
203-204	4.694	5,808	548,927	193,310	10,722	15,392	1,591,414	534,500	25,714
204-205	6.006	1,323	162,498	47,068	3,947	3,201	393,261	113,907	7,540
205-206	7.719	1,177	176,433	53,692	6,249	2,579	386,388	117,585	9,770
206-207	9.788	1,187	234,545	70,680	7,992	2,601	513,686	154,790	16,715
207-208	4.648	2,139	213,427	61,591	6,838	4,684	467,382	134,883	14,301
208-209	5.649	1,483	187,455	51,960	5,761	3,248	410,501	113,589	12,048
209-210	8.695	4,154	744,179	223,042	24,845	9,097	1,669,364	489,765	51,962
SUBTOTAL	67.200	3,715[b]	5,164,099	1,523,294	145,830	8,253[b]	12,224,753	3,466,296	310,106
210-28	20.004	7,099	3,222,478	913,013	97,684	16,130	7,767,184	2,085,303	191,592
TOTAL	87.204	4.491[b]	8,386,577	2,436,307	243,514	10,060[b]	19,991,937	5,551,599	501,698
Alternate Route A-3									
101-302	9.927	5,415	1,139,723	318,920	36,989	11,860	2,604,592	700,176	76,689
302-303	10.074	8,495	1,806,416	503,031	41,675	18,604	4,126,317	1,104,368	91,609
303-304	9.115	6,402	1,285,119	354,396	23,243	14,021	2,942,611	778,187	51,085
304-305	7.839	6,402	1,067,068	320,429	24,246	15,492	2,724,025	781,167	48,329
305-306	10.420	7,314	1,522,196	456,540	30,550	17,700	3,826,235	1,107,056	73,945
306-307	4.999	12,390	1,182,886	361,423	24,671	32,833	3,362,549	961,219	65,612
307-308	2.350	13,571	588,952	184,931	12,703	35,963	2,237,640	499,919	33,915
308-309	8.012	10,016	1,524,636	509,180	39,082	24,239	4,001,895	1,238,321	94,891
309-310	12.613	3,443	881,886	272,397	29,882	7,540	1,930,971	596,547	46,484
310-311	1.755	2,323	90,499	26,159	2,805	5,087	198,283	57,283	6,127
311-312	10.320	2,363	495,691	145,720	16,779	5,175	1,085,596	319,125	36,670
312-313	3.950	2,456	204,737	58,699	6,673	5,378	448,583	128,547	14,580
SUBTOTAL	91.374	6,345[b]	11,789,809	3,511,825	289,298	14,822[b]	29,489,297	8,271,918	639,936
313-28	12.751	7,297	2,257,226	621,565	64,020	16,915	5,351,792	1,448,334	122,805
TOTAL	104.125	6,462[b]	14,047,035	4,133,390	353,318	15,078[b]	34,841,089	9,720,252	762,741
Alternate Route A-4									
101-402	8.243	8,255	1,394,058	405,217	42,385	18,078	3,218,420	890,076	102,202
402-403	8.404	5,004	906,685	259,837	26,195	10,959	2,085,794	570,651	63.160
403-404	2.153	4,810	232,144	69,117	6,444	11,640	667,737	168,972	19,785
404-405	8.006	4,881	784,793	236,116	24,341	10,690	1,816,547	518,665	67,570
405-406	7.603	5,214	800,038	262,915	24,669	11,419	1,853,698	577,456	68,546
406-407	4.000	6,027	491,292	146,689	15,002	13,199	1,196,714	323,187	21,222
407-408	4.730	6,760	622,627	189,310	12,696	16,360	1,638,476	460,193	31,105
408-409	6.511	10,016	1,280,828	384,427	25,894	24,239	3,546,503	937,494	63.440
409-410	3.408	11,071	895,189	227,964	14,981	29,340	2,640,564	608,468	40,190
410-411	4.800	8,521	793,397	240,422	16,240	20,620	2,108,958	584,851	39,787
411-412	2.569	8,670	415,775	130,277	8,843	20,982	1,175,114	317,913	21,665
412-413	5.781	5,337	594,354	181,352	19,200	12,917	1,556,555	440,770	30,014
413-414	8.443	4,325	762,447	242,480	22,723	9,472	1,669,765	531,033	63,142
414-415	5.054	2,488	259,516	87,407	7,832	5,448	568,328	191,422	21,741
415-416	9.840	2,488	512,049	154,869	15,249	5,448	1,121,420	339,160	36,770
416-417	4.935	2,555	333,874	78,537	7,854	5,597	565,714	171,997	18,936
417-418	8.962	2,628	481,963	148,219	14,669	5,755	1,055,512	324,600	40,727
SUBTOTAL	103.442	5,432[b]	11,561,029	3,445,155	305,217	12,513[b]	28,485,819	7,956,908	750,002
418-28	4.357	7,715	825,822	213,953	20,939	18,670	2,169,403	520,509	64,246
TOTAL	107.799	5,515[b]	12,386,851	3,659,108	326,156	12,762[b]	30,655,222	8,477,417	814,248

(a) Interchange to interchange.
(b) Weighted on basis of vehicle-miles.

TABLE 47

MILEAGE, AVERAGE DAILY TRAFFIC, AND ROAD-USER COST FOR I-888 WITHOUT AND WITH ALTERNATIVES A-1 TO A-4 FOR 1970 AND 1990

		YEAR 1970				YEAR 1990			
Route Section[a]	Distance (Mi)	ADT	Running Cost ($)	Travel Time (Hr)	Accident Cost ($)	ADT	Running Cost ($)	Travel Time (Hr)	Accident Cost ($)
		Without Any Alternatives A-1 to A-4							
21-22	3.648	5,161	375,573	110,667	12,950	11,303	926,095	244,022	27,084
22-23	11.037	3,217	785,990	215,031	24,425	7,046	1,721,307	470,918	51,079
23-24	5.464	3,237	363,471	104,162	12,168	7,089	796,000	228,112	26,586
24-25	7.000	2,633	408,211	112,598	12,629	5,767	893,982	246,590	27,593
25-26	4.889	4,853	536,837	142,623	16,417	10,628	1,185,004	312,343	35,804
26-27	10.214	5,333	1,247,720	343,532	37,692	11,679	2,733,506	752,335	82,197
27-28	7.108	5,500	874,747	273,432	27,051	12,045	1,915,698	576,916	58,993
TOTAL	49.360	4,209[b]	4,592,549	1,302,045	143,332	9,218[b]	10,171,592	2,831,236	309,336
		With Alternative A-1							
21-106	2.344	5,760	273,610	79,364	9,280	12,614	714,677	175,658	20,245
106-22	1.304	6,129	154,971	46,979	5,493	13,422	462,250	104,854	11,983
22-23	11.037	4,125	1,007,846	275,725	31,292	9,034	2,207,155	603,838	68,263
23-24	5.464	4,145	465,315	133,429	15,566	9,078	1,019,040	292,111	33,960
24-25	7.000	3,443	533,692	147,213	16,565	7,540	1,203,086	323,063	36,136
25-26	4.889	5,920	654,650	173,990	19,893	12,966	1,552,384	382,943	43,398
26-27	10.214	6,105	1,428,421	393,270	42,860	13,370	3,250,635	862,519	93,501
27-28	7.108	6,273	997,707	300,459	30,648	15,181	2,553,392	728,540	52,597
TOTAL	49.360	5,058[b]	5,516,212	1,550,429	171,597	11,285[b]	12,962,619	3,473,526	360,083
		With Alternative A-2							
21-22	3.648	5,161	375,573	110,667	12,950	11,303	926,095	244,022	27,084
22-23	11.037	3,217	785,990	215,031	24,425	7,046	1,721,307	470,918	51,079
23-24	5.464	3,537	397,154	113,815	13,294	7,746	869,765	249,254	27,801
24-25	7.000	3,633	563,245	155,363	17,423	7,956	1,269,545	340,892	36,431
25-210	2.207	6,303	312,762	82,329	9,568	13,804	684,897	180,276	20,008
210-26	2.682	7,557	461,251	123,402	13,941	16,550	1,161,605	272,663	29,156
26-27	10.214	6,952	1,626,184	447,788	48,847	15,225	3,700,714	982,893	102,153
27-28	7.108	7,137	1,135,043	341,823	34,896	17,272	2,904,865	829,747	60,283
TOTAL	49.360	5,166[b]	5,657,202	1,590,218	175,344	11,551[b]	13,238,793	3,570,665	353,995
		With Alternative A-3							
21-22	3.648	5,161	375,573	110,667	12,950	11,303	926,095	244,022	27,084
22-23	11.037	3,217	785,990	215,031	24,425	7,046	1,721,307	470,918	51,079
23-24	5.464	3,237	363,471	104,162	12,168	7,089	796,000	228,112	26,586
24-25	7.000	2,633	408,211	112,598	12,629	5,767	920,246	247,097	27,593
25-26	4.889	4,651	514,665	135,847	15,647	10,185	1,220,300	298,505	34,183
26-313	4.571	5,846	548,623	158,281	18,354	12,781	1,318,329	348,474	40,099
313-27	5.643	7,286	1,095,523	271,709	28,291	15,956	2,378,768	599,061	61,805
27-28	7.108	7,305	1,161,703	349,856	35,729	17,677	2,973,024	849,273	61,000
TOTAL	49.360	4,759[b]	5,253,759	1,458,151	160,193	10,578[b]	12,254,069	3,285,462	329,429
		With Alternative A-4							
21-22	3.648	5,161	375,573	110,667	12,950	11,303	926,095	244,022	27,084
22-23	11.037	3,217	785,990	215,031	24,425	7,046	1,721,307	470,918	51,079
23-24	5.464	3,237	363,471	104,162	12,168	7,089	796,000	228,112	26,586
24-25	7.000	2,633	408,211	112,598	12,629	5,767	920,247	247,097	27,593
25-26	4.889	5,052	559,016	148,480	15,383	11,063	1,325,466	326,794	37,052
26-27	10.214	5,237	1,255,075	337,328	33,318	11,469	2,853,592	740,428	80,338
27-418	2.751	5,913	307,660	119,249	10,130	14,309	875,481	290,680	31,079
418-28	4.357	7,715	825,822	213,953	20,939	18,670	2,169,403	520,509	64,246
TOTAL	49.360	4,427[b]	4,880,818	1,361,468	141,942	9,928[b]	11,587,591	3,068,560	345,057

(a) Interchange to interchange.
(b) Weighted on basis of vehicle-miles.

TABLE 48

RUNNING COSTS, ACCIDENT COSTS, AND TRAVEL TIME FOR AFFECTED AREA TRAFFIC WITHOUT AND WITH I-666 ALTERNATIVES A-1 TO A-4

	Route Alternative				
YEAR	Existing	A-1	A-2	A-3	A-4
	Running Costs - $1000				
1970	27,724	26,332	20,706	18,789	20,888
1975	35,003	34,189	27,037	23,928	26,598
1980	43,587	44,296	35,335	29,851	35,592
1985	55,135	55,793	44,454	38,154	44,389
1990	72,618	70,984	56,578	50,023	56,407
	Accident Costs - $1000				
1970	2,609	2,422	1,899	1,737	1,933
1975	3,271	2,458	2,042	2,129	2,370
1980	4,048	2,720	2.415	2,461	2,432
1985	5,226	3,143	3,040	3,177	3,016
1990	6,205	3,815	3,510	3,859	3,557
	Travel Time - 1000 Hours				
1970	18,680	17,525	13,714	12,613	13,578
1975	23,478	20,385	15,943	15,707	16,905
1980	33,634	25,496	20,360	22,678	19,230
1985	42,544	31,944	25,926	28,156	24,527
1990	59,441	41,106	33,387	39,119	31,394

For 1985 to 1990:

$$PW = \{[(70{,}984 - 55{,}793) \div 5](GPW,7\%,5) + 55{,}793(SPW,5\%,5)\}(PW,7\%,15) = \$95{,}849$$

Total Present Worth at 1970 = $445,210

$$EUAC = 445{,}210(CR,7\%,20 = 0.094393) = \$42{,}025 \text{ thousand}$$

Difference between $42,025 and $42,022 (Table 45) caused by rounding off.

Note: Calculation for the area-affected traffic accidents and for travel-time hours follows the same procedure as illustrated here for running cost.

For examples of the procedure for calculating the economy of grade reduction, size of culvert, high-level versus low-level bridge, and for stage construction, see Winfrey (*14-1*, Chap. 27).

ECONOMIC ANALYSIS OF THE NONUSER CONSEQUENCES

1. Aesthetics

Route A-1:

Benefits: The granite outcroppings in the hill areas are of possible geological interest. Roadside landscaping would improve the aesthetic quality of the route. Stonework on retaining walls would blend with the granitic character of the geology. Scenic views of river and of West Valley are attractive.

Costs: The abandoned worked-out quarries are much in the view. Blighted rural housing is in evidence (depressed area). There is general lack of visual merit to the route.

Route A-2:

Benefits: The route separates the industrial-commercial "westside" of Hilldale from the residential area—a logical boundary. Granite outcropping in hill area is of possible geological interest. Views of the farmlands west of the river are pleasing.

Costs: The view of the industrial-commercial area of Hilldale is unattractive and so are the views of quarry and mine tailings. Blighted rural housing exists. The route generally lacks visual merit.

Route A-3:

Benefits: Access is convenient to central Easton where there are a number of Colonial, Federal, and Victorian houses. Historic Garber House, home of first state governor, is accessible from interchange 308. Views of residential areas of Easton, Hilldale, and Riverton and occasionally a view of the river are seen. Impressive bluffs forming sides of valley are visible. A generally scenic route.

Costs: Barriers: divides residential neighborhoods in

DETAILED CALCULATIONS FOR TRAVEL ON TANGENT GRADES BETWEEN INTERCHANGES 305 AND 306 FOR 1970, BY GRADE SEGMENTS

Grade, %	± 1.4		± 0.6		0.0		± 3.75	
Distance, Miles	3.568		4.427		1.379		1.046	
Speed On Grades, Plus (Minus)								
Passenger Car	65	(65)	65	(65)	65	(65)	60	(60)
Commercial Delivery	60	(60)	60	(60)	60	(60)	52½	(55)
Single-unit Truck	50	(52½)	55	(55)	55	(55)	30	(35)
2-S2 Comm. Vehicle	45	(47½)	50	(50)	50	(50)	25	(27½)
3-S2 Comm. Vehicle	45	(47½)	50	(50)	50	(50)	22½	(25)

ADT Distribution

Vehicle Type	
Pass. Car =	6,056
Comm. Del. =	336
SUT =	322
2-S2 =	373
3-S2 =	227
TOTAL	7,314

Unit Cost of Travel on Tangent; Plus, Minus - Average ($ per 1,000 Vehicle-Miles)

	(+)	(-)	(av)	(+)	(-)	(av)	(+)	(-)	(av)	(+)	(-)	(av)
Passenger Car	44.60	38.39	41.49	42.93	40.27	41.60	41.71	41.71	41.71	47.78	31.66	39.72
Commercial Delivery	52.91	43.64	48.27	50.12	46.17	48.14	48.11	48.11	48.11	55.58	34.91	45.24
Single-unit Truck	89.95	69.33	79.64	87.10	75.94	81.52	80.24	80.24	80.24	89.82	51.97	70.89
2-S2 Comm. Vehicle	158.41	92.14	125.27	144.67	107.62	126.14	118.70	118.70	118.70	171.11	68.43	119.77
3-S2 Comm. Vehicle	138.22	91.71	114.96	128.71	105.48	117.09	113.63	113.63	113.63	151.97	73.67	112.82

1970 Annual Vehicle-Miles Of Travel On Tangent

	± 1.4	± 0.6	0.0	± 3.75	TOTALS
Passenger Car	7,886,850	9,785,618	3,048,197	2,312,120	23,032,785
Commercial Delivery	437,580	542,927	169,121	128,281	1,277,909
Single-unit Truck	419,347	520,305	162,074	122,936	1,224,662
2-S2 Comm. Vehicle	485,765	602,714	187,744	142,408	1,418,631
3-S2 Comm. Vehicle	295,627	366,799	114,257	86,666	863,349
TOTAL	9,525,169	11,818,363	3,681,393	2,792,411	27,817,336

1970 Annual Running Costs on Tangent Segments, $

	± 1.4	± 0.6	0.0	± 3.75	TOTALS
Passenger Car	327,225	407,081	127,140	91,837	953,283
Commercial Delivery	21,121	26,136	8,136	5,803	61,196
Single-unit Truck	33,396	42,415	13,004	8,714	97,529
2-S2 Comm. Vehicle	60,851	76,026	22,285	17,056	176,218
3-S2 Comm. Vehicle	33,985	42,948	12,983	9,777	99,693
TOTAL	476,578	594,606	183,548	133,187	1,387,919

DETAILED CALCULATIONS FOR ADDITIONAL TRAVEL COSTS ON HORIZONTAL CURVES BETWEEN INTERCHANGES 305 & 306 FOR 1970, BY HORIZONTAL CURVE

Horizontal Curve° (Grade, %)	1° (1.4%)			2° (3.75%)			3° (0%)		
Distance, Miles	0.890			1.043			0.180		
Additional Unit Cost Of Travel On Horizontal Curves; Plus Grades, Minus Grades - Average ($ per 1,000 Vehicle-Miles)	(+)	(-)	(av)	(+)	(-)	(av)	(+)	(-)	(av)
Passenger Car	6.16	6.16	6.16	9.71	9.71	9.71	19.96	19.96	19.96
Commercial Delivery	5.50	5.50	5.50	7.58	8.90	8.24	18.68	18.68	18.68
Single-unit Truck	6.84	8.22	7.53	5.25	5.52	5.38	32.49	32.49	32.49
2-S2 Comm. Vehicle	10.12	12.97	11.54	8.71	9.78	9.24	55.41	55.41	55.41
3-S2 Comm. Vehicle	13.19	16.89	15.04	11.28	11.45	11.36	71.88	71.88	71.88

1970 Annual Vehicle-Miles of Travel On Horizontal Curves

	1°	2°	3°	TOTALS
Passenger Car	1,967,291	2,305,488	397,879	4,670,658
Commercial Delivery	109,149	127,913	22,075	259,137
Single-unit Truck	104,601	122,583	21,155	248,339
2-S2 Comm. Vehicle	121,169	141,999	24,506	287,674
3-S2 Comm. Vehicle	73,740	86,417	14,913	175,070
TOTAL	2,375,950	2,784,400	480,528	5,640,878

1970 Additional Operating Costs For Horizontal Curves, $

	1°	2°	3°	TOTALS
Passenger Car	12,118	22,386	7,941	42,445
Commercial Delivery	600	1,054	412	2,066
Single-unit Truck	787	659	687	2,133
2-S2 Comm. Vehicle	1,398	1,312	1,357	4,067
3-S2 Comm. Vehicle	1,109	981	1,071	3,161
TOTAL	16,012	26,392	11,468	53,872

DETAILED CALCULATIONS FOR 1970 ANNUAL TRAVEL TIME ON TANGENT SEGMENTS BETWEEN INTERCHANGES 305 & 306 FOR 1970, BY GRADE SEGMENT. (HOURS)

Grade, %	± 1.4%		± 0.6%		± 0.0%		± 3.75%		
1970 Annual Vehicle-Miles Of Travel On Tangent									
Passenger Car	3,943,425	3,943,425	4,892,809	4,892,809	1,524,098.5	1,524,098.5	1,156,060	1,156,060	
Commercial Delivery	218,790	218,790	271,463.5	271,463.5	84,560.5	84,560.5	64,140.5	64,140.5	
Single-unit Truck	209,673.5	209,673.5	260,152.5	260,152.5	81,037	81,037	61,468	61,468	
2-S2 Comm. Vehicle	242,882.5	242,882.5	301,357	301,357	93,872	93,872	71,204	71,204	
3-S2 Comm. Vehicle	147,813.5	147,813.5	183,399.5	183,399.5	57,128.5	57,128.5	43,333	43,333	
1970 Annual Travel Time On Grade Segments; Plus - Minus (Hours)									**Total**
Passenger Car	60,668.1	60,668.1	75,274.0	75,274.0	23,447.7	23,447.7	19,267.7	19,267.7	357,315
Commercial Delivery	3,646.5	3,646.5	4,524.4	4,524.4	1,409.3	1,409.3	1,221.7	1,166.2	21,548
Single-unit Truck	4,193.5	3,993.8	4,730.0	4,730.0	1,473.4	1,473.4	2,048.9	1,756.2	24,399
2-S2 Comm. Vehicle	5,397.4	5,113.3	6,027.1	6,027.1	1,877.4	1,877.4	2,848.2	2,589.2	31,757
3-S2 Comm. Vehicle	3,284.7	3,111.9	3,668.0	3,668.0	1,142.6	1,142.6	1,925.9	1,733.3	19,677
TOTAL									454,696

Figure 42. Detailed calculations for motor vehicle running costs, accident costs, and travel time for highway segment 305-306 of Alternative A-3 for 1970 and 1990.

- 1970 -

Vehicle	Spd. Ch.	ADT	Unit Cost ($ per 1,000 Cycles)	1970 Annual Cost ($)	Unit Time (Hrs. per 1,000 Cycles)	1970 Annual Time (Hrs.)
Passenger Car	65 55	6,056	15.09	33,355	0.18	398
Commercial Delivery	60-50	336	13.69	1,678	0.43	53
Single-unit Truck	55-35	322	44.52	5,232	1.84	216
2-S2 Comm. Vehicle	50-25	373	166.65	22,688	4.88	664
3-S2 Comm. Vehicle	50-25	227	210.64	17,452	6.19	513
TOTAL				80,405		1,844

- 1990 -

Vehicle	Spd. Ch.	ADT	Unit Cost ($ per 1,000 Cycles)	1990 Annual Cost ($)	Unit Time (Hrs. per 1,000 Cycles)	1990 Annual Time (Hrs.)
Passenger Car	65-55(2)	14,656	15.09	161,446	0.18	1,926
Commercial Delivery	60-50(2)	813	13.69	8,124	0.43	255
Single-unit Truck	55-35	779	44.52	12,658	1.84	523
	55-45		26.00	7,393	0.71	202
2-S2 Comm. Vehicle	50-25	903	166.65	54,927	4.88	1,608
	50-40		85.71	28,249	1.66	547
3-S2 Comm. Vehicle	50-25	549	210.64	42,209	6.19	1,240
	50-40		110.26	22,094	1.95	391
TOTAL				337,100		6,692

DETAILED CALCULATIONS FOR ACCIDENT COSTS BETWEEN INTERCHANGES 305 & 306 FOR 1970 & 1990

		Frequency Per Year(a)			Cost Per Accident, $			Total Accident Costs, $			
Year	Vehicle-Miles	Fatal	Injury	Prop. Dam.	Fatal	Injury	Prop. Dam.	Fatal	Injury	Prop. Dam.	Total
1970	27,817,336	0.47	14.8	36.4	6,821	1,427	171	3,206	21,120	6,224	30,550
1990	67,317,953	1.14	35.8	88.2	6,821	1,427	171	7,776	51,087	15,082	73,945

(a) See Table 42 for rates per 100,000 vehicle-miles. Based on Winfrey (14-1, Table 15-11, for urban-controlled access).

SUMMARY OF DETAILED CALCULATIONS FOR TRAVEL COSTS AND TRAVEL TIME BETWEEN INTERCHANGES 305 & 306 FOR 1970 & 1990

		1970 Travel Costs, $				1970 Travel Time, Hrs.			
Vehicle	ADT	On Tangents	Added By Curves	Added By Spd.Chgs.	TOTAL	On Tangents	Added By Spd.Chgs.	TOTAL	Accident Costs, $
Passenger Car	6,056	953,283	42,445	33,355	1,029,083	357,315	398	357,713	
Commercial Delivery	336	61,196	2,066	1,678	64,940	21,548	53	21,601	
Single-unit Truck	322	97,529	2,133	5,232	104,894	24,399	216	24,615	
2-S2 Comm. Vehicle	373	176,218	4,067	22,688	202,973	31,757	664	32,421	
3-S2 Comm. Vehicle	227	99,693	3,161	17,452	120,306	19,677	513	20,190	
TOTAL	7,314	1,387,919	53,872	80,405	1,522,196	454,696	1,844	456,540	30,550

		1990 Travel Costs, $				1990 Travel Time, Hrs.			
Vehicle	ADT	On Tangents	Added By Curves	Added By Spd.Chgs.	TOTAL	On Tangents	Added By Spd.Chgs.	TOTAL	Accident Costs, $
Passenger Car	14,656	2,306,945	102,717	161,446	2,571,108	864,702	1,926	866,628	
Commercial Delivery	813	148,094	5,000	8,124	161,218	52,146	255	52,401	
Single-unit Truck	779	236,020	5,162	20,051	261,233	59,046	725	59,771	
2-S2 Comm. Vehicle	903	426,448	9,842	83,176	519,466	76,852	2,155	79,007	
3-S2 Comm. Vehicle	549	241,257	7,650	64,303	313,210	47,618	1,631	49,249	
TOTAL	17,700	3,358,764	130,371	337,100	3,826,235	1,100,364	6,692	1,107,056	73,945

NOTE: 1990 Travel Costs on Tangents and Curves and 1990 Travel Time on Tangents Calculated by Multiplying applicable figures by 2.42.

Figure 42 (continued).

Hilldale, Easton, and Riverton. Elevated highway would spoil the view from urban residences. The highway is out of scale with the historic houses along highway path through Easton; may require depressing and landscaping to avoid adverse effect on historic area of Easton. High glare lighting could create nuisance in residential areas of Easton, Riverton, and Hilldale. The right-of-way takes four historic houses in Easton. Four acres of ten-acre Fernhill Park, a recreation area serving south Easton, are taken for right-of-way. The area of blighted housing is visible in Hilldale. Landfill garbage dump is visible on approach to interchange 309, west of Easton.

Route A-4:

Benefits: The route follows the natural boundary along the base of the bluffs forming the side of the river valley. Route A-4 provides occasional views of the river from higher ground and forms the edge of residential development in Easton. Easy access is provided to Piney Bluffs Battleground National Monument, scene of Civil War siege of Easton, via interchange 410. There are excellent views of bluffs between interchanges 409 and 410 when northbound.

Costs: The route is a barrier dividing the residential area of Riverton. The route is out of scale with the high-value residential area of Riverton through which it passes. The right-of-way may require depressing and landscaping to avoid adverse effects in that area. Landscaping and sensitive design needed in vicinity of National Monument due to highway's high visibility from the Monument overlook. Joint development needed to replace 3-acre neighborhood park in Riverton taken for right-of-way. A junkyard is visible near Lasting—needs screening treatment to obscure it.

2. Agriculture

A summary of the statistical effects on agriculture of each alternative is as follows:

CORRIDOR LAND USE AND CAPABILITY (ECONOMIC BASE)	LAND AREA (SQ MI) BY ALTERNATIVE ROUTE			
	A-1	A-2	A-3	A-4
Land in agricultural development	50	125	300	450
Developable agricultural land	25	40	130	100
Land in resource development	10	30	50	75
Developable resource land	30	30	40	60
Land in urban and other uses	15	40	150	175
Developable for uses (urban, industrial, commercial, recreational, etc.) other than agriculture and resource	120	155	130	100
Undevelopable land	200	250	100	70
Total land in corridor	450	670	900	1,030

Route A-1:

Benefits: The highway improvement will have a potential for assisting in recovery of depressed area by increasing productivity of existing and potential resources (agricultural, mineral and recreational) through improved access. The potential exists for income supplement from industrial jobs in Southton.

Costs: Because farms are small there is the possibility of creating uneconomical unit sizes by partial right-of-way takings. Farm incomes and population lowering are likely if the takings result in small remainders.

Route A-2:

Benefits: As in case of Route A-1, highway improvement has potential for relieving a depressed farming and mining area through better access leading to greater productivity and resource development.

Costs: Right-of-way taking and severance may create uneconomical farm units.

Route A-3:

Benefits: Improved access will open farms near Easton and Riverton to urbanization thereby raising the values of affected farms. Farmers will be able to obtain part- or full-time urban jobs due to decreased travel time and distance.

Costs: At least three cattle passes probably will be required due to severance of large dairy-farm holdings on the route.

Route A-4:

Benefits: As in Route A-3, potential exists for urbanization of farmland with value increases. Farmers may obtain urban employment for income supplement. Highway opens to development a considerable area of rich bottom land.

Costs: Right-of-way taking will deplete orchard lands near Lasting which are difficult to reproduce except over long periods.

3. Commercial

The following data on dislocations give the commercial disruption for the four route locations:

DISLOCATIONS	ALTERNATIVE ROUTE			
	A-1	A-2	A-3	A-4
Proprietors	1	3	9	4
Employees	2	12	40	15
Annual payrolls ($1,000)	18	84	300	101
Annual trade volumes ($1,000)	105	1,302	3,201	1,607
Value of structures ($1,000)	30	110	350	175

In the following descriptions the commercial factors are presented in some detail for each alternative location.

Route A-1:

Benefits: Increasing the volume of traffic on I-888 by tying in I-666 near West Valley would increase the sales potential of tourist-oriented retail outlets located at I-888 interchanges. Tourist sales potential would be generated at interchanges 102 and 105 where Route A-1 interchanges with other key routes with heavy tourist use.

Costs: Dislocation of one commercial enterprise with one proprietor and two employees.

Route A-2:

Benefits: Northward expansion of Hilldale along the route would create a shopping-center potential at interchange 204. Tourist sales potential would be generated at interchanges 204 and 207 where Route A-2 interchanges with other key tourist routes.

Costs: The route location separates most of Hilldale from the west side industrial-commercial "strip." The outlets are mostly oriented to through traffic (food-gas-lodging) so local inconvenience is limited to extra travel for commuters bound for industrial plants. Traffic diversions will reduce demand at auto-oriented outlets in Quincy's and Hilldale's commercial-industrial "strip." The increase in the trade area of Hilldale to the south and northwest will have but limited effect. Toward the south, the competition is with Southton. The sparse, depressed population to the northwest would not increase Hilldale's trade from that direction.

Route A-3:

Benefits: Population growth in the area between Easton and Riverton will create opportunity for a major shopping center at interchange 306. The result will be to draw trade away from the CBD's and shopping centers in Hilldale; Easton and Riverton would be expanded along the alignment. Gainers would be Easton and Hilldale which would capture trade from Riverton and Monroe, respectively, due to the greater attraction of larger centers over smaller ones when they are equally accessible.

Costs: In Easton, Route A-3 forms a barrier between the CBD and southwest residential areas with considerable inconvenience in that the CBD is the main center for this area for both "shopping" and "convenience" goods. The high level of walk-in trade will suffer greatly. A barrier is also formed between the Northeast shopping center and 50 percent of its trade area north of the right-of-way. Survival of marginal enterprises is doubtful. Route A-3 probably would accelerate the tendency for middle and upper income groups to decentralize from central Easton and reduce the trade level in the CBD which would then attract only the remaining lower-income groups. Bypassing will affect strip development along alternative routes in Hilldale, Monroe, Riverton, Easton, and Albany.

Route A-4:

Benefits: Due to the river barrier, the population growth of Riverton is likely to proceed south and west. Southward expansion would create shopping-center potentials at interchange 407. Easton's eastward expansion and the barrier between that portion of the city and the CBD formed by the river will create similar potentials at interchange 409. Riverton's trade area would be expanded toward the south, and could capture a portion of the trade now going to Monroe and Lasting. Hilldale might also gain from the north-south expansion of its trade area due to the tie-in at interchanges 403 and 404. Easton's trade area would be expanded up and down the valley into areas presently served by Riverton and Albany.

Costs: A highway barrier will be formed between east Riverton and the CBD. Local convenience shops on the east side are ample, however, and the CBD will experience only slight impact. Decentralization of middle- and upper-income groups in Riverton could cause a decline in CBD sales. Bypassing will adversely affect commercial strip development along the bypassed alternative routes in Hilldale, Lasting, Monroe, Riverton, and Easton. Local trade probably will be sufficient to make up any loss in Easton and Riverton. Hilldale, New Field, and Hastings will suffer most from the diversion of traffic because of having economic bases heavily oriented to tourist trade. Motels will feel the adverse effect to greatest extent, particularly in the smaller centers without tourist attractions or business trip destinations to draw trade in spite of bypassing.

4. Community Government

Route A-1:

Benefits: Public policy for area redevelopment of economically depressed area traversed by this route is abetted.

Costs: Rural school district boundaries are altered by barrier effect of right-of-way. Counter measures will require one consolidation and two school expansions.

Route A-2:

Benefits: The area redevelopment policies are furthered by Route A-2 location. The bookmobile service area from Hilldale can be expanded by 10 miles.

Costs: Right-of-way taking removes one volunteer firehouse; replacement cost is $60,500.

Route A-3:

Benefits: Route A-3 aids the public policy of promoting tourist travel to historic sites in Easton's vicinity.

Costs: The right-of-way takes 4 acres of parkland in Easton.

Route A-4:

Benefits: The route will promote tourism to Easton historic sites and conforms to Riverton's urban development policies to encourage growth in the south-central portion of the city. Riverton's industrial promotion policies are also abetted.

Costs: Three-acre neighborhood park taken in Riverton; replacement cost is $30,000.

5. Construction

Route A-1:

Benefits: Assistance will be provided to local depressed economy due to hiring construction workers locally for work on highway. A long-term boost to the construction industry will be given as the highway-induced development of resources generates need for plant, employee housing, and commercial facilities.

Costs: Construction activity will temporarily impair local access due to detouring.

Route A-2:

Benefits: Depressed local economy will be temporarily boosted by highway construction payrolls. Long-term construction benefits will come from resource development in the area.

Costs: The disruption to traffic patterns due to detouring will be heavy, especially in Hilldale's "commercial-industrial strip" where bypassing may harm motel trade.

Route A-3:

Benefits: Local economy will be boosted by worker-hiring for construction of the highway. Gains will be greater on Route A-3 than A-4 due to longer length of roadway and additional time to construct. Expansion of industry, residential, and commercial sectors of Riverton and Easton will generate long-term construction demands.

Costs: Street blockage, dust, noise, and truck traffic will create nuisance effects in residential areas of the affected cities.

Route A-4:

Benefits: Similar to Route A-3.

Costs: Similar to Route A-3.

6. Employment

Route A-1:

Benefits: Because of improved access, the resource development will increase employment opportunities in this area of high unemployment.

Costs: Employment probably will decline in agriculture due to movement toward larger, more efficient farm units and the severance of smaller units, making them uneconomical.

Route A-2:

Benefits: Employment increases are likely in the industrial area of Hilldale that is well-served by Route A-2. Rural employment increase, projected on basis of resource development, will aid recovery of a high unemployment area. Rural dwellers near Hilldale can commute to jobs in town. Commercial employment may decline temporarily due to bypass effect on Hilldale's "gas-food-lodging" sector.

Costs: Some decrease in farm employment due to farm unit expansion and severance of small land units by the highway. The result will encourage farm-to-town migration.

Route A-3:

Benefits: Industrial growth of Easton and Riverton will be encouraged by highway improvement that will increase employment. Secondary employment increases in commercial sector will occur to service basic industry employment growth.

Costs: Employment declines in central business areas of Easton and Riverton are likely, due to the highway's decentralizing effect on industry and commerce.

Route A-4:

Benefits: Employment in tourist-serving sector will increase most with Route A-4 in that it best serves tourist sites while disrupting the fewest number of same. Other benefits are similar to Route A-3.

Costs: Similar to Route A-3.

7. Environment

Route A-1:

Benefits: The highway, if properly designed, can improve drainage patterns and create badly needed farm ponds in agricultural areas.

Costs: Traffic noise would adversely affect turkey farms in corridor if alignment is too close.

Route A-2:

Benefits: A potential for creating farm ponds in the agricultural areas from borrow pits.

Costs: Streams, tributary to Main River, carry large migrations of sport and commercial fish. Highway disruption of streams with negative effect on fish migration would adversely affect fisheries industry and recreation potential of area.

Route A-3:

Benefits: A potential for aiding farm drainage patterns.

Costs: Adverse effects on residential areas of Riverton and Easton are expected because of the potential consequences from highway generated noise, vibration, and air pollution. The air pollution problem is already serious in Easton, where there is a high incidence of respiratory disease, vegetation blight, and low visibility levels.

Route A-4:

Benefits: Same as Route A-3.

Costs: Same as Route A-3.

8. Industrial

Route A-1:

Benefits: Resource-oriented industry growth potential will be enhanced in agriculture, canning, grain products, mining, quarrying, and forestry.

Costs: The dislocation of two manufacturing enterprises includes the sawmill and woodcrafts plant of a total investment of $400,000 and a total employment of 25.

Route A-2:

Benefits: An expansion of the industrial area in Hilldale is likely, based on access improvement. A resource-oriented industry potential exists in rural areas (e.g., agriculture, canning, mining, and quarrying).

Costs: Hilldale will suffer displacement of one industrial enterprise, a boxboard plant, total investment of $220,000, and total employment of 19.

Route A-3:

Benefits: New industry is likely to be generated in Easton and Riverton in noncentral locations. A large skilled labor force exists, along with a mix of industries that could complement new industry. Support services and suppliers are abundant.

Costs: Easton will suffer displacement of two industrial plants—a soft drink bottler and an electronics parts maker. The total investment is $1,100,000 and total employment is 48. Easton stands to lose some tax base and employment if Route A-3 encourages relocation of central area industries beyond city boundaries.

Route A-4:

Benefits: Industrial growth will be encouraged in Easton and Riverton.

Costs: Displacement of a concrete manufacturing plant in Riverton will involve a total investment of $450,000 and an employment of 12. Riverton could lose employment and some tax base due to decentralizing industry.

9. Institutions

Route A-1:

Benefits: Rural areas will have greater access to in-town institutions via improved highway than before.

Costs: One grange hall will be dislocated; replacement cost is $40,000.

Route A-2:

Benefits: More rural farm dwellers will have access to institutions in Hilldale.

Costs: One church is made relatively inaccessible to most of its congregation due to the limited-access feature of the highway. The average distance to church per parishoner will be increased from 1 mile to 3 miles.

Route A-3:

Benefits: Central area institutions in Easton and Riverton will enjoy improved accessibility to their service areas and probably increased patronage. Decentralization of population will create demand for suburban institutions.

Costs: Right-of-way taking dislocates one private school and one church; total replacement cost is $850,000. A settlement house in Easton will lose 60 percent of its patrons due to dislocation of households for right-of-way.

Route A-4:

Benefits: Central area institutions will have service areas expanded to provide for increased patronage.

Costs: A fraternal organization's hall dislocated in Riverton; replacement cost is $150,000.

10. Population

Route A-1: Corridor population: 10,000.

Benefits: New resource-oriented industry would lead to population growth in corridor.

Costs: Farm population likely to fall; highway would hasten decline through displacement of farm labor by mechanization.

Route A-2: Corridor population: 21,000.

Benefits: New industry would cause population growth.

Costs: Out-migration of farm population encouraged by highway effects on farming patterns and practices.

Route A-3: Corridor population: 134,000.

Benefits: Population increases are predictable for Easton and Riverton due to attractions of highway access.

Costs: Central area densities will fall due to right-of-way takings and residential decentralization.

Route A-4: Corridor population: 139,000.

Benefits: Population growth due to industrial expansion in Easton and Riverton is likely. Route A-4 would serve the largest population of the four alternative routes.

Costs: Residential decentralization would increase suburban densities and lower central city densities.

11. Public Utilities

Route A-1:

Benefits: Monetary worth of utility line easements: 45 miles at $4,000/mi = $180,000.

Costs: Cost to relocate utility lines for highway construction: $95,000.

Route A-2:

Benefits: Worth of utility easements: $268,000.

Costs: Utility line relocation cost: $150,000.

Route A-3:

Benefits: Worth of utility easements: $364,000.

Costs: Utility line relocation cost: $410,000. Low-density residential pattern resulting from residential decentralization in Easton and Riverton will cost more to service with utilities due to "leapfrog" development and increased linear feet of utility line per dwelling.

Route A-4:

Benefits: Worth of utility easements: $412,000.

Costs: Utility line relocation cost: $520,000. The capital cost of utilities installation will be higher under decentralized pattern of residential development outside Easton and Riverton than before.

12. Residential Neighborhoods

Route A-1:

Benefits: The higher incomes due to new industry will encourage improvement of housing. Residential property values will rise in response to increased demand.

Costs: Residential dislocations due to right-of-way taking: 12; total replacement cost, $480,000.

Route A-2:

Benefits: Better housing will result from pay offered by the new industry encouraged by highway improvement. Higher property values will ensue.

Costs: Residential dislocations, 19; total replacement cost, $610,000.

Route A-3:

Benefits: Slum clearance will result from right-of-way takings in Easton and Riverton. Forty units will be affected. Residential decentralization is likely due to highway's increasing the commuter range of employment centers in Easton and Riverton.

Costs: Residential dislocations, 73; total replacement cost, $1,500,000. Slum area dislocatees will pay higher rents or prices than presently due to competition for a reduced supply of central area housing. Land taking will disrupt community linkages for a cohesive ethnic neighborhood.

Route A-4:

Benefits: Decentralization of residents into newer housing in suburban Easton and Riverton will be facilitated by highway improvement.

Costs: Residential dislocations, 35; total replacement cost, $800,000. Quality of neighborhood life and property values will decline if there is a protracted period between route selection and right-of-way takings due to owner neglect of upkeep and loss of potential buyers.

13. Road User

Route A-1:

Benefits: Safety of road users will be enhanced by bypassing traffic around commercial strips on existing roadways.

Costs: Development of resource industries in corridor will generate commuter traffic on highway and begin a rise in user cost due to congestion.

Route A-2:

Benefits: Traffic flow through Hilldale will be improved by bypass effect of limited-access highway on the "commercial-industrial" strip development.

Costs: Commercial development probably will reorient itself to interchange locations and then will generate congestion at peak hours.

Route A-3:

Benefits: Faster commuter trips will be possible from outlying residential areas to central employment opportunities.

Costs: Development responding to lower trip times occurring at greater distances and lower densities will increase total trip distances in the aggregate. Higher user operating costs will result.

Route A-4:

Benefits: Similar to Route A-3.

Costs: Similar to Route A-3.

14. Spatial and Geographical Changes

Route A-1:

Benefits: Access to regional markets is improved by Route A-1 enabling increased resource development.

Costs: Bypassed commercial areas will reorient to interchanges at the cost of relocation.

Route A-2:

Benefits: Many rural residents will be able to obtain part- or full-time jobs in industries in Hilldale.

Costs: Bypass of commercial strip in Hilldale will encourage relocation of enterprises there to interchanges.

Route A-3:

Benefits: The metropolitan spread of Easton and Riverton will produce residential amenities. New opportunities for commercial and industrial relocation in outlying areas will occur.

Costs: Decentralization will occur at the expense of the central city which will lose residents, commerce, and industry. Patrons of smaller trading centers will be drawn to the larger centers for wider choice of goods and prices when the highway improvement makes the access equal.

Route A-4:

Benefits: Greater intra- and interregional accessibility will enhance tourist potential of the region based on historic sites reached via Route A-4.

Costs: Some regional industry in small towns may be attracted to larger metropolitan centers for reasons of efficiency, accessibility, and agglomeration economies. Depression of small-town economies may result.

15. Urban Form and Development

Route A-1: No urban areas.

Benefits: None.

Costs: None.

Route A-2:

Benefits: Growth predicted for Hilldale will increase demand for land and therefore increase land values. More space will be required for industry and commerce. A dispersed pattern of residential units will begin to form about the old town core.

Costs: Value of land taken for right-of-way through Hilldale: $2,680,000.

Route A-3:

Benefits: Economic growth of Easton and Riverton promoted by Route A-3 will raise land values. All land uses will be increased in area. More land will be required for auto-oriented use to accommodate the predominant mode (e.g., parking, garages, streets, car lots).

Costs: Central business districts will not be able to absorb the added traffic volumes. Competitive advantage of CBD retail stores will be lost to suburban shopping centers.

Route A-4:

Benefits: Higher land values will result from highway-influenced economic growth.

Costs: CBD retail sales will suffer from congestion and attraction of outlying shopping centers.

SUMMARY DISCUSSION OF THE ILLUSTRATIVE ECONOMIC ANALYSIS

This economic analysis illustrates the detailed procedure, steps, and results of a two-part analysis: (1) the engineering economy of the road-user consequences are calculated, and (2) the descriptions of the nonuser consequences (consisting of the social, economic, environmental, and community effects) are developed. Considerably more detail and analyses could be presented to render some assistance to the decision maker in reaching his choice of Interstate alternative route location.

The analyst usually is confronted with three limitations, whether it be on the road-user analysis or the nonuser analysis. First, there is the absence of input data that may be physically possible to collect, given the resources of time, money, and talent; second, particularly in the nonuser area, many of the effects after completion of construction must be forecast without solid guidelines or experience; and third, there is usually insufficient time, money, and talent available to collect all the information that could be used to advantage and then make the necessary analyses using that information.

Other than these three main restraints to completing the ideal economic analysis, there are many factors that do not arise on any assured basis until highway design is well advanced, public hearings are held, and the analyst and decision maker become deeply involved in the project proposal. Nevertheless, this illustrative analysis can be a helpful guide to anyone who will study it objectively.

Some of the missing information could be named more specifically.

1. Many local rural roads and city streets will be closed and the traffic rerouted, usually necessitating greater travel than is required by present facilities. The closing of these routes at the interstate boundary is one of the adversities to travel after construction of I-666 as well as to the community, land use, and land values that are not discussed in this analysis.
2. No doubt the travel on I-888, now completed, will be affected by construction of the supplementary improvements at the five-year intervals. Such effects on the road user and on the nonuser along I-888 are not discussed.
3. From the place where each of the four alternative route locations (A-1, A-2, A-3, and A-4) join I-888 to West Valley and to Northville there will be adverse effects on the traffic on that route as compared to without I-666 traffic. Alternative A-1 contributes the most and A-4 the least adverse effects on I-888 traffic.
4. Should Alternative A-2 or A-4 be initially constructed, there is a real possibility that in some future year locations A-1 or A-2 will be needed as relief for the traffic through the urban areas. Should Alternative A-1 or A-2 be initially constructed, no doubt in some future year the urban areas along the A-3 and A-4 locations will need a full-length high-capacity facility equivalent to what the Interstate would provide now. These probabilities are subjects for study by the decision maker.
5. Not covered in the analysis are the social and economic developments in the northeast up to 1990 with and without any Interstate, as well as with each one of the four alternative locations. Certainly this Atlantic area and northeast United States will experience great social and economic changes in the next 20 years. The urban area and rural area directly affected by any location of the I-666 connection with I-888 will change in spite of the I-666 location or whether it is built or not.

When one is reading the descriptions of the nonuser consequences pertaining to this illustrative economic analysis, it is suggested that frequent reference be made to Appendix B for a detailed summary and an evaluation of the social and economic consequences as outlined under the 15 major headings of Table 17. The basic divisions of subject matter in this solution follow those in Appendix B so that cross reference is relatively convenient.

REFERENCES

14-1. WINFREY, R., *Economic Analysis for Highways.* International Textbook Co., Scranton, Pa. (1969) 923 pp.

14-2. SCHNEIDER, N. J., "Estimating Operating Costs in the Economic Evaluation of Traffic Networks." HRB Annual Meeting (Jan. 1969).

APPENDIX A

SUMMARY OF REPORTS OF PROJECTS 2-1 TO 2-9

This appendix provides summaries of NCHRP Projects 2-1 through 2-9 inclusive, on which a large proportion of this report is based. It is designed to pull out the important aspects of the research, those usable by the reader, whether decision maker, highway planner, or researcher, for measuring highway costs, benefits, and other consequences. For this purpose, the objectives, approaches, and findings of the reports are presented briefly to indicate what was done, why and how, and what was found out.

These summaries are intended to supplement this report with supporting data useful in economic and financial analyses. If more detailed information on methodologies and findings is desired, refer to the published reports.

PROJECT 2-1: CRITERIA FOR HIGHWAY BENEFIT ANALYSIS [1]

Research Agency: University of Washington

OBJECTIVES

The project's objectives were: (1) to provide estimates of the relevance of different types of benefit and cost data to different highway location and design decision-making processes; and (2) to furnish (a) basic guides with respect to priorities for research on the consequences of highway improvement, (b) guidelines for highway agencies in assigning priorities to collection of data for the analysis of specific projects, and (c) information basic to cost responsibility questions.

APPROACH

The research plan for Project 2-1 was conceived as interdisciplinary and thus was set up so that the organization of the research was fashioned by the nature of the desired product: an integrated contribution to the solution to the problem of determining criteria for highway benefit analysis. To achieve this, a team of scholars representing highway engineering, economics, sociology, urban planning, public administration, general business, and economic geography undertook to examine the problem from the viewpoints of their several disciplines in order that they might: (1) identify a number of the consequences of highway improvement that have not previously been the objects of organized study, and (2) come to conclusions concerning these consequences.

The results of these investigations comprise the bulk of the final report. Chapters One through Three are concerned with the principles and practices of economic analysis as it applies to highway problems. Chapters Four through Nine explore the nonengineering aspects of highway problems with which highway engineers and public officials should familiarize themselves. Chapters Ten through Thirteen present a series of guidelines for the reference of highway engineers and of public officials at several levels of government—county, city, state, and federal. These guidelines, based on the interdisciplinary studies, appear as follows.

[1] Published in summary form in NCHRP *Summary of Progress to June 30, 1968.*

FINDINGS

County Road Decisions

Local Road Classification

Criteria.—The classification of local rural roads rests on their functional purpose and scale of use. In other terms, county roads are classified through qualitative and quantitative analyses of benefits (service).

Implementation.—Classification recognizes different primary purposes and beneficiaries of the several portions of the county road system and assigns to each level that of road service appropriate to its transportation needs and wants, as expressed in demand and willingness to pay.

Basis for Decision.—Amplitude and frequency of traffic generation of centers and areas of economic and social activity. Desire lines indicating linkages between centers; traffic counts, indicative of the volume of trip demands.

Level of Investment in Secondary Road System

Criteria.—Net benefits to users and others. Road users, landowners, and the total community are recognized beneficiaries.

Implementation.—Investment in secondary roads is set at that level where marginal investment is marked by the acceptable benefit/cost ratio or rate of return. The public interest is primary and is affected by the gains in economic productivity and social interaction that are furthered by lowering the transportation costs attached to those activities.

Basis for Decision.—Economic base of the community; potential for increased investment in resource development; location exploitation or renewal of capital plant, as disclosed by surveys of: soils capabilities, resource and market locations, local economic conditions, land use, land valuation. Benefit/cost analysis of traffic demands on present routes to be affected by the improved facility.

Level of Investment in Tertiary Road System

Criteria.—The direct beneficiaries are the owners of the contiguous property. Net gains or rate of return can be computed in terms of increased land values, reflecting higher and better land uses, increased economic productivity, and social benefits.

Implementation.—Tertiary roads are improved in response to the demands, individual or collective, of abutting owners as expressed through political channels or in the organization of improvement districts.

Basis for Decision.—Data on road costs and probable land value increments; established design standards that reflect the anticipated volume of traffic. Estimates of land value increments may be guided by historical data on roads providing comparable economic and social service to residents of the land served.

Cost Allocation

Criteria.—Joint costs of arterial roads should be shared between road users and the general public in proportion to their corresponding benefits. In the case of tertiary (land service) roads, it is expedient to distinguish between roads that merely provide access and those that provide a higher level of service. In either case it would be correct to charge costs against property owners, but in the former instance such a policy could retard land development because of the inability of pioneer farmers to pay current costs out of future benefits; here the general property tax is an appropriate alternative in view of the ubiquity of tertiary road service.

Implementation.—Traffic on the tertiary road system is relatively light and it is expedient to ignore the cost responsibility of the road user in this case. In the case of secondary roads a practicable if empirical measure of user responsibility would be the amount of highway user excises that corresponds to the traffic on these roads.

Basis for Decision.—Road cost data for established standards of service; traffic counts; land value appraisals.

City Street Decisions

Access Street Issues

Criteria.—Where the street function is provision of access, value of access determines project justification, scale of improvement, and cost responsibility.

Implementation.—Access streets are improved at the petition of the owners of adjacent property; their decisions depend on information provided by city administrators, who also are motivated to reduce the high maintenance expense on poorly surfaced streets.

Basis for Decision.—Information on improvement costs; statistical data on land value consequences of street improvement; benefit/cost analysis.

Arterial Street Issues

Criteria.—Urban capability for the accommodation of its resident population is tied to the quality and capacity of its arterial street system; user and community benefits are interwoven determinants of warrants for investment, design, and cost allocation.

Implementation.—Arterial improvements are designed by the city engineer and authorized by the city council.

Basis for Decision.—Benefit/cost analysis, with community benefits counted along with user benefits. Continuing transportation study. Planning commission reports. Traffic counts. Land-use studies. Costs allocated between user groups and community on basis of relative benefits.

Mass Transit Alternatives

Criteria.—The social objectives urged by the advocates of mass rapid transit have not yet been fully tested for public acceptance at realistic prices. Until the utility of mass rapid transit has been demonstrated, it is best analyzed by methods that bypass this factor.

Implementation.—Approval by the electorate at some estimated annual cost.

Basis for Decision.—Analysis of alternative modes of urban transportation for total transportation costs: fixed charges for physical facilities, vehicular operation, time, discomfort, personal risk, financial liability, community interactions, urban arrangement and development, etc.

Urban Expressways

Criteria.—Much, if not most, of the benefit derived from urban expressways and freeways accrues to the city's suburban residents and cannot be charged against the general revenues of the central city. The warrants for such projects, together with the responsibility for their costs, are best analyzed on the basis of road-user benefits and costs. Incremental costs, incurred to achieve city planning objectives, should be viewed from a county or metropolitan standpoint.

Implementation.—Varies with the nature of the local governmental structure. Alternative having the best benefit/cost ratio or rate of return, considering only user costs and benefits, should be identified. If total costs and benefits indicate a different choice, it should be approved, but the incremental cost should be charged against the other beneficiaries.

Basis for Decision.—All identifiable consequences of the proposed facility. Long-range metropolitan plan and its related over-all transportation plan. Finance study.

State Highway Decisions

Level of Expenditure on State Highways

Criteria.—Maximization of net benefits.

Implementation.—Public opinion leading to the ballot and then to tax legislation.

Basis for Decision.—

a. Exposition of highway needs. Traffic forecasts.
b. Benefit/cost comparisons for highway investment levels.
c. Input-output studies for various qualities of road system.

Project Justification

Criteria.—Rate of return exceeds that of marginal project.

Implementation.—Administrative approval and acquiescence of legislature.

Basis for Decision.—

a. Estimates of present and future traffic.
b. Road costs—construction, maintenance, operation.
c. Vehicular costs—depreciation, operation, maintenance.
d. Comfort, convenience, safety costs.

Location and Design Alternatives

Criteria.—Incremental investment must be profitable.

Implementation.—Staff decisions (test marginal expenditure by benefit/cost or rate-of-return analysis).

Basis for Decision.—

a. Road and road-user costs, as for project justification.
b. Those secondary benefits involving added costs.
c. Proceedings of public hearings.

Programming

Criteria.—Warranted road projects should be ranked for execution inversely as the relative costs of their postponement.

Implementation.—Staff decision, legislative acquiescence.

Basis for Decision.—Annual costs; deferred net benefits counted as costs. Relevant data include deferred system benefits; efficient use of construction plant; disruption of regional or local economic base.

Project Cost Allocation

Criteria.—Charge joint costs against beneficiaries in proportion to benefits received; charge other costs against the responsible beneficiary.

Implementation.—Staff decision (after legislation, if needed).

Basis for Decision.—

a. Cost analysis.
b. Benefit analysis, including effects on land values.
c. Boundaries of appropriate local improvement district.

Highway User Taxation

Criteria.—Tax vehicles for average road costs attributable to the demands of the several classes of vehicle.

Implementation.—Legislation after staff or consultant report. Incremental-cost method.

Basis for Decision.—

a. Road-use study.
b. Road cost and road life studies.
c. Forecasts of future traffic.

Federal Highway Policy

Balanced Transportation

Criteria.—The allocation of resources to transportation should be so adjusted as to maximize net benefits.

Implementation.—Federal taxation, subsidy, and regulation in the field of transportation should maintain neutrality with respect to competing modes of transportation so as to avoid distortion of economic pricing of transport services; at the same time these federal activities should assume positive roles in furthering long-run national objectives as a counterbalance to short-run influence of market demand.

Basis for Decision.—The fundamental issues in this area should be resolved with the assistance of competent economists. The basic policies once established, engineering economic analysis can aid in their implementation; in the process either benefit/cost ratio or rate of return will be useful.

Federal Interest in Main Highways

Criteria.—The nature and extent of federal participation in the provision of interstate and intrastate highways should be determined by the comparison of costs and benefits measured in terms of national interest.

Implementation.—The national interest extends to location and design decisions and is implemented by federal aid to the states and through the exercise of federal influence on location and design standards.

Basis for Decision.—Federal concurrence in project level decisions is properly dependent on conformity with system standards. The establishment of system standards for design and location and the extent of federal participation in system financing should follow the findings of economic analysis of costs and benefits associated with the federal participation.

Federal Interest in City Streets

Criteria.—The trend toward urbanization has consequences for society as a whole. Federal aid in financing city street construction and in influencing the formation of urban transportation systems should be guided by the expression of this interest, both in terms of long-run national objectives as such and by temporary intervention to protect those interests during periods of transition to which local authority has not yet developed a capability for adequate response.

Implementation.—Federal aid in financing improvements, with appropriate influence on design and location policy, based on the corresponding involvement of national interest.

Basis for Decision.—Federal concern with projects is limited to examination for conformity to system standards. In the establishment of appropriate system standards, the relevant benefits tend to be of a social character.

Federal Interest in Local Roads

Criteria.—Historically there has been a recognition that the national interest warranted federal assistance to undeveloped regions of the country; aid to rural roads is one step in supplying the infrastructure for economic development. Aid should be limited to situations where it serves to release other forces promoting development; it should not serve to maintain an uneconomic activity.

Implementation.—Federal aid to financing improvements, with appropriate influence on design and location policy, based on the corresponding involvement of national interest.

Basis for Decision.—Federal concern with individual projects is limited to examination for conformity to system standards. In the establishment of appropriate system standards, the involvement of national interest is evidenced through such data as increased efficiency of agricultural production, the improvement of rural education, support of conservation measures, and other governmental functions.

Federal Interest in Natural Resource Roads

Criteria.—Government has the primary responsibility for safeguarding the national heritage. Federal expenditures for natural resource roads in general, and for forest highways in particular, should be guided by the consideration of consequences (i.e., gains and losses) as these affect the national interests.

Implementation.—Either benefit/cost ratio or rate of return will provide a convenient tool for analysis of investment in natural resource roads; the streams of future costs and gains must be expressed in terms of present worth, or compared at other specific points in time.

Basis for Decision.—Because the anticipated primary benefits are tangible for the most part, economic quantities of various sorts will be found relevant to the several issues: projection of supply and demand for the products of mine or forest; related matters of national interest—water supply, recreational areas, national defense, transit corridors.

PROJECT 2-2: GUIDELINES FOR THE DETERMINATION OF COMMUNITY CONSEQUENCES [1]

Research Agency: University of Washington

OBJECTIVES

The general objective of this project was to establish guidelines for identification and prediction of community consequences, both favorable and unfavorable, of highway improvement. This would involve: (1) correlation and evaluation of existing studies on economic impact and other community consequences, (2) development of guidelines for highway agencies to follow in considering the community consequences of highway improvements, and (3) specification of those aspects of this problem in most urgent need of detailed research.

APPROACH

The general research plan consisted of three phases: (1) evaluation of existing studies, (2) identification and prediction of nonuser or community consequences, and (3) a general synthesis. The evaluation of existing studies was conducted through the development of an automated library, which involved a classification system for the literature by which it was examined for comparability of findings and correlation of results.

By and large, it was extremely difficult to get statistical correlations that digest the results of the various studies with any degree of rigor. The differing methodological approaches and the lack of uniformity in the variables examined really preclude anything but a descriptive evaluation of studies in the different categories. Nevertheless, some attempt was made to provide crude averages of data that may serve as guidelines in the effort to arrive at a consensus regarding the findings.

An important factor in the evaluation of the existing studies was a series of interviews conducted at strategic locations where considerable work had been done, whereby the results of past work could be discussed and evaluated.

If one expects to gain a rather broad understanding of the community consequences of highway development, such knowledge will not be found from the type of studies that have characterized highway economic impact research in the past. Most of these studies have been done to accomplish rather limited objectives, and they have not been designed to answer questions of community changes in a larger framework. Some of the larger questions that may be of substantial interest to highway agency people, as well as legislators and local officials, concern large-scale changes in the nature of the economic base of the region that may arise out of transportation system developments.

A limited number of case studies was made to demonstrate the range and probabilities of community consequences of highway improvement, with an effort being made to develop case studies that have been touched on only implicitly in the past. Obviously, the research resources were limited for conducting field investigations and an early decision had to be made to select case studies and topics for analysis that might become more significant in the immediate future.

FINDINGS

Bypasses

Analysis of bypass studies, concerned with hamlets of 125 persons to cities of more than 135,000, reveals that places of 5,000 and larger have a somewhat better chance of adjusting to the economic changes that the bypass induces. Highway-oriented businesses (i.e., those providing fuel, food, and lodging for transients) were most seriously affected.

Service stations and restaurants were often able to adjust to changed conditions by reorienting their merchandise to local trade. Although this precluded economic loss in the long run, there must have been costs for this reorientation. Service stations promoted tires, repairs, and parts, rather than gasoline. Restaurants switched to lunch and dinner instead of short orders. Motels and hotels, however, were unable to adjust in this manner and subsequently suffered the greatest losses.

One study concluded that the distance a bypassed town was located from the bypass highway had an effect on the total impact that town felt. The Colorado Department of Highways report found that: "Business activity in communities more isolated by the bypass is influenced to a greater extent by the bypass. . ." The validity of this contention is well supported in the Colorado report. No other study drew this kind of conclusion; in fact, none dealt with locational theory in any way, with one exception—the Marysville, Wash., study.

The most valid results came from studies that included control areas in their analysis. This was done with only four variables, but a somewhat different picture emerges than where only percentage change in variables is reported. There can be little argument with this method if the highway bypass is the only economic force affecting the com-

[1] Published as "Community Consequences of Highway Improvement," *NCHRP Report 18* (1965).

munity. This is never the case, of course; the bypass effects must therefore be identified and isolated by control.

Results are tempered when a control is used. Thus, it is found that even though towns of each population group gained in retail sales, there was, in fact, little effect from the highway bypass. Similarly, only about one-half the losses reflected in the average change in sales for restaurants could be attributed to bypassing, because control area restaurants were also losing sales during the study period.

Although several variables were examined as indicators of community economic conditions, their relationship to the bypass cannot be established. In fact, an examination of total retail sales raises serious doubts as to whether the over-all economy reflects the bypassing at all. Losses in sales to transients may well be offset by trade area extensions. That is, more remote areas can be served with better highways, providing less congested business districts for shopping enjoyment.

In a large number of observations there was damaging effect to highway-oriented businesses. The most apparent failure in the analyses was to account for the position of the bypassed town in the hierarchy of the linear settlement pattern on the alignment of the transportation improvement. Although it has been proved only in the case of the Marysville study, it is probably a safe conjecture that bypassed towns within 15 to 25 miles of larger ones along the same highway element suffer substantially. Conversely, the larger or more centrally located communities along the transportation system are probably substantial beneficiaries of highway improvement, even though bypassed, this benefit being at the expense of their smaller sister cities.

Circumferentials

The common feature possessed by four of the five circumferential studies examined in the foregoing is their documentation of the relatively rapid and intense land-use changes occurring along belt routes. Commercial and industrial are the predominant new uses and the increased value of land proximate to beltways reflects the space demands of these higher order uses.

Of significance to the highway planner, although little explored in these studies, is the traffic-inducing character of such decentralized employment and the future system demands it portends, including (1) the substitution of lateral for radial movements, and (2) the balancing or reversal of the direction of peak commuter flows.

Radials

Unimproved or vacant land receives greatest benefit from radial highway improvements, ranging from two to three times the value increase received by improved property.

Land value computed with improvement value deducted also emerged with increases in value that were double to triple those of land inclusive of improvements.

Value of land abutting the highway facility, the "A" tier of the studies, exceeded that of land further removed, as well as land in control areas, in the majority of instances. The value of land in the "B" tier, not abutting but proximate to the freeway, also exceeded the average value increase in control areas. Property in the "C" tier, still further removed from the facility, shows least benefit; its percentage increase usually falls below that shown for the control area or, at best, is not a great deal more. The percentage increase in the "B" tier is usually one-third to one-half that of the "A" tier, indicating that the area of impact falls off rapidly. The "C" tier percentage increase is far below that of the "A" and "B" tiers, indicating that the impact is largely diffused at this distance (usually more than four blocks away). The fall-off of impact appears least rapid for vacant or unimproved land, reaffirming that this type of property receives greatest benefit both near and far from the facility. This impact on vacant land infers the speculative nature of highway benefits.

Mohawk Regional Corridor Case Study

One of the probes developed in this research effort points to fairly interesting changes in the economic base of the various communities along the New York Thruway. The major conclusion that can be drawn is that accessibility provided by a major highway improvement such as the New York Thruway is a significant influence on employment patterns in communities within the commutershed of large urbanized areas. Further, economic opportunities along a regional corridor will become concentrated in nodal locations, probably spaced at intervals relating to tolerable commuting times along the corridor. With significant growth of many linear regional corridors of settlement, a comprehensive study of changes in the structure of the economic base of all of the communities along the corridor is needed to avoid the pitfalls inherent in the examinations of individual communities that have been commissioned in the past. Certainly, more research is needed in this comprehensive type of impact analysis to relate changes in any given community to changes in neighboring ones.

Los Angeles Urban Area Case Study

An extensive research was made into land-use and residential density changes in the Los Angeles Urban Area between 1940 and 1960 by juxtaposition of these changes with the emerging freeway system through visual examination in a series of 16 maps. This analysis made application of graphic techniques of computer analysis as well as new methods of handling large-scale data inputs for urban analysis developed over the past few years at the University of Washington. What was accomplished in six man-months with the aid of these computer programs would otherwise have taken approximately ten man-years to produce.

The results of this study are of two types:

1. In terms of technique or method, it presents large amounts of information concerning a geographic area visually and representationally for analysis and interpretation.
2. Subsequently, the study indicated findings applicable to one very populous urban area and from which the implications may be inferred concerning others.

The Los Angeles Urban Region has a long history of freeway development. Its Pasadena Freeway, opened in December 1940, was the first such urban link completed in the United States, and since that time highway mileage has been extensively increased. Substantive findings with respect to the freeways are threefold:

1. Freeway construction has had a differential impact, the nature of its effect on population density and land use depending on time or phrase of the freeway construction under particular consideration. The findings identified three phases of regional growth linked to freeway development: (1) the substitution phase, wherein freeways serve existing demands from the present population created by auto-for-transit substitution; (2) the transition phase, wherein freeways follow induced demands caused by population spread into newly developed areas; and (3) the developmental or deterministic phase, wherein freeways traverse previously undeveloped areas and begin to determine the location and timing of land-use change, thus creating demands. Also apparent was the tendency of the freeway network to decentralize work and residence, lower central residential densities, disperse population, and encourage industrial location and relocation near freeways.

The Los Angeles Urban Region experience suggests that when the pace of achievement of the freeway program has arrived at the third stage, its impact with respect to population density and land use will be greatest.

2. During the period 1940-1960 the greatest increases in population density occurred within ranges usually considered modest (less than 15 persons per acre), whereas no increases (even some declines) occurred in the importance of the high-density ranges. This suggests that the expanding freeway system, increasing mobility and land accessibility within the Los Angeles Urban Region, further dispersed population, rather than centralized it, in an area one of whose notable advantages was comparatively low levels of population density.

3. The study showed that when freeways do affect the patterns of land use the most pronounced contiguous relationship is found with respect to industrial land use, although other types of land use showed responsiveness as well. The exact causes of the considerable responsiveness on the part of industrial land use found in this study would presumably reflect a greater conscious concern of industrial decision makers with maximizing transportation advantages, although another potentially important factor—namely, the effect of local land-use zoning—deserves further study.

Guidelines for Determining Consequences

The major problem in this particular analysis was incompatible analytic and reporting procedures among the various studies. It is recognized that certain study elements are better indicators of change than others. These should certainly be included in analysis. When presented, however, they should conform to a set of adopted conventions that permit them to be compared with other studies.

The following recommendations, most of which are discussed in the Bureau of Public Roads' *Guide for Highway Impact Studies,* are re-emphasized for future analyses. If observed, they will result in uniform approaches and easier comparisons:

1. All absolute figures should be translated into percentage changes. This enables larger centers to be compared with smaller ones on a more equitable basis.
2. Sales figures should be adjusted by the Consumers Price Index (CPI) to allow for inflationary effects over the study period.
3. Before and after traffic counts (ADT) should be given for the old route and, if available, for the new one.
4. The same spans of time before and after opening the new route should be used in all studies. The two-year before and two-year after study periods used in a majority of the studies appear to produce representative data and should be standardized.
5. Terminology should be standardized and a glossary of terms should be provided for investigators.
6. The United States Standard Industrial Classification Code (SIC) should be used to establish and designate each category of economic variable. When variables are combined, this code should be used to designate groups.
7. Where it becomes necessary to combine establishment types to keep from revealing information on particular establishments, the same variables and only those variables should be combined in all studies (e.g., only service stations, restaurants, and motels and hotels should be considered as a group). Even where data for individual variables can be published, standard combinations of variables should also be included to make them more comparable with reports that cannot publish separate variable data.
8. The travel-time distance change induced by the route should be included in the report.
9. Telephone installations, water meter installations, parking meter revenue, electricity use, postal receipts, bank deposits, and employment are subject to many extraneous factors and are not reliable indicators of highway impact. They should be omitted from future studies.
10. All studies should compare changes in the study area with changes in a carefully selected control area. This will indicate the effects that can be attributed to the highway improvement.

Utility of the Studies

Concerning the utility of the studies, there are essentially three overriding reasons why the nonuser highway economic impact studies have been made. Most admittedly have been made for public relations purposes, in response to actual or foreseeable problems arising out of anticipated access control or highway relocation activities. Others were made in response to Section 210 of the Highway Revenue Act of 1956, and apparently mounting concern by the Bureau of the Public Roads over excessive severance damages as the Interstate system got under way. In a few states there has been legislative interest in highway cost allocation problems, particularly the potential for special assessment districts to finance extraordinary developments.

Gaps in Knowledge

Gaps in knowledge expressed by interviewees relate mainly to uncertainty over methodological approaches to highway impact analysis, as well as a sharper understanding of the impacts themselves. Examples of the former are the means of isolating the impacts of highway change in the economic base of the community affected by the highway improvement and changes in public service districts of schools, libraries, and similar services. Expressed gaps in knowledge further affect new problems such as the effects of the highway on urban renewal, the impact of billboard legislation on highway-oriented businesses, the consequences of route adoption announcements on right-of-way costs, land-use impacts regarding congestion at interchanges, the effect of urban area development on freeway service itself, and the relationship of highway development to regional economic development.

By way of sugegsting guidelines for highway agency use on the subject of studies dealing with the community consequences of highway development, it appears that three types of studies must be conducted in the future.

1. Spatially Localized Studies.—These are the public relations oriented, limited objective type of field studies that make up the majority of the present body of reports. They are the operational and practical studies necessary to present information at public hearings, to produce advanced information before development occurs, and to assist in specific ways the development of highways and their appurtenances. Although generally having a single purpose, these studies must be functionally comprehensive within the limited objectives of their scope.

It is not overly important that these studies repeat those conducted in other states, nor must these studies be theoretically defensible in terms of general highway benefit theory. Fundamental knowledge need not necessarily be the goal of these types of studies. They must be conducted as a result of particular problems or controversy and they must delve deep enough to accomplish their limited objectives.

Gaps in knowledge in the spatially localized study classification relate either to new field problems which have arisen or to the limitations inherent in conducting past studies. In the latter sense, the gaps in knowledge can be answered only by studies with broader spatial context, as is discussed subsequently. Examples of newly emerging problems are the following:

a. *The use of air rights above or under freeways.*— There is little information as to the value of these rights, their impact on the highway, or the social costs or benefits of the use of such spaces. For example, should the air rights over freeways or the use of land below freeways relate to a public need such as recreation, which may not pay rents, rather than an income-producing use?
b. *The assessment of noise in the vicinity of highways.*— How are freeway noises to be separated from other locally generated sounds? How are sounds and vibrations to be measured and, once measured, how are their impacts on people to be evaluated?
c. *The impact of land use changes at interchanges.*— What are the real problems of local traffic congestion resulting from land-use development in relation to the apparent problems? In many instances isolated interchanges with no development near them have been found congested because of remotely generated traffic. In other instances interchanges with a great deal of development within their proximity run smoothly because of a lack of remotely generated traffic. Little is known or recorded about this problem, and there is a great deal of irrational thought about its solution, if it is a problem.
d. *The efficacy of land-use controls.*—Highway agencies are prone to accept local community controls as operational policies when in fact these controls may not always be adhered to by local authorities. Local agencies have not yet been oriented to providing the kind of feedback data needed to evaluate their own controls.

2. Spatially Integrated Studies.—This type examines phenomena comprehensively in terms of space, which may be either the total urban region or space in some linear context, such as a regional development along a river valley or freeway. These studies differ substantially from the spatially localized studies in that they are comprehensive, are not concerned with the user versus nonuser differentiation, involve time sequence feedback of information, relate to the formation of spatial models, and are usually seeking to answer questions of fundamental knowledge rather than to assuage particular local concerns.

Studies of this nature require essentially different tools, or will require substantially different tools in the future as compared with the spatially localized studies. They tend to be involved with large-scale data systems and computerized data technology. These also tend to be studies for strategic planning purposes rather than the tactical studies needed to answer field-oriented problems.

Studies in this category of potential interest include the following:

a. *Relationship between residential, commercial and industrial settlement and the development of urban freeway systems.*—Studies of this nature can give a clue as to the rapidity with which changes take place, the scale at which the changes occur, and a broad knowledge of freeway system impacts.
b. *Studies of linear regional economic change.*—This type of study can examine the economic base of a linear corridor or development, such as exemplified in the Mohawk Valley study, to determine the relative changes between communities as well as differing patterns of transportation consumption.
c. *Studies of central place importance.*—Such studies could examine fundamental changes in the nature of economic activities conducted in various cities or communities and the change in their hierarchy as the transportation system itself is changed or competitive systems are introduced. These types of studies will be particularly important in the long-range future as mass rapid transit systems are developed.
d. *Studies of threshold limits of cities.*—To what extent will cities or communities remain stationary because of the nature of the critical mass of their economic base? Along these lines, to what extent may transportation improvement move a city from the limits of one threshold of size to another, thus changing its nature substantially? For example, transportation development can centralize medical service functions,

making a hospital feasible in one community of a regional hierarchy and precluding one from developing in another.

3. Theoretically Oriented Models.—This classification of research may lead to the development of models of economic activities or settlement from which policy decisions may ensue. Models such as these can test various patterns of regional development and suggest the needed patterns of transport development to match.

PROJECT 2-3: ANALYSIS OF MOTOR VEHICLE ACCIDENT DATA AS RELATED TO HIGHWAY CLASSES AND DESIGN ELEMENTS [1]

Research Agency: Cornell Aeronautical Laboratory

OBJECTIVES

The objective of this study was to determine the relationship of motor vehicle accidents to highway types and highway design elements.

APPROACH

The study consisted of two phases: Phase 1 was a one-year study to determine the accident and severity rates for various highway types; Phase 2 was a two-year study to extend these rates to various geometric elements of the highway.

Phase 1

Highway data had to provide information on segment length, traffic volumes, and type of highway. Accident data had to provide information on severity and type of accident. There had to be a method of highway identification on both highway data and accident data so that the two sets could be matched.

A nationwide survey was undertaken to determine where data meeting these requirements were available. The results of the survey and follow-up inquiries indicated that the necessary data were available in five states—California, Louisiana, Oklahoma, Ohio, and Oregon. During Phase 1, California, Louisiana, and Ohio data were obtained and analyzed.

Data, processed to be analyzed, were composed of segments of highway; each segment had a known length; each had a known ADT; each was homogeneous with respect to number of lanes, median, and access control; and to each was affixed the record of the accidents that had occurred on it during the period of years under study. From these data, traditional accident and severity rates were calculated—accidents per million vehicle-miles, one-vehicle accidents per million vehicle-miles, injury accidents per mile of highway, etc. In addition, regression analysis techniques were applied to the data by use of the model

$$\log A^* = a + b_1 \log L + b_2 \log T \qquad \text{(A-1)}$$

in which A is the number of accidents; L is the segment length; T is the average daily traffic; a, b_1, and b_2 are constants determined from the data; and * indicates estimation.

[1] Published as "Accident Rates as Related to Design Elements of Rural Highways," *NCHRP Report 47* (1968).

The results of the regression analysis indicated the expected number of accidents for each type of highway at selected ADT levels and for selected segment lengths. These values could be converted into rates per million vehicle-miles or into rates per mile of highway.

Phase 2

The extension of accident and severity rates to geometric elements necessitated obtaining data on specific geometric elements of the roadway. Ohio had automated records of the state-maintained highway system that provided information on several geometric elements—namely, location, length, and sharpness of curves; location, length, and steepness of grades; location and length of structures; location of the intersections of state-maintained roads; and visibility restrictions. Connecticut and Florida had similar data in graphic form. All three states had automated accident records, which included highway identification, so that the accident records could be matched to sites of occurrence. Data from these states were obtained and used in the study.

The Phase 2 data, as processed for analysis, consisted of 0.3-mile highway segments, each with known ADT; each homogeneous with respect to number of lanes, access control, and median; each containing known geometric elements (curvature, gradient, intersections, and structures); and to each affixed the record of the accidents that had occurred on it.

For the statistical analysis, the segments were arranged in 15 ADT groups. Within each ADT group the annual mean number of accidents per segment, A, and the ADT, T, were determined. These data were smoothed by use of the model

$$\log \overline{A^*} = a + b_1 \log \overline{T} + b_2 \log^2 \overline{T} \qquad \text{(A-2)}$$

in which a, b_1, and b_2 are constants estimated from the data, and * indicates estimation.

This analysis was applied to each of the several highway types (number of lanes, median, access control) subdivided by the geometric elements (curve, grade, intersection, structure) for each accident type (multi-vehicle, one-vehicle, injury, property damage, and all accidents). The results are presented as accident rates—expected annual number of accidents per 0.3-mile segment—on "pure" segments (no curve, no grade, no intersections, and no structures) of a given highway type with multiplication coefficients for segments containing geometric elements or combinations of elements. These rates may be easily converted to the traditional rates—per mile of highway, or per million vehicle-miles.

FINDINGS

Phase 1 results, verified by Phase 2, were:

1. Four-lane highways had higher accident rates than two-lane highways when there was no median and no access control.

2. Access control had the most powerful accident-reducing effect, and partial control of access was partially effective.

3. Medians tended to decrease the number of accidents, although the effect was not clearcut.

4. The number of one-vehicle accidents per million vehicle-miles (MVM rates) decreased with increasing ADT, and the MVM rate for multi-vehicle accidents increased with increasing ADT.

5. The relationship of the total accident rate (MVM) and ADT was not defined, because in some instances the rate increased with increasing ADT and in other instances the rate decreased with increasing ADT.

Another result of Phase 1 was that accident rates were dependent on segment length—high accident rates on short segments and low accident rates on long segments. Evidence indicated that segment length measured, in addition to the physical length of the segment, additional factors that caused traffic disturbances (i.e., segment lengths were shorter in those locations having more intersections, more driveways, etc.). Segment length was made constant in Phase 2.

Phase 2 results were:

1. The presence of the geometric elements (curves, grades, intersections, and structures) increased the accident rate on highways. The dominant element was intersections, which often gave accident rates three times as high as the rates on pure segments.

2. The presence of combinations of the geometric elements generated higher accident rates than the presence of individual elements. Combinations gave accident rates as high as six times the rates on pure segments.

3. Partitioning of grade and curvature by magnitude did not show any effect due to steepness of grade and sharpness of curve. The only effect occurred when the change was from no grade (less than 4 percent) to a grade of 4 percent or greater, and from no curvature (less than 4°) to a curve of 4° or greater.

4. There was no evidence that geometric elements affected severity rates.

PROJECT 2-4: THE VALUE OF HIGHWAY TRAVEL TIME, COMFORT, CONVENIENCE, AND UNIFORM DRIVING SPEED [1]

Research Agency: Texas A & M University

OBJECTIVES

This project was concerned with the value of time savings that accrue for commercial vehicles. The objectives pursued in the project were:

1. To conduct "a survey of the research on this subject previously done and now in progress, including the correlation and synthesis of available research results."

2. To design "a research method or methods that will develop more accurate estimates of the unit value of time savings and of reductions of impedances to uniform driving, including variations of these unit values with critical factors relating to highway provision and use, and the application of this method (or methods) on such a scale as to produce provisionally usable figures and formulas for the variation of the unit value of time savings and the impedances to uniform driving."

APPROACH

The project reviewed and analyzed various methods that have been proposed for evaluating time savings that accrue to highway vehicles. It also developed a cost savings approach to the determination of values of time savings and applied this approach for a composite cargo vehicle, a composite intercity bus, and a number of cargo vehicle types. Finally, the research dealt with major problems inherent in the determination of the value of time savings and suggested facets of the question that should receive attention in future research.

The several methods previously used to estimate the value of time savings fall into four major categories:

1. Revenue (net operating profit) method. Assumes that time savings will be translated into additional revenue miles. The method uses the theory of the firm and has certain empirical advantages. Its weaknesses are the lack of knowledge of fixed versus variable costs in relation to time savings, the implied assumption that time savings generate additional gross revenues, and the difficulty of localizing revenue data.

2. Cost savings method. Assumes that time savings lead to a saving in resources required to perform a given volume of output. The method generally follows the theory of the firm, the principle of cost minimization, and has empirical advantages compared to the revenue approach. Greater localization of data can be obtained. The method's basic weakness is that too little is known about time-associated cost functions.

3. Cost-of-time method. Refers to the cost of providing time savings to highway vehicles. The method was conceived as a decision-making aid at the highway project level. The method does not measure the value of time in an absolute sense. Its strength is in its potential for alleviating the need for such a value.

4. Willingness-to-pay method. Attempts to assess the value of time in a market framework. The measurement may be through toll fees or in opportunity costs (utility or value foregone to attain time savings). Extrapolation to average values and the application of the method in general are complex. Secondary data for the approach are scarce and the generation of primary data appears to be difficult and expensive.

The revenue method and the cost savings method were chosen for further study in the project. The availability of secondary data from ICC records bore heavily on this choice. More importantly, it was felt that tenable assumptions for the methods could be developed. Cost relationships lend themselves to empirical analysis and thus to a continuing improvement in the model forms and solutions. The cost savings approach was preferred on the grounds that it avoids the assumption of the revenue model that time savings generate a higher volume of revenue miles. Furthermore, cost savings solutions are amenable to direct

[1] Published as "Values of Time Savings of Commercial Vehicles," *NCHRP Report 33* (1967).

adjustment to account for variations on a local level, in vehicle types and in other factors. Finally, the approach has no limitations not also inherent in the revenue method.

FINDINGS

Conclusions

The major conclusions of the study are:

1. The cost-of-time approach to the value of time savings of commercial vehicles is rejected as not practicable. This method attempts to measure the cost of providing time savings through road improvements. In a sense, it circumvents the measurement of the value of time savings. It does appear to be a useful decision-making aid at the highway project level. Division of costs between private passenger cars and commercial vehicles is an unsolved problem.

2. The willingness-to-pay approach attempts to determine the market value of time savings in the market place. Owing to the nature of the observations that can be made, it tends to measure a minimum value of time for those who "buy"; the demand schedule for nonusers, those who will not pay the going "price," must be surmised. Empirically, it suffers from a paucity of data and the comparative complexity of isolating the portion of "prices" that is paid for time savings.

3. The revenue approach (net operating profit approach) assumes that time savings will be used to obtain additional gross and net operating revenues. It is based on the theory of the firm and has the empirical advantages of simplicity and availability of data (ICC records). Its fundamental weakness is that it assumes implicitly that additional gross revenues are generated by time savings. It is rejected in deference to a cost savings method.

4. The cost savings approach assumes that time savings will lead to resource savings, the value of which reflects the value of time. The method has all the advantages of the revenue approach, but is simpler and avoids the revenue generation assumption. The several cost items also are easily varied for area and vehicle differences. What resources will be saved is, of course, to some extent conjectural.

5. Records compiled by the Interstate Commerce Commission are the best single source of secondary data on commercial vehicle costs. These data are available on a regional basis (nine ICC regions) in annual reports. Attempts to obtain greater localization of data through the use of individual carrier records were not generally successful. ICC data require numerous adjustments to make them adaptable for value of time savings models.

6. From the application of the cost savings model, it is concluded that periodic updating of value of time coefficients should be practiced in view of the definite changes (uptrend) shown in the estimates by years.

7. Regional variations are demonstrated and further localization of value of time savings components should be made where data are available.

8. The value of time savings is highly sensitive to drivers' wages; sensitivity to depreciation is smaller but important; the latter component should be reduced according to the percentages to be reserved for mileage as the causative factor.

9. The recommended values of time savings per hour for composite vehicles, by ICC regions, are as follows:

REGION	SAVINGS PER HOUR ($) COMPOSITE CARGO VEHICLE	SAVINGS PER HOUR ($) COMPOSITE INTERCITY BUS
Southern	5.45	6.96
New England	4.86	4.97
Middle Atlantic	5.16	
Central	5.39	7.43
Northwestern	6.11	6.77
Midwestern	5.62	
Southwestern	6.56	7.43
Rocky Mountain	5.16	6.23
Pacific	5.75	

To obtain values of time savings for composite intercity buses, it was necessary to combine the New England and Middle Atlantic regions, the Northwestern and Midwestern regions, and the Rocky Mountain and Pacific regions.

Recommendations

Knowledge of time-associated cost items in commercial highway carriage is woefully insufficient for the development of substantiated measurements of the value of time savings. Also, there is a lack of both concepts and data regarding the second and successive rounds of time savings beneficiaries.

The following problems warrant considerable research attention:

1. The relationship between equipment depreciation and hours of operation (and other factors of use).
2. The feasible rate of use of time, and thus of time savings, in line-haul operation.
3. Whether time savings in line-haul operations lead to savings in "extra" equipment or change the nature of pickup and delivery operations.
4. The short- and long-run effects of time savings and the rate (or lag) of realization of benefits.
5. Values assignable to time savings increments of various sizes (investigation of additivity assumption).
6. Variations in time values among additional carrier types (private carriage among other types), vehicle types, and trip purposes.
7. Variations in cost items for local areas.
8. Kinds and amounts of quality of service benefits that result from time savings.

Not all of these problems were amenable to empirical research within the time and resource limits of the project. Only tentative solutions or methods can be developed for recommendation to those who study local situations. It is known, however, that time savings to commercial vehicles comprise an important benefit of highway development. For this reason a continuing study of the value of time savings is needed. Only such a research program can assign this factor its proper weight in the economic justification of highway improvements and in the selection among alternative highway policies.

PROJECT 2-5: RUNNING COST OF MOTOR VEHICLES AS AFFECTED BY HIGHWAY DESIGN AND TRAFFIC [1]

Research Agency: The Catholic University of America

OBJECTIVES

The study objectives were: (1) to develop appropriate procedures and equipment for investigating the effect of highway and traffic conditions on motor vehicle operating costs (where existing equipment and procedures were unsatisfactory), and (2) to measure the cost of fuel consumed by a passenger car for a variety of highway and traffic conditions. The first objective provided for establishing the best methods of accumulating useful information for each of the five categories of operating cost; the second encompassed development of an extensive array of data for one of these categories, vehicle fuel consumption, for one type of highway vehicle, the passenger car.

APPROACH

The approach selected for achieving the project objectives involved making five closely related studies. One, a review of relevant information either existing or in the process of development at the time the project was begun, was carried out first to provide bibliographical material and other information to help guard against inadvertently repeating the efforts of others. The principal part of the investigation, the measurement and analysis of fuel consumption data for a passenger car as affected by each of several highway and traffic conditions, was conducted last. Three other separate studies were made after completion of the literature review and before the passenger-car fuel consumption study was made, including: (1) development of a precision electronic fuelmeter, (2) investigation of a radioisotope techniques for measuring tire wear, and (3) review of methods for estimating engine lubrication costs, maintenance costs, and depreciation costs.

The passenger-car fuel consumption rates were determined by carefully measuring the fuel consumption rates of a typical vehicle as these are affected by vehicle speed, road surface condition, gradients, curvature, and vehicle speed changes. To assure the validity of the results several special studies were included to determine the effect on the accuracy of fuel consumption measurements of each of the following: wind velocity, vehicle weight, fuel characteristics, vehicle operating efficiency, and differences in driver techniques of throttle manipulation.

A precision electronic fuelmeter was developed before proceeding with the measurement of fuel consumption rates for the passenger car because no dependably accurate meter capable of highly precise measurement existed at the time the study was conducted.

The vehicle used for the passenger-car fuel consumption study was a new 8-cylinder 1964 sedan of U.S. make with automatic transmission and weighing 4,175 lb when loaded for the test runs. The fuelmeter was of the buret type, with an electronic device for automatically opening and closing valves and for automatically recording the fuel used to the nearest 5 cc.

Test runs were made at each of several sites at which appropriate study conditions were available. The primary test site, however, was a section of I-495 (Capital Beltway) near Andrews Air Force Base, Washington, D.C. This road was available for making test runs without interference by traffic during a five-week period after it had been completed but before it was opened to traffic.

Fuel consumption rates of passenger cars (in gallons per mile, miles per gallon, and gallons per hour) vary with vehicle speed for a full range of speeds from 0 to 80 mph. The road conditions for which these data were obtained were those for minimum resistance to movement—level and straight with a high-type surface and no wind. All values are for uniform speeds of travel maintained at a steady manifold vacuum.

Fuel consumption costs were developed for corresponding fuel consumption rates for the operation of a passenger car on uniform grades where in all other respects road conditions are those for minimum resistance to movement.

Research was also conducted on the fuel consumption costs of passenger cars on level straight roads where rough or unpaved surface conditions exist, as well as on the excess fuel and time costs that arise as a result of vehicle stops and slowdowns from initial speeds of from 5 to 60 mph.

It was thought that industrial methods using radioisotopes to measure the thickness of material might provide a scientific means for convenient measurement of tire wear. However, the results of this research were not of immediate use for road-user cost studies, largely because of the variability of radioactive absorption noted in tire rubber. To use this technique it is necessary to establish a specific correlation between radioactive absorption and tire thickness for each separate tire, inasmuch as no single correlation curve is suitable for more than one tire. Thus, the technique at present is useful mainly for multiple studies of a single tire.

Furthermore, although field measurements of tire wear can be made more easily using the radioisotope method than by using a tire gauge, the precision is about the same in each case. The most precise method of tire wear measurement, although the most inconvenient, is by tire weight.

A comprehensive review of engine lubrication requirements, especially as these are affected by highway conditions, was made to determine the best method of estimating engine lubrication cost. This review included an analysis of the effects of vehicle type, vehicle maintenance, conditions of vehicle use, oil filter use, and oil characteristics, as well as consideration of the effects of road conditions, on oil consumption rates. Particular attention was given to the manner in which engineering advancements in engine design and construction are reducing oil consumption for all types of vehicles.

[1] Published as "Running Cost of Motor Vehicles as Affected by Highway Design—Interim Report," *NCHRP Report 13* (1965).

FINDINGS

Fuel Consumption of Passenger Cars

The optimum speed for passenger-car fuel economy on level straight high-type pavement is a steady 35 mph. At this speed, the fuel consumption rate is 20.7 miles per gallon for a 4,000-lb gross weight vehicle. The same vehicle achieves only 13.4 miles per gallon at a steady 80 mph, and only 10.9 miles per gallon at a steady 8 mph.

The fuel consumption rate of the passenger car, loaded at 4,000 lb, is reduced by only 0.9 (20.7 to 19.8) mile per gallon when operated at a steady 35 mph on bituminous-treated gravel surface rather than paved surface. It is reduced by 12.0 (20.7 to 8.7) miles per gallon for operation on a +8 percent grade rather than on the level.

Passenger car fuel consumption, noted previously as 20.7 miles per gallon at 35 mph, is reduced to 17.5 miles per gallon if the vehicle is brought to a momentary stop once in each mile. On a level high-type pavement at 20 mph the fuel consumption is reduced from 19.1 miles per gallon for operation on a straight alignment to 9.6 miles per gallon for operation on a 65-ft-radius curve and to 17.9 miles per gallon for operation on a 955-ft-radius curve.

Tire Wear

The effect of tire wear on the total cost of motor vehicle operation, as this cost is affected by highway and traffic conditions, is second in magnitude only to that of fuel consumption. Tires are in direct contact with roadway surface and their wear is affected by the highway design elements of surface roughness, curvature, and gradient, and by vehicle speed changes, both stops and slowdowns.

Sharp curvature is particularly destructive of tire tread. Loss of tire tread on sharp curves as used in this test constitutes a problem of growing importance as the frequency of cloverleaf-type interchanges grows with the construction of new expressways and freeways. Left-turning vehicles at cloverleaf intersections must turn through 270° rather than 90° as for a direct left turn. If the radius of the left-turn ramp is 65 ft the additional curve travel due to the extra 180° of arc is 0.038 mile. The number of times a vehicle can be turned this extra length of arc before two tires (one front and one rear) will be worn out, found by dividing 27.5 miles of tire life on the curve by 0.038 extra miles per turn, is 723 turns. Thus, a commuter who had to negotiate four such left-turn ramps getting to and from work daily would wear out two tires yearly solely from this cause (unless he rotates tires regularly).

The effect of most highway and traffic factors on tire wear is much less evident, however, than that for an extremely sharp curve such as the 65-ft-radius curve. For example, excess tire tread lost through operation on a 1° curve as compared to operation on a straight alignment or for travel on a bituminous-treated gravel surface rather than on a high-type pavement, is very small, perhaps on the order of 0.00001 in. per mile. Using existing means for measuring tire wear it would be necessary to have test sections with identical tire wear characteristics throughout for a length of 1,000 miles or more in order to measure accurately the effects on tire wear of differences in these highway factors. Inasmuch as very few such test sections are available, the effect of many highway design characteristics on tire wear would be impossible or at least very expensive to determine with present equipment.

Engine Lubrication Cost

Oil consumption rates of all vehicle types are closely related to vehicle maintenance; that is, a well-maintained engine will have low oil consumption even on a road having poor design characteristics, whereas a poorly maintained vehicle will use excessive oil even on the highest type of road.

It is noted that for vehicles taken as a group, the only highway factor that may be related to oil consumption is road length. That is, an average rate of oil consumption may be determined in gallons per mile for operation under conditions typical of modern roads and modern speeds. In road-user cost studies this item would be included as a standard cost per mile by vehicle type.

Vehicle Maintenance Costs

There are many difficulties in determining how the maintenance or repair costs of motor vehicles are related to highway and traffic conditions. Numerous variable elements are involved, including the average level of preventive maintenance adhered to by each category of vehicle owner, and the characteristics of the service for which vehicles are used. Certain items of maintenance are undoubtedly related to specific highway conditions, such as the relationship between brake and transmission maintenance costs and the frequency of vehicle stops, the effect of rough road surfaces on the cost of maintaining vehicle suspension systems, and the cost of more frequent engine repairs when vehicle operation is predominantly on steep grades. At present, however, data for relating maintenance costs to these and other highway conditions are unavailable except for the general records on vehicle maintenance costs, by mile of use and by type of service, kept by most operators of commercial fleets.

Vehicle Depreciation

The problem of determining whether highway and/or traffic conditions contribute to the cost of depreciation of a properly maintained motor vehicle, and if so how much, is difficult, surrounded as it is by much uncertainty and controversy. Numerous investigators believe that depreciation cost is almost entirely unaffected by use. Others suggest that about one-half of vehicle depreciation cost is due to miles of travel accumulated by a vehicle, arguing that if a vehicle were not operated at all, its depreciation cost would be about 50 percent of what it is after being used. Still others claim that, at least for passenger cars, depreciation is partially due to vehicle use, not as measured by miles of travel but as measured by such matters as frequency of stop-and-go operations, frequency of persons entering or leaving the vehicle by sliding over the seats, and the type of service performed by the vehicle.

PROJECT 2-5A: RUNNING COST OF MOTOR VEHICLES AS AFFECTED BY HIGHWAY DESIGN AND TRAFFIC [1]

Research Agency: Dr. Paul J. Claffey

Project 2-5 was continued as 2-5A, with the principal investigator as the contracting agency, to obtain more detailed data on running costs of motor vehicles in order to eliminate certain gaps that still exist in the information available on this subject. This includes more data on minor variations in road gradients and curvature on the fuel consumption of passenger vehicles, together with data on the effect of rough surface on tire wear, maintenance, and oil consumption. The results of the earlier work on Project 2-5 and Project 2-7 were to be combined with the additional results of this phase of the project into a single comprehensive final report.

Field measurements for four passenger cars at various speeds on selected grades and curves have been completed and the analysis was presented in an interim report. The effect of ambient temperatures on fuel consumption was studied through the winter months.

Work included the collection of fuel consumption of passenger vehicles on selected grades and superelevated horizontal curves. A study was made to determine the effect of elevation on the consumption of fuel. Tire-wear studies were made on both straight roads and horizontal curves.

PROJECT 2-6: WARRANTED LEVELS OF IMPROVEMENT FOR LOCAL RURAL ROADS [2]

Research Agency: Stanford University

OBJECTIVES

This project was concerned with the setting of economic standards for the construction and maintenance of local rural roads. The objective of this research was to examine prevailing rural design standards to determine their economic justification. This would evaluate in depth the cost of some of the most significant design practices (for example roadway and shoulder width and surfacing type). Resulting user benefits such as operating, accident, and time savings would be weighed against the cost of individual features. In addition to the analysis of user-benefit relationships, the economic and social consequences to local residents, businesses, and communities should be studied, and suitable means of including them in the reckoning of warranted levels of improvement should be found.

APPROACH

The research covered by this report was devoted largely to data gathering and preliminary exploration. The aim was to compare the costs accruing to providers and users of low-volume rural roads constructed to different geometric standards and with several surface types. For the purposes of this study, costs were subdivided as follows:

1. Costs of capital improvements.
2. Maintenance costs.
3. Vehicle operating costs.
4. Accident costs.

The data-gathering efforts can be categorized as follows:

1. Interviews with knowledgeable engineers.
2. A literature search.
3. Assembly of information, as it relates to low-volume roads, on:
   a. The geometry of existing roads, the minimum acceptable (tolerable) standards, and the standards proposed for new projects.
   b. Common surface types.
   c. Construction costs.
   d. Maintenance procedures and their costs.
   e. Vehicle operating costs.
   f. Accidents and their associated costs.

Preliminary calculations were made to determine the relative magnitudes of the four cost elements for level, straight roads on a 2-ft-high embankment. These were limited to comparisons involving 11 different widths of traveled way, six surfacing types, and two sets of unit costs, one to the high side and one to the low. On the basis of these cost comparisons, certain conclusions were drawn and recommendations were made regarding changes in the recommended cross sections to be used when low-volume rural roads are constructed or reconstructed.

The economic aspects of standards for vertical and horizontal alignment and sight distance also were examined. It was concluded that, because each individual situation is unique in one or more of its cost elements, no generalized recommendations could be made. Rather, a method of approach for setting such standards, situation by situation, was proposed.

Community consequences of low-volume rural roads in general and of the effects of design standards on these consequences were examined. A means for evaluating them and criteria for this evaluation were developed. It was concluded that quantitative values for community consequences were unique to each situation and that, for each of these, the magnitude of the consequences was dependent on the viewpoint of the analyst. For these reasons, no attempt was made to offer quantitative results.

FINDINGS

Conclusions

The following conclusions seem justified by this research:

1. There is little uniformity among highway agencies as to the standards they employ for roadbed width on lightly traveled rural roads. They seem to be based to a large degree on value judgments tempered by past practices, political considerations, and the agency's financial situation. Without question, standards set "from the top down" by engineers of federal and state agencies who control the purse strings are higher than those where control lies at the local level.

Standards for surfacing types are not uniform among

[1] Published as "Running Cost of Motor Vehicles as Affected by Road Design and Traffic," *NCHRP Report 111* (1971).
[2] Published as "Economics of Design Standards for Low-Volume Rural Roads," *NCHRP Report 63* (1969).

agencies. Here, however, there appears to be little interference from supervising agencies.

2. Economic analysis, as contrasted to financial programming, seems to play little, if any, part in decisions related to standards for roadbed width or surface type. In fact, no evidence was found that highway agencies keep data on construction and maintenance costs in a manner that would make this possible. Neither has information been gathered from which the effects of roadbed width or surface type on driving speeds on unobstructed roadways or when meeting or passing can be appraised. Fortunately, data have been developed that, once an agency develops information on operating behavior, will make it possible to determine vehicle operating costs and changes in travel times with considerable accuracy.

For the purposes of this study it became necessary to derive construction, maintenance, vehicle operating, and time costs. No claim is made that these are exact or even correct for all situations. Yet they allow certain generalizations and provide a framework and procedure that individual agencies may follow in developing economic criteria as an aid to decision making.

3. At traffic volumes up to 400 vpd, there seems to be no economic justification whatsoever for a roadbed width greater than that necessary to eliminate vehicle interaction. Whether some lower widths offer greater economy cannot be determined, primarily because no firm data are available on speed reductions when vehicles meet and pass on roadbeds of different widths.

At traffic volumes in the range of 100 vpd, there appear to be no economic arguments favoring roadbeds wider than 16 ft, because total annual costs increase as width increases.

4. Where roadbeds are being built or rebuilt in toto, bituminous surface treatment (or possibly road- or plant-mix surfacings, as compared to gravel) is justified economically at traffic flows of approximating 100 vpd. The break-even point where surface treatment might replace calcium-chloride-treated gravel is somewhat higher.

5. Accidents are rare events on low-volume rural roads. Furthermore, there is almost no evidence to indicate that higher standards for roadbed width or surface type will reduce the already small number. It appears that demands for high standards to reduce accidents are based on the impression of "it seems dangerous" rather than on the proven fact that "accidents happen."

From an economic standpoint, accident costs are in a lower order of magnitude than construction and operating costs. For example, if all nonintersection accidents are prevented on a mile of straight road carrying 400 vpd, the reduction in direct accident costs will be about $330 per year. Providing wide shoulders offers an annual cost reduction of only $10.

6. In contrast to upgrading the cross section, which calls for continuous reconstruction along the length of the road, there is indication that spot improvements to flatten sharp horizontal curves may in many situations pay their way, primarily because the costs of slowing and accelerating are eliminated. Also, the evidence is strong that accidents occur at occasional sharp curves in relatively straight alinements; this offers an additional argument for curve flattening. Similar advantages do not seem to accrue where vertical alignment is improved, because drivers do not slow down nor are there many accidents where vertical sight distance is impaired.

7. Neither the techniques nor data for quantifying the many and complex community consequences of standards for low-volume rural roads are available. Furthermore, if the individual consequences could be quantified, their inclusion or exclusion in a given study must be determined for each project from a specific viewpoint and recognizing several complicating factors. Such quantification as has been done is for roads generally, without reference to standards. They show very low consequences as compared to those to highway agencies and highway users. Thus, as of today, community consequences, good or bad, or changes in standards must be weighed as an irreducible and not in money terms.

Recommendations

The recommendations given here are intended to apply only to low-volume (less than 400 vpd) roads in rural areas that are expected to remain rural. Within these limitations and based on the findings of this report, it is recommended:

1. That the AASHO and NACE suggested standards for cross sections of low-volume rural roads be reconsidered. Changes to these standards coming from that review might include:

   a. Abandoning the requirement that a constant cross section be maintained for the full length of a road segment. Rather, the standards could suggest that narrower roadbeds be considered for straight sections than on curves or over crests where sight distances are limited. This change in approach could bring substantial reduction in the costs of new construction. Also, where roads are to be reconstructed, this flexibility would cause engineers and administrators to think in terms of spot improvements rather than complete rebuilding.

   b. Changing the philosophy for prescribing standards for roadbed width by recommending maximums instead of minimums. As examples, the recommendations might be:

      (1) For straight roads free of sight distance impairments and with a current ADT of 250 to 400 vpd, the maximum recommended width of roadbed (surfacing and shoulders combined) might be 22 or 24 ft. Provision should be made in the standards to permit narrower roadbeds where economic or other advantages of narrower roadbeds can be demonstrated.

      (2) For similar roads with a current ADT lower than 250 vpd, the maximum recommended width might be set at 20 ft, but agencies would be urged to consider narrower designs, particularly at volumes less than 100 vpd.

2. That agencies responsible for low-volume rural roads, who are not now doing so, seriously consider evaluating their present practices. Study topics might include:

a. Short range:
   (1) Looking into the feasibility of spot improvement programs for rebuilding those road segments that have sharp curves, particularly those where the curves follow long straights. Priorities among these spot improvements could be set by evaluating annual savings to vehicle users and costs to the highway agency. Where accident records are available, they could also be weighed, either in dollar terms or with other irreducibles in selecting among economically and financially viable projects.
   (2) Investigating the feasibility of deferring impending projects that involve reconstruction for continuous stretches of road. Likely candidates for postponement would be (1) roads carrying very low volumes, (2) those having relatively straight alinements, and (3) those for which the intended standards are higher than suggested.
   (3) If the road system includes gravel roads carrying over, say, 100 vpd, consider the feasibility of a program or surface treatment, provided the gravel surfacings are suitable as base courses.

b. Long range:
   (1) Institute a program of data gathering for the low-volume rural road system. This objective would be to supply pertinent information on traffic volumes and composition, road by road, and on driver behavior on roads having typical widths and surfacings.
   (2) For a range of typical cross sections, with width and surfacing type as parameters, determine approximate construction and maintenance costs.
   (3) Assess the relative economy to highway agency and users for these cross sections, following the procedures outlined in this report but using applicable data. Solutions at several interest rates probably should be made.
   (4) Explore and evaluate the irreducibles that would result if various standards were adopted.
   (5) In cooperation with elected officials or other decision makers: (1) establish an appropriate level of expenditure for the agency, and (2) develop a scheme for setting and revising priorities among the proposed improvements to the road system.[1]

3. That highway engineers and administrators alike recognize that:

a. Low-volume roads and major highways serve different functions and that the demands on them in serving these functions are not the same. To require that low-volume rural roads fit the needs associated with major highways is to overdesign them and make them far more costly than need be.

b. Accidents on low-volume rural roads are rare events so that, even if all accidents could be eliminated, the economic gain is extremely small. Furthermore, because accident records show that higher standards do not seem to reduce nonintersection accidents, to adopt high standards with this aim in view is pointless.

c. Because high standards are not economical and do not reduce accidents, adopting them is taking up scarce resources that might be used to better advantage elsewhere.

PROJECT 2-7: ROAD-USER COSTS IN URBAN AREAS [2]

Research Agency: The Catholic University of America

OBJECTIVES

The purpose of this research was to provide data on road-user costs as classified by arterial type, operating speed, traffic composition, and delay factors. Basic tables applicable for planning and for selecting arterial street and highway systems from the various alternates in urban areas were developed.

APPROACH

The research of road-user costs in urban areas developed, through experiment, a comprehensive array of information on the cost of operating motor vehicles on primary routes in and through cities. Although the bulk of the research results relate to fuel consumption rates and vehicle speeds for specific road and traffic conditions, extensive experimental data were also prepared on the costs of tire wear, oil consumption, maintenance, and accidents. Exhaustive experiments were conducted to measure fuel and time consumption for a typical passenger car, a transit bus, a single-unit truck, and a tractor semi-trailer combination truck. However, determination of tire wear, oil consumption, and maintenance costs were confined to a limited sequence of experiments for one vehicle—the passenger car.

Primary urban arterials vary in physical design and traffic flow characteristics over a broad range of road types from completely free-flowing freeways to congested downtown streets. Intermediate types of arterials are the major streets, routes on which traffic flow is promoted by parking prohibitions, progressive signal timing, and limitations on access. Typically, vehicles on major street arterials outside the downtown area move at an average over-all speed of 20 mph, with an average of two traffic signal stops per mile. Motor vehicle operating cost data were developed for freeway operation, congested downtown operation, and operation on each of several representative types of major street arterials outside downtown areas.

All data developed in the study of road-user costs, except those related to accident costs, were established by experiment. Rates of fuel consumption were determined by mea-

[1] An approach to this problem using economic criteria has been developed in considerable detail by J. W. Spencer in "Planning and Programming Local Road Improvements: An Approach Based on Economic Consequences," *Report No. EEP-23,* Program in Engineering-Economic Planning, Dept. of Civil Eng., Stanford Univ., Palo Alto (1967).

[2] Published as "Running Costs of Motor Vehicles as Affected by Road Design and Traffic," *NCHRP Report 111* (1971).

suring with the precise photoelectronic fuelmeter the quantities of fuel drawn into test vehicle engines under a variety of operating conditions. Tire wear and brake lining wear were ascertained by accurately weighing tires and linings before and after tests and recording the weight difference as the wear occasioned by the operations conducted during the tests. Oil volumetric measurements were made with carefully calibrated glass graduates before and after the specific test operations conducted on oil consumption. The validity of the study is that of the research experiment, with direct measurements made to determine the effects highway operations have on the principal elements of vehicle operating cost.

FINDINGS

1. Rates of fuel consumption and speed for vehicle operation on urban freeways are given in values for specific road conditions. For example, when vehicles attempt a speed of 45 mph on a six-lane freeway with traffic volumes in the direction of travel of 2,100 to 2,799 vehicles per hour, they will consume fuel at a rate of 0.0528 gpm (18.9 mpg) for passenger cars, 0.1106 gpm (9.0 mpg) for transit buses, 0.1225 gpm (8.2 mpg) for single-unit trucks, and 0.1977 gpm (5.1 mpg) for tractor semi-trailer combination trucks. Gross vehicle weights for these vehicles are 4,000 lb, 14,500 lb, 24,420 lb, and 52,580 lb, respectively.

2. Vehicle fuel consumption and average speeds for operation on each of several designs of major street urban arterials outside the downtown areas are given in the report. It is interesting to note the effect of traffic signal stops on fuel consumption rates. Thus, the data show that passenger car fuel consumption varies from 0.0586 gpm (17.1 mpg) when there are no traffic signal stops to 0.0825 gpm (12.1 mpg) when there are four traffic signal stops per mile. Similarly, the data from Table 5 show that the fuel consumption rates of a transit bus increase from 0.1021 gpm (9.8 mpg) for travel without stops to 0.1668 gpm (6.0 mpg) for three stops in each five-block distance.

3. Average rates of fuel consumption and speed for each of the test vehicles for operation on congested downtown streets were found. Sample fuel consumption rates include 0.1661 gpm (6.0 mpg) for passenger cars and 0.7857 gpm (1.3 mpg) for tractor semi-trailer combination trucks for operation when vehicles are stopped once at each intersection.

4. Information on the fuel and time consumption of highway vehicles stopped at intersections on major street urban arterials outside the downtown area was obtained from more than 2,300 miles of travel on such routes. Average passenger car fuel consumption while stopped for traffic signals at intersections on these routes was determined to be 0.038 gal per stop on the basis of data recorded for more than 5,000 stops. Vehicle stopped delay at the traffic signals average 19.8 sec per stop. On the average, the test vehicle was stopped twice for a traffic signal for each mile of travel on these routes. Average over-all fuel consumption for the passenger car was found to be 0.075 gpm for operation on the major street urban arterials for an average over-all speed of 19.9 mph.

5. Data on passenger car tire wear and oil consumption for various types of operation were developed. Average rates of tire wear in grams per mile are 0.156 for four tires for travel on a freeway at 45 mph and 0.764 for travel on a major street urban arterial (two stops per mile), a ratio of nearly 5 to 1. Oil consumption rates on the freeway and on major street urban routes are about the same. However, oil used for driving on city streets is deteriorated more by service than is the case with oil used for freeway driving.

Tire wear is $0.0023 less per mile for travel on urban freeways than for travel on major street urban arterials for each tire on the rear wheels of passenger cars. The corresponding tire wear cost difference for each front wheel is $0.0013 per mile. The total difference in tire cost for all four wheels of a passenger car for operation on an urban freeway rather than on a typical major street urban arterial is $0.0072 per mile of travel.

Although oil volume change and specific gravity change are relatively unaffected either by type of operation or road design, oil viscosity is reduced appreciably by stop-and-go driving and by other types of speed change operations. Rates of oil consumption are fairly constant regardless of type of vehicle operation employed, but the viscosity of the oil (and thus its capability for providing good lubrication for the engine) is reduced by frequent speed changes. Speed change driving, especially stop-and-go driving, thus adds to the cost of engine lubrication by causing oil to deteriorate and be replaced more frequently than otherwise would be necessary, rather than by directly affecting the volume of oil consumption.

6. Data on maintenance costs and on accident costs were gathered. Both maintenance and accident costs on major street arterials are closely associated with the intersections at-grade found on such routes. The cost of maintaining brake systems, for example, is largely due to the effects of stop-and-go driving at traffic signals. Accident costs are particularly frequent and costly at intersections because of the greater opportunity for vehicle conflict at such points.

Average brake maintenance cost in this case was $0.0012 per mile if distributed over total mileage, or $0.0031 per mile if distributed only over urban route mileage (23,000 miles). If it can be assumed that brake wear in nonhilly areas is largely due to travel on urban routes at two stops per mile, this latter average brake wear cost corresponds approximately to $0.0015 per stop. This value agrees well with the research result of $0.0018 per stop for brake wear.

Property damage costs for accidents on urban freeways in the Washington, D.C., area vary from $0.0006 per vehicle site of travel on I-495 (Capital Beltway) to $0.0018 per vehicle-mile on the extension of I-95 into the Washington area. Property damage accident costs on US 50 in Northern Virginia (Washington metropolitan area), a divided, limited-access highway, are $0.0024 per vehicle-mile of travel. These values compare well with the results of a study made in Chicago in 1958 which showed that property damage accident costs averaged $0.0039 per vehicle-mile on major street urban arterials but only $0.0015 per vehicle-mile on expressways.

7. Special studies involved in the research of road-user costs in urban areas were made as follows: (1) passenger

car fuel consumption arising from passing maneuvers, and (2) effects of grade and curvature on motor vehicle fuel consumption rates for operation on urban routes.

It is clear that passing operations cause an increase in the fuel consumption of highway vehicles. The increase is greatest at speeds between 35 and 40 mph, and is about the same on downgrades as on upgrades and least for operation on relatively flat grades.

This information is useful in the determination of road-user running cost, particularly on sections of road where numerous passings are necessary for drivers to maintain desired speeds. For example, consider a level, two-lane road carrying passenger cars only, where traffic volumes average 700 vehicles per hour for four peak hours each day, 200 vehicles per hour for 10 off-peak hours each day, and a negligible traffic flow during the remaining 10 hours daily. Information published in the *Highway Capacity Manual* shows that during each of the four daily peak hours, drivers must accomplish one passing per mile to maintain their desired speed. The excess fuel consumed by each passenger car each passing is 0.0050 gal at 40 mph and 0.0045 gal at 30 mph. Assuming 50 percent of the drivers wish to travel at 40 mph and 50 percent wish to travel at 30 mph, the excess fuel consumed for each 4-hr daily peak period would be 13.3 gal per mile. The calculations are as follows: multiply 350 vehicles per hour times 4 hr times 0.0050 gal per passing at 40 mph and add to the product of 350 vehicles per hour times 4 hr times 0.0045 gal per passing at 30 mph. This would amount to nearly 5,000 gal per year or, at $0.30 per gallon, nearly $1,500 per year per mile for the cost for fuel for passings.

The results of the investigation of vehicle fuel consumption as affected by speed change variation on level roads, sloping roads, and curved roads indicate that the effect of grades and curves on fuel consumption is nearly the same whether or not vehicle speed is uniform. It follows that differences in fuel consumption rates for operation on different gradients at uniform speeds for passenger car fuel consumption rates on different gradients can also be applied where operating speeds are not uniform (i.e., on urban routes).

8. An item developed in the study of motor vehicle costs that is of interest pertains to the problem of alleviating smog conditions in cities through reducing the contribution of automobile exhaust gases to the atmosphere. On the basis of more than 5,000 stops for traffic signals on urban arterials in Washington, D.C., it was found that the passenger car consumed an average of 0.0038 gal of fuel while stopped idling at traffic signals. This expenditure of fuel results in no useful work but does add to smog conditions. Elimination of busy intersections at-grade will materially assist in controlling the automobiles' contribution to urban smog.

9. The total cost difference (in cents per mile) to operate a modern passenger-car sedan on a nearly level, gently rolling urban freeway for an attempted speed of 45 mph with traffic volumes between 1,400 and 2,099 vehicles per hour in the direction of travel, rather than on selected urban arterials having level grade lines and the same traffic volume range, can be developed from the research findings as follows:

	COST DIFFERENCE (CENTS/MILE)		
COST ITEM	URBAN FREEWAY	MAJOR STREET ART'L OUTSIDE DOWNTOWN (2 STOPS/MILE)	DOWNTOWN ART'L (5 STOPS IN 5 BLOCKS OR 10 STOPS/MILE)
Fuel ($0.30/gal)	1.518	2.094	6.021
Time ($0.50/hr)	1.134	2.840	10.000
Tires ($18.50 each)	0.185	0.932	2.650
Oil ($1.00/1 qt)	0.060	0.060	0.090
Maintenance of brakes and trans.	—	0.368	1.840
Intersection accidents	—	0.140	0.140
Total	2.897	6.434	20.741
Excess over freeway	—	3.537	17.844

PROJECT 2-8: ESTIMATION AND EVALUATION OF DIVERTED AND GENERATED (INDUCED) TRAFFIC [1]

Research Agency: Northwestern University

OBJECTIVES

Traffic volumes on new or improved highway facilities are found to increase more than can be attributed to normal growth of existing traffic. This extraordinary traffic increase is composed of two components—diverted and generated. In making analyses of highway improvement consequences, such diverted and generated traffic must be taken into account. At present, sufficient information is not available concerning characteristics of this type of traffic. The major objective of the research was to develop methods of dealing incisively with traffic diversion and generation.

[1] Published in summary form in NCHRP *Summary of Progress to June 30, 1967.*

APPROACH

A consideration of alternative levels of study led to the conclusion that a disaggregated approach was highly desirable and the study focused mainly on the household as the unit of travel generation. The household is in a spatial and a temporal setting, and studies were made that stressed each of these attributes.

Disaggregation

As conventionally defined, the terms "traffic diversion" and "traffic generation (or induction)" describe dependencies between the pattern of daily travel and the nature of the existing transportation system. The occasion of a change (or "shock") to this system (e.g., the opening of a new freeway or the extension of a rapid transit line) generates a modification in the pattern of travel demand. This modification of demand is then categorized as either "diversionary," referring to a change in the characteristics of previously existing trips, or "inductive," referring to the generation of wholly new travel.

Previous studies of induction and diversion, both empirical and theoretical, have concentrated on gross changes in areal travel patterns consequent on a major system modification. Little attention has been paid either to the response of individual travelers or to the cumulative effects of a set of minor "shocks," applied either simultaneously or in sequence one after the other. It is argued here that such aggregate studies, particularly if they are based on the results of a simple before and after study can yield only a superficial and possible misleading description of the mechanics of the induction and diversion processes.

Further, it should be recalled that travel behavior is dependent not merely on the characteristics of the existing transportation system, but on the total environment within which successive travel decisions are made. This environment encompasses not only the physical transportation plant, with its associated time, distance, and cost structure, but also the unique environment of the individual traveler (including his resources, location, and his perception of the transportation alternatives available to him) and a set of exogenous factors (such as the weather, the time of day), each of which may exert a significant influence on a given travel decision. This postulate necessarily implies an analysis couched at the level of the individual decision maker (e.g., the single traveler, the household, or the firm). Aggregation, unless it succeeds rather than precedes the process of analysis can only act to suppress and obscure pertinent relationships.

The point to be noted here is not that aggregation is undesirable per se, but that it should be based on terms meaningful to the analysis in hand and not on an arbitrary consideration such as fortuitous spatial proximity.

Given the disaggregate decision-making environment just postulated, the range of potential "shocks" that may influence travel behavior varies considerably, both in character and in consequence. At one extreme, for example, one may consider the effect on a single household's travel of the purchase of a second car, a movement within the family life cycle, or a change in a place of employment. At another extreme, concern may be of the widespread implications of a transit strike, a nationwide holiday, or the opening of a new link in an urban highway network.

Similarly, one may also distinguish between different dimensions of diversionary effect. In some cases a change in the decision-making environment may generate an increase or decrease in the absolute frequency of travel. In others, the result may be a diversion from one destination point to another, a change in an established route or mode of travel, or a transference of a given trip from one point in time to another. One may also usefully distinguish between the duration of different effects. Distinction may be drawn, for example, between "short-term" shocks, of strictly limited duration (e.g., an increase in transit use following the occurrence of a sudden snowstorm, or the transfer of a shopping trip from one day to the next due to the breakdown of the family car), "medium-term" consequences (e.g., a change in household location, the relocation of an industrial plant or a long-term transition from transit to automobile use for the trip downtown).

The distinction between the duration of different response categories requires knowledge by the analyst of the stability of the analysis unit's travel behavior over a sustained period of time. That is, a knowledge of the unit's day to day trip-making pattern, and the probability that an observed change in behavior may have occurred either independently of the occurrence of a given "shock," or else due to some other simultaneous but possible unrelated change in the unit's decision-making environment. This requirement in turn leads directly into the main themes of this research: namely, the analysis of travel behavior, and particularly household travel behavior, as a "longitudinal" or continuing process over time.

Longitudinal Analysis

In recent years a number of discussions of social science research methods have stressed that the identification of fundamental relationships requires use of time series data. Similar arguments have been presented by Oi and Shuldiner and others with respect to the fundamental structure of household travel and by Garison with respect to data inputs for land-use models.

In a similar vein, it may be argued that an extended longitudinal analysis, conducted at a considerable level of disaggregation, is a prerequisite for the development of an adequate forecasting ability. It is particularly interesting to consider the role that longitudinal surveys might possibly play in a major metropolitan transportation study, supplementing and extending the standard techniques that are in use today. One may, for example, consider the increased validity to be obtained by basing an estimate of average daily trip-making not on a single, isolated day's observation for each sample unit, but rather on an average computed for a series of successive days. Alternatively, a continuous "response panel" might be developed (analogous to the consumer panels used in market and TV rating research), made up of a sample of households dispersed throughout a metropolitan area and designed to monitor changes in the daily, monthly, and annual patterns of travel demand on a continuing basis. The concept of such a panel has obvious attractions for a "continuing transportation study."

An empirical study was made to explore the temporal approach to travel analysis. A sample of 104 households in Skokie, Ill., was selected and alternative survey mechanisms were applied. Skokie, which adjoins Chicago, is a "bedroom" suburb of 70,000. Findings from this study bear on (1) the temporal stability of household travel, (2) the efficacies of alternative survey methods, and (3) definitional and taxonomic problems and properties for travel and for households.

Spatial Analysis

The study stressing the spatial setting of the household investigated the short-run rearrangements of trips consequent to the opening of the Southwest Expressway of Chicago. Three subareas were selected from the 750,000 population study area and a survey was made of travel from the household just prior to the opening of the Southwest Expressway on October 24, 1964. Follow-up surveys were made in February and March 1965. In addition to information from the household, information was obtained from students in schools in the area. Several methods of questioning were studied.

A set of quantitative measures of spatial properties of travel was developed:

1. Length.
2. Number of trips and inflections (90° or more).
3. Velocity.
4. Distance relations of origins and destination.
5. Circuity, the difference between the length of trips and the associated desire lines.
6. Measures of the spatial structure of traffic patterns.
7. Locational indicies.

Each element in the sample was then classified, using multivariate methods, with respect to the spatial properties of its travel. One class, for example, was "housewife car driver." Travel by persons in this class was characterized by a set of properties, including short travel times, supplemental use of public transport facilities, short trip lengths, and use of rather direct routes. In all, seven classes were recognized.

Diversion of traffic to the new expressway was studied for each class of travelers. This was a study, then, of the spatial stability of travel. In addition, it treated questions of the efficacies of alternative survey methods and of definition and classification.

FINDINGS

This research effort was highly methodological in orientation and in purpose, and the more important conclusions are methodological ones.

1. This study stressed again and again that travel behavior is essentially both a temporal and spatial phenomena. Logically, therefore, its analysis must be couched in those terms. In particular, reliance on purely cross-sectional data, particularly when these are subject to an ill-defined spatial aggregation, can act only to suppress rather than clarify fundamental relationships. The simple, uncontrolled, nonrandomized before and after survey much used in the literature may frequently provide only a very crude and/or invalid identification of a given effect.

2. Attention has been drawn to the potential of the continuing "panel" survey (in which a series of repetitive observations are made on a selected sample set irrespective of the occurrence or otherwise of a particular experimental treatment) as a mechanism for the analysis of travel. Valid short- and long-run information is needed to treat the induction and diversion problems and panels will provide such information.

3. The self-administered travel diary provides a convenient mechanism for the continuing study of household travel behavior. The success of such a study depends primarily on the maintenance of an adequate level of sustained surveillance and the provision of some form of respondent reimbursement.

Unit survey costs, expressed in dollars/data-day are approximately half to one-third of the per-interview costs incurred in a conventional cross-sectional study. For a suburban community of approximately 70,000 population the annual cost may be estimated at between $20,000 and $50,000, depending on the precise monitoring design adopted. For a large metropolitan area, a continuing panel sample of 2,000 households would require an annual expenditure of between $200,000 and $500,000. But these costs are small relative to the value of the information they would provide.

No significant biases appear in the socio-economic structure of the families accepting and rejecting initial survey contact. Similarly, socio-economic characteristics appear to have little or no bearing on the maintenance of an adequate sustained response rate.

4. With exception of certain isolated and highly constrained trip-types (e.g., the journey to work or to school), the temporal distribution of household travel is very irregular. The pattern of "choice" trips is essentially nonrepetitive. A significant cyclical pattern is exhibited only for the *timing* of certain select trip-types within a given day; no equivalently significant cyclical patterns are identifiable at the daily or weekly level. Similarly, repetitious travel patterns, expressed in terms either of the frequency distribution of visitation points in space or as the repetition of particular home-home trip links are the exception rather than the rule.

5. Although the small sample available for this study precludes performance of full taxonomical analyses, there is strong evidence to suggest that a grouping of household types exists, defined in terms of the variability of their temporal travel behavior. An analysis of the spatial structure of travel suggested a grouping of household types from this point of view.

6. The most efficient, single estimate of average daily trip-making, allowing for data-collection costs, appears to be that derived from a consecutive, three-day weekday sample. Such a study, it should be noted, provides a more efficient measure of *disaggregate* travel, *not* zonal or district trip-making.

7. At the level of the single household, a variety of dis-

aggregate measures may be identified that relate closely to the pattern and intensity of daily travel. Particularly effective in regard to the family per se are selective "head-count" indices and measures of a family's maturity and occupational status. In regard to the spatial structure of travel, measures of distance, frequency, and velocity proved specially useful.

8. In the instance of the Southwest Expressway in Chicago, diversion to the expressway was mainly of male car drivers. On the average, drivers travel greater distances but for shorter time periods.

PROJECT 2-9: EFFECT OF HIGHWAY LANDSCAPE DEVELOPMENT ON NEARBY PROPERTY [1]

Research Agency: Franklin Institute Research Laboratories

OBJECTIVES

The over-all purpose of this project was to study the effect of highway landscape development on nearby property; the following were its specified objectives:

1. To determine to what extent, and under what circumstances, landscaping of freeway (expressway) facilities and property adjacent thereto affects the value of nearby property.
2. To learn whether, and to what extent, landscape development can make modern highways compatible with nearby land uses.
3. To learn the extent to which adequate landscaping of the right-of-way makes certain features of freeway (expressway) design acceptable to residential and other adjacent nearby land uses.
4. To determine the comparative effects of different basic types of landscape treatments.

APPROACH

The approach to this study was based on the hypothesis that the presence of highways affects the value of adjacent properties, and their effect may be modified by landscaping/landform features, such as planting, screening, and highway geometry. Proper use of landscaping/landform requires that the relationship between landscaping/landforms and property values be known. However, the main effects of landscaping are indirect rather than direct (i.e., landscaping/landform shields adjacent property from the effects of highways). These effects are caused by a variety of physical disturbances, including noise, odors, and lights. Therefore, to understand the effects of landscaping/landforms it is necessary to ascertain the influence of landscaping/landforms on these physical disturbances and, in turn, the effect of these disturbances on property use, value, and homeowners.

The Franklin Institute Research Laboratories designed and carried out a program to measure these disturbances, determine property-value differentials, and record and assess landscaping/landform techniques. The purposes of the program were to test the hypothesis that highways affect property values, and to determine the relationships between disturbances, property values, and landscaping/landform techniques.

Questionnaires and data-collection forms were drafted and a pilot test of the experimental method was conducted using the draft forms. The forms were refined according to the results of the pilot test and were further refined as experience was gained during the first year's data collection. Following this period, data-collection procedures and method of conducting the field investigation were finalized and documented.

Disturbances were measured on about 600 properties in northeastern United States, and 200 sites in the Midwest and West. Approximately 800 interviews were conducted, of which 459 were analyzed; of these, 252 were eastern homesites, 156 were midwestern, and 51 were western.

To determine the effect of the physical disturbances on nearby property values, the measurements were correlated with property-value differentials, which were determined by searching out sale and resale prices of the selected property sites in county courthouses. Eighteen groups of resold homes in six geographic areas were examined; in these areas, data were collected on 156 homes next to, and 137 homes away from a limited-access highway.

Three types of analyses were performed on these collected data: major-variable analysis, economic analysis, and interview analysis.

In the major-variable analysis, relationships, and correlations were examined between sound levels and sound-level reductions at specific measurement points, and other variables, such as sound-level perception, percentage of tree density, and homeowners' attitudes of buying another house next to a highway. Scatter graphs of these relationship were plotted so that t tests and correlation analyses could be conducted. Then, to determine the amount of disturbance reduction attributed to different combinations of landscape design, highway geometry, and traffic conditions, multiple regression analysis was initiated.

The economic analysis evaluated the effect of highway disturbance and landscape/landforms on property values. Four basic types of information were analyzed: property-value changes, relation of property to highway, quantity of landscaping/landforms, and highway disturbances. Six meaningful interrelationships were found among these information types, of which the following four are analyzed and evaluated as economic relationships:

1. Property-value change versus distance from highway.
2. Distance from highway versus landscaping/landforms.
3. Highway disturbance versus property-value change.
4. Property-value change versus landscaping/landforms.

Interview data were summarized to facilitate a comparison of the attitudes of single-dwelling suburban property owners toward expressways in different parts of the United States. In addition, data gathered from interviews with apartment-building and farm-property owners were synthesized to gain insights into the effect of highway disturbances on such properties.

In supplementary study, field experiments were con-

[1] Published as "Effect of Highway Landscape Development on Nearby Property," *NCHRP Report 75* (1969).

ducted to define the relationships between sound-level reductions and various landscaping/landform configurations and distances, including highway elevations, depressions, and landscaping with trees and brush.

FINDINGS

Conclusions

Based on the data collected and analyzed for the study, the following conclusions are drawn:

1. Presence of a limited-access highway adjacent to a property does not devalue the property.
2. Presence or absence of landscaping on the right-of-way of a limited-access highway adjacent to a property does not affect the value of that property. However, people living next to such highways indicated that they would accept the presence of the highway better if it were concealed from view by landscaping.
3. Sound from trucks is the most objectionable highway disturbance to persons living next to limited-access highways, regardless of geographic location. Other disturbance factors (vibration, light, odor) are present, but are much less objectionable.
4. Landscaping and landforms affect highway sound levels, but the amount of reduction or increase contributed by an individual landscaping element (such as trees) is difficult to determine. However, supplementary study demonstrated that trees reduce sound level only minimally, and that highway depression is potentially the greatest single reducer of sound level.
5. Attitudes relating to disturbance factors of people living next to a highway, even in the same geographic location, vary greatly. Therefore, a large sample size is necessary to reveal any significant findings. From the present sample, it was learned that people living in older, relatively less expensive homes next to limited-access highways tended to accept associated disturbances more readily than people in more expensive homes; however, Los Angeles homeowners interviewed accepted the highway as a necessary evil, regardless of property value.
6. Lack of proper maintenance of highway right-of-way was the second most objectionable highway annoyance.
7. Equations developed through multiple-regression analysis are useful in designing expressway landscaping and landforms.
8. Sound disturbance at high-rise apartment buildings located adjacent to a limited-access highway is highly objectionable and caused apartment owners to make economic adjustments for units facing the highway.
9. Farm areas have the same complaints as the suburban areas, but not as many. The sound-level threshold is lower (about 10 dBA) because the background and sound level are about 10 dBA lower.
10. Measurements of such variables as tree density and highway visibility vary among observers because no standardized measures are available.
11. Sale and resale prices are the best indicators of property value, regardless of geographic location.

Recommendations

From the conclusions, two groups of recommendations are made. The first group lists remedial actions that can be taken to reduce highway disturbances; the second group suggests areas for additional research.

Remedial Actions

1. Reduce noise from trucks at the source through improved tire and muffler design.
2. Depress highways wherever possible.
3. Shield properties from the sight of adjacent highways by planting trees and shrubs in the right-of-way. Shielding growth should occur within 5 to 7 years.
4. Establish a program to maintain highway right-of-way at a standard of cleanliness and neatness comparable to that of adjacent property.

Suggested Research

1. Continue the regression analysis to establish an equation(s) for predicting sound-level reductions at properties adjacent to limited-access highways.
2. Study ways of improving measures of tree density, visibility, and right-of-way maintenance level. Refine methods of obtaining, weighting, and analyzing attitudes of homeowners next to expressways.
3. Conduct more detailed attitude surveys on a larger sample of homeowners adjacent to limited-access highways than those conducted in the present study, with concentration on differences in sensitivity of homeowners in different income groups and different geographic areas.
4. Study in detail the effects of different landscape treatments or combinations of treatments on highway disturbances.
5. Study the effects of highway noise on the economics of high-rise apartments in sufficient detail to aid apartment-building planners.
6. Conduct further study of property value on a larger sample to reduce the effect of other variables in the analysis.
7. Study the feasibility of converting county deed recording and searching procedures to automatic data-processing equipment; such a conversion would facilitate all deed searches.
8. Study the economic feasibility of air conditioning or soundproofing homes along limited-access highways to decrease highway disturbance.

APPENDIX B

DESCRIPTION AND EVALUATION OF SOCIAL AND ECONOMIC CONSEQUENCES

Appendix B is relatively self-sufficient as an analysis tool; thus, it can be detached from the report and used independently. Table 17 is repeated here as Table B-1.

Appendix B is expected to serve as a reference source for detail about specific types of social, economic, and community consequences of highway design and use. For instance, when a new route location, or improvement of a specific highway project or route, is being considered, the nonuser factors involved can be classified along the same lines as given in Table B-1. The next step is to refer to the detailed factor descriptions in Appendix B for the general types of consequences, favorable and unfavorable, that may be expected from construction of the proposed highway improvement being considered.

Further, Appendix B may be used as a locator for those types of consequences that need to be looked for in connection with a specifically proposed highway improvement. Once one is aware of the types of consequences that may come about, a field study can be made as one of the steps in evaluating such probable consequences.

CATEGORY: 1. Aesthetics
VARIABLE: A. The View From the Highway

Area:	Urban and Rural
Type of Consequence:	Social
Location of Impact:	Right-of-Way Corridor
Timing of Impact:	After Construction—Short Term After Construction—Long Term

Consequences

The "view from the highway" looks at the problem of beauty and appearance of highway and roadside from the user's point of view. The pleasure and satisfaction (perhaps safety) of driving are enhanced by a positive visual experience. Although a "user benefit" is involved, the actions taken to secure this benefit frequently affect nonusers whose properties in the user's line of sight are affected.

A public desire that highways be aesthetically pleasing as well as functional, safe, and efficient has been evidenced by (1) the popularity of parkways and scenic highways, and (2) public willingness to pay for aesthetic enhancement of highways. The latter is evidenced by the *Highway Beautification Act of 1965* (*1-19*) and the funds appropriated for its execution.

To the same extent that highways and roadside views can be enhanced by design, planning, expenditure, and regulation, they can, by the absence of such measures, also be spoiled. Spoilation has frequently given rise to the counteractive measures designed to prevent it.

Spoilation of beauty visible to the user as a consequence of highway improvement has occurred in a variety of ways:

1. Right-of-way taking may remove scenes of natural or man-made beauty.
2. Roadside beauty may be spoiled by unaesthetic or insensitive treatment of roadsides.
3. An area be spoiled by making it accessible to too many people or cars, which upsets a natural ecological balance or destroys some intrinsic beauty or environmental character.
4. Possible scenic views may not be exploited in highway routing or design.
5. Points of interest may not be made accessible.
6. Development induced by the highway's access advantages or market potential may be unaesthetic and may not be prevented from occurring or may be removed by regulation, purchase, or design where it exists.
7. Unaesthetic views may be exposed by highway routing or design.
8. Scars and blight left in the process of highway construction may not be enhanced.
9. The highway may lack aesthetic merit and fail to create pleasureful driving through lack of good design applied to materials, alignment, curvature, elevation, surfaces, structures, signs, and other appurtenances.

Alternatively, the "view from the highway" can be made visually stimulating and pleasureful with favorable consequences to user and, often, nonuser, by means designed to avoid or correct the foregoing potential negative consequences. Positive gains to both groups, rather than just the avoidance of negative effects, may result from efforts to enhance the user's view. The third possibility is that of mutually exclusive enhancement and spoilation for user and nonuser (e.g., an elevated highway that secures a scenic vista for users may block that of nonusers; a depressed highway or tunnel may preserve the view of nonusers while depriving users of it) (*1-1*).

Local conditions will indicate what opportunities for improving the "view from the highway" are possible and the extent to which they complement or deny nonuser aesthetic benefits. The potential opportunities inherent in most situations can be categorized in four ways:

1. Preservation of aesthetic features.
2. Exploitation of aesthetic features.
3. Correction and avoidance of unaesthetic features.
4. Enhancement of the highway or its roadside to provide aesthetic features.

The degree of foresight and planning adopted with respect to these opportunities will determine the aesthetic consequences of highway route location and design.

Gains and Utilities

1. To users:
   a. Enhancement of driving pleasure (*1-20*).

b. Possible enhancement of driver safety (*1-20*).
c. Possible enhancement of driver orientation (*1-3*).
d. Stimulation of interest in history and national culture by routing and signing directed to places of interest (*1-20*).
e. Fosters an awareness of nature for its educational and spiritual values (*1-20*).
f. Encourages an appreciation of beauty through opening scenic ways and vistas (*1-20*).
g. Provides added capacity and access for defense and emergency traffic (over scenic roads) (*1-20*).

2. To nonusers:
   a. Commercial enterprise sales in areas attracting pleasure drivers, and tourist and recreational traffic, due in whole or in part to aesthetic enhancement of highways.
   b. Land and property value increases due to the desire to reside proximate to and in areas served by aesthetically enhanced highways.
   c. Advertising and public relations value from attractively landscaped industrial plants visible from the right-of-way.
   d. Absorbs growing demands for recreational opportunities; relieving the strain placed on the present facilities (*1-20*).
   e. Promotes tourism; expenditures for recreation and travel equipment; tourist-oriented goods and services (*1-20*).
   f. Construction expenditures help employment and local economies (*1-20*).
   g. Mental and physical health promoted by scenic and recreational opportunities; lower expenditure for therapeutic measures (*1-20*).
   h. Reduction of unsightly environments by landscaping, screening of ugly areas, removal of blight, unaesthetic signs, etc. (*1-20*).
   i. Encourages support for conservation of resources (*1-20*).

Costs and Losses

1. To users:
   a. To the extent that aesthetics are neglected in highway route location and design, users forego or receive less of the foregoing benefits or gains.
   b. Highway investments will be increased to beautify design highways over that required otherwise. Revenues may be expended to arrange for the retention or enhancement of scenic roadsides and corridors through various legal arrangements (*1-24*, p. 36):

1) Purchase of rights necessary to preserve scenery.
2) Purchase of fee, and resale to allow public residual rights.
3) Purchase of fee and lease back.
4) Purchase, subject to right of occupancy for life.
5) Tax concessions, in return for land use covenants, or contracts for specified terms.

   c. Travel time may increase on scenic routes due to traffic slowing down or stopping at overlooks to prolong viewing time.
   d. Some potential motor vehicle efficiency and economy of operation may be sacrificed in highway route location and design to accommodate aesthetic enhancement.

2. To nonusers:
   a. To the extent that aesthetics are neglected in highway route location and design, nonusers forego or receive less of the foregoing benefits or gains.
   b. Outdoor advertisers suffer loss of future revenues and investment due to billboard restriction and removal (may be partly or wholly offset by compensation payments and freedom to display billboards in industrially or commercially zoned areas).
   c. Screening or removal of junkyards, to the extent uncompensated.
   d. Landowner loss of income or land value due to restrictions on development in interest of scenic preservation, to the extent uncompensated by payments for rights, easements, or tax concessions.

Decision-Making Factors

1. Definition.—Aesthetics, the study of that which is beautiful, is highly subjective. Each person defines beauty somewhat differently, according to his own background and sensitivities. Searching for those qualities that most people associate with beauty, Peterson (*1-12*, p. 15) found that the simultaneous fulfillment of the following goals produced environmental beauty for the population he surveyed:

   a. "Sound physical quality as evidenced by the appearance of newness and expensiveness."
   b. "Harmony with nature, as evidenced by an appearance of greenery, open space, privacy, and naturalness."
   c. "Variety of richness of appearance, as opposed to uniformity and monotony."

In addition to these goals, identification of the highway aesthetic and proposals of principles of design, the application of which will presumably approach its achievement, have been the subject of several studies (*1-4, 1-5, 1-8, 1-13, 1-15, 1-16, 1-22*).

2. Inventory in the various right-of-way locations:
   a. Areas and objects worthy of preservation:
      (1) Scenic views, parks, open space, recreation areas.
      (2) Historic or architectural sites, areas, or structures.
      (3) Rare natural phenomena or ecological communities.
   b. Areas and objects that can be exploited by highway route location or design to increase the pleasure of the traveler:
      (1) Landmarks, symbolic imagery.
      (2) Historic trails and sites.
      (3) Waterfronts.
      (4) Interesting geologic formations.
      (5) Scenic overlooks, views, panoramas.
      (6) Unusual natural or man-made objects or phenomena.

TABLE B-1

SOCIAL AND ECONOMIC CONSEQUENCES OF HIGHWAY IMPROVEMENT BY AREA, TYPE, LOCATION, AND TIMING

SOCIAL AND ECONOMIC CONSEQUENCE VARIABLES	AREA		TYPE		LOCATION				TIMING			
	URBAN	RURAL	ECONOMIC	SOCIAL	RIGHT-OF-WAY	CORRIDOR	COMMUNITY OR SYSTEM	REGION OR NATION	BEFORE CONSTRUCTION	DURING CONSTRUCTION	AFTER CONSTRUCTION -SHORT TERM-	AFTER CONSTRUCTION -LONG TERM-
1. Aesthetics												
A. The View from the Road	X	X		X	X	X					X	X
B. The View of the Road	X	X	X	X	X	X					X	X
C. Highway-mode-Induced Aesthetic Effects	X	X	X	X	X	X	X				X	X
2. Agriculture												
A. Access to Improved Road		X	X	X		X	X				X	X
B. Economic Units (Size of Farm Unit)		X	X		X	X				X	X	X
C. Productivity		X	X			X	X	X			X	X
D. Dislocation		X	X	X	X	X			X	X	X	X
3. Commercial												
Commercial sales receipts and incomes:												
A. Change Due to Dislocation and Relocation	X		X		X	X			X	X	X	
B. Change Due to Barrier	X		X		X	X				X	X	
C. Change Due to Population Change	X		X			X					X	X
D. Change Due to Income Group Change	X		X			X				X	X	X
E. Change Due to Traffic Volume Change (Bypass Effect)	X		X				X				X	X
F. Change Due to Accessibility Change (Trade Area)	X		X			X					X	X
G. Change Due to Community Price Change (Resulting from Transportation)	X		X				X	X			X	X
H. Rental Property Receipts	X		X		X	X			X			
I. Employment	X		X			X	X			X	X	X
J. Land Use	X		X		X	X	X			X	X	X
K. Land Value	X		X		X	X	X			X	X	X
L. Effect on Public Transportation	X		X	X		X	X				X	X
M. Parking	X		X		X	X	X			X	X	X
4. Community Government												
A. Community Services and Facilities	X		X		X	X				X	X	
B. Park, Recreation and Open Space	X		X	X	X					X	X	X
C. Non-Highway Government Revenue and Expenditure Changes	X		X		X				X			
D. Public Policy and Laws	X	X	X	X	X	X	X	X	X	X	X	X
E. Community Goals	X	X	X	X	X	X	X	X	X	X	X	X
5. Construction												
A. Community Social and Economic Effects During Construction	X		X	X	X	X	X			X		
B. Immediate Effects on Highway Construction Industry	X		X				X	X		X		
C. Long Run Effects on Non-highway Construction Industry	X		X				X	X			X	X
6. Employment												
A. Employment Change Due to New Land Use Development	X	X	X			X	X			X	X	X
B. Employment Change Due to Dislocation and Relocation	X	X	X		X	X	X		X	X		
7. Environment												
A. Noise	X	X	X	X		X				X	X	X
B. Air Pollution	X		X	X		X	X	X			X	X
C. Vibration	X		X			X				X	X	X
D. Drainage Patterns	X	X	X		X	X				X	X	X

TABLE B-1 (*continued*)

SOCIAL AND ECONOMIC CONSEQUENCE VARIABLES	AREA		TYPE		LOCATION				TIMING			
	URBAN	RURAL	ECONOMIC	SOCIAL	RIGHT-OF-WAY	CORRIDOR	COMMUNITY OR SYSTEM	REGION OR NATION	BEFORE CONSTRUCTION	DURING CONSTRUCTION	AFTER CONSTRUCTION -SHORT TERM-	AFTER CONSTRUCTION -LONG TERM-
8. Industrial												
A. Industrial Development	X		X			X	X	X			X	X
B. Industrial Dislocation	X		X		X				X	X		
C. Industrial Relocation	X		X			X	X			X	X	
D. Industrial Land Use	X		X			X	X				X	X
E. Industrial Land Value	X		X			X	X				X	X
9. Institutions												
A. Institutional Dislocation and Relocation	X		X	X	X					X	X	X
B. Institutional Accessibility and Patronage Change	X		X	X		X				X	X	X
10. Population												
A. Population Growth	X	X		X		X	X					
B. Population Density	X			X		X	X					
C. Population Geographic Shifts	X	X		X			X	X				
D. Population Distribution	X			X			X					
11. Public Utilities												
A. Utility Joint-Use of Right-Of-Way	X	X	X		X					X	X	X
B. Utility Dislocations and Relocations	X	X	X		X	X			X	X		
C. Utility Patterns and Costs	X		X				X				X	X
12. Residential Neighborhoods												
A. Rents, Costs and Prices of Replacement Housing	X		X			X	X		X	X	X	
B. Residential Relocation Costs	X		X		X				X			
C. Social and Economic Relationships of Dislocatees	X		X	X	X	X			X	X		
D. Quality of Neighborhood Life	X			X	X	X			X			
E. Property Values in Right-Of-Way Before Taking	X		X		X				X			
F. Neighborhood and Community Stability	X		X	X	X	X					X	X
G. Neighborhood and Community Linkage Patterns	X		X	X		X					X	
H. Residential Land Development	X		X			X	X				X	X
I. Residential Property Values	X		X			X	X				X	X
J. Neighborhood and Community Patterns	X			X		X	X				X	X
K. Social Life and Social Patterns	X			X		X	X				X	X
13. Road User												
A. Accident and Safety	X	X	X	X	X	X	X	X			X	X
B. Running Costs--Distance Related	X		X		X	X	X			X	X	X
C. Running Costs--Land-Use Intensity and Population Density Related	X		X		X	X	X				X	X
14. Spatial and Geographical Changes												
A. Local	X	X	X	X	X	X	X		X	X	X	X
B. Metropolitan	X	X	X	X			X				X	X
C. Regional	X	X	X	X				X			X	X
15. Urban Form and Development												
A. Land-Use Inventory	X		X				X			X	X	X
B. Land Values; General	X		X			X	X				X	X
C. Central Business District	X		X	X	X	X	X	X		X	X	X
D. Urban Form and Development Patterns	X		X	X		X	X	X			X	X
E. Real Property and Land Taken for Right-of-Way; Use and Value	X		X				X			X	X	

c. Areas or objects needing correction or that should be kept from view of the traveler where possible:
   (1) Industrial areas.
   (2) Gravel pits and quarries.
   (3) Garbage dumps.
   (4) Billboards.
   (5) Blighted areas.
   (6) Junkyards.

d. Areas that may need enhancement and areas where the benefits of good design would give pleasure:
   (1) Groundcover over raw earth cuts.
   (2) Landscaping roadside.
   (3) Adding park or recreation space-air rights, joint development, joint use.
   (4) Stonework on retaining walls.
   (5) Well-designed highway surface, structures, signing, related structures (roadside shelters, etc.)

3. Factors for consideration.—In judging the degree that highway costs and nonuser costs may be justified to support aesthetic enhancement of highways, it is important to consider the following factors.

a. Community and highway agency goals are aids in identifying potential conflicts between individuals, groups, and levels of government as perceived in discussions, hearings, controversy, and goals statements related to:
   (1) Land-use planning and community character.
   (2) Traffic planning.
   (3) Highway engineering.
   (4) Highway costs and quantifiable and non-quantifiable gains and losses. See Table B-2.
   (5) Visual goals: whether the highway is visually to be:
      (a) A unified work of art, beautiful in itself (e.g., a parkway).
      (b) A unified visual experience resulting from a highway so arranged to provide an interesting and pleasing sequential flow of images.
      (c) A harmonious element in its environment, fitted in but with no particular effort to make an aesthetic statement.
      (d) A roadway with intrinsic visual merit in the form of attempts to follow good design principles and to provide for some beautification after the fact, but with no particular effort to make an environmental fit.

   The foregoing visual goals represent a gradation of attention given to the problem of highway aesthetics ranging from the design of a highway as a work of art to the cosmetic beautification of highway designed on engineering principles of economy and efficiency alone. They also are ordered high to low in terms of their potential conflict with social and engineering goals, becoming easier to implement toward the end of the list.

b. Type of improvement, including the degree of access limitation and design capacity, will produce differential aesthetic effects. Limited-access highways usually preserve the character of the roadside between interchanges in that, lacking access, there is little impetus to change the type of development. Because access is only visual, the advertising function is usually the only commercial one served. What development does take place is often in the character of billboards or on-premise signing of enterprises such as industrial plants or commercial outlets. Industrial plants usually make such signing visually attractive for the public relations aspect. Commercial outlets favor signs that are extremely high or large where displays near the roadway are not permitted so they will be conspicuous at a great distance. Commercial outlets and their signs usually locate near interchanges.

   At the other end of the scale, unlimited access coupled with high volumes precipitates greater degrees of roadside commercial and industrial development (in part responsible for the highway volumes due to being trip generators). At the highest volumes, development becomes almost continuous, giving rise to the descriptive terms "ribbon development" and "string streets." The incidence of signs and the degree of enclosure of the roadway correlate and likewise rise with volume and development. Billboards and highway signing also appear to have a positive correlation with volume of traffic (*1-9*).

   Intersections, combining the volumes of two routes, tend to have the most intensive development, signs, and degrees of spatial enclosure (*1-9*).

   By the same token, roadsides and intersections that contain higher degrees of development have fewer trees, less vegetation, and more openness (*1-9*).

   The width of the right-of-way is significant in that wider and wider highways take up more and more of the field of vision, and the roadway itself becomes an important component of the visual scene (*1-16*, p. 3). Signing, the landscaping or lack of it on roadsides and in median strips, light standards and other highway furniture, and the color, marking, and texture of pavement together determine the quality of the user's visual experience. In such cases, the amount of aesthetic consideration that can or needs to be given to the off-the-road visual scene diminishes proportionately. A six- or eight-lane "scenic" highway is probably a contradiction in terms. The more scenic the area, the narrower should be the right-of-way.

c. Function of the highway will also play a part in determining the extent of visual enhancement justified. A route handling predominantly commuter traffic probably has fewer vehicle occupants who can look at scenery. Along urban freeways, for example, the average number of travelers is 1.5 persons per car. On the other hand, cars in recreational areas average 3 persons per car, mean-

TABLE B-2

COSTS AND GAINS, QUANTIFIABLE AND NONQUANTIFIABLE, OF AESTHETIC HIGHWAYS

GAINS	COSTS
Quantifiable Gains	Quantifiable Costs
1. Reduction in accident costs. 2. Capacity and access for emergency traffic (loss reduced or avoided due to prompter response to emergencies). 3. Increased sales of commercial enterprises serving travelers according to projected trip generation. 4. Land and property value increases according to projected population and type of development in area made accessible. 5. Advertising value—billboards, signs, landscaped buildings visible. 6. Recreational travel and tourism and expenditures therefor. 7. Construction expenditures' multiplier effect on local economies. 8. Reduction in cost of therapy for health whose betterment is promoted by recreation opportunity. 9. Land value increase due to attractiveness of travel via the facility to and from the area developed. 10. Reduction in recreational, leisure, and tourist travel cost due to the provision of more accessible opportunities therefor.	1. Highway right-of-way and construction; or marginal additions thereto in the interest of aesthetics and fulfilling the highway's visual goals. 2. Cost of legal arrangements to ensure preservation of scenery. 3. Marginal user costs that are traded off to procure added amenity (e.g., travel time, extra distance, gradients, curvature). 4. Property value loss due to unaesthetic environments. 5. Property value loss due restrictions on land use to preserve scenery (to extent uncompensated). 6. Outdoor advertising loss (to the extent removals uncompensated). 7. Junkyard screening or removal costs (to extent uncompensated).
Nonquantifiable Gains	Nonquantifiable Costs
1. Driving pleasure. 2. Driver orientation, alertness. 3. Stimulation of interest in history and culture. 4. Awareness of nature. 5. Appreciation of beauty. 6. Capacity and access for defense traffic. 7. Symbolic values. 8. Mental, physical, and social health. 9. Promotion of support for conservation. 10. Reduction of nonquantifiable costs.	1. Distraction. 2. Tunnel vision. 3. Monotony. 4. Confusion. 5. Lack of orientation, sense of direction. 6. Assault on aesthetic sense of billboards, signs, junkyards, construction scars, unscenic roadsides. 7. Reduced information concerning services available and their location where signs and billboards are removed.

ing a majority of travelers can enjoy the view without distraction (*1-24*, p. 34).

If a highway is mainly for recreation and tourist travel, the scenic aspects should take precedence over user efficiency and economy where trade-offs are necessary. Where a highway is constructed mainly to handle truck and commuter traffic, more weight to the results of the engineering economy study and less to creating a scenic roadside is justified. Design ingenuity and coordination are needed to effect the necessary compromises.

4. Decision rules:
   a. Preservation of aesthetic features:
      (1) Extent that right-of-way has avoided seriously spoiling natural or man-made beauty or removing features of historic, cultural, or scientific interest.
      (2) Minimum spoilation of existing aesthetic features in the process of right-of-way clearance and construction.
      (3) Limited access to areas whose natural or human ecology cannot suffer large numbers of people or cars may, by attracting them there over the highway, spoil them. Some areas deserve to remain inaccessible except to those who are willing to make the effort to reach them by transit, on foot, canoe, horseback, etc., and whose numbers the environment can tolerate without damage to its natural balances or environmental quality.
   b. Exploitation of aesthetic features:
      (1) Advantages taken of opportunities to provide the traveler with scenic views, panoramas, views of landmarks, attractive sequences and

flows of images and space, and access to scenic or recreational areas. Route and design highways to capture the available scenic advantages.

(2) Provision of overlooks, roadside campgrounds, information centers, historic markers, and other means to aid the highway traveler in enjoying unique or interesting features of his environment.

c. Correction and avoidance of unaesthetic features:

(1) Removal of ugly appurtenances or activities from view where they can be removed (e.g., billboards) or screen them where removal is difficult (e.g., junkyards).

(2) Avoidance of route location where ugly views exist that are difficult to correct or change (e.g., industrial areas, gravel pits and quarries, garbage dumps).

d. Enhancement of the highway or its roadside to provide aesthetic features:

(1) Where the highway goes through areas that are ugly or that have no particular beauty or where right-of-way clearing or construction have left scars.

(2) Where beautiful designs as well as functional qualities have been achieved through good professional design by design-oriented engineers, architects, landscape architects, or design consultants.

e. More specific guidelines and criteria relating to aesthetic details of freeway design as regards "the view from the highway" appear in *The Freeway in the City* (*1-22*, pp. 37-46).

CATEGORY: 1. Aesthetics
VARIABLE: B. The View of the Highway

Area:	Urban and Rural
Type of Consequence:	Economic and Social
Location of Impact:	Right-of-Way
	Corridor
Timing of Impact:	After Construction—Short Term
	After Construction—Long Term

Consequences

The "view of the highway" approaches highway location and design from the standpoint of the viewer in the highway's vicinity. It is part of his visual scene; he is aware of its appearance as an aesthetic feature of his neighborhood.

Aesthetic considerations affect the community socially—the pride people feel concerning their community's or their neighborhood's attractiveness and the satisfaction and pleasure they take in their environment. Economically, aesthetic considerations are reflected in the price of space. Unaesthetic environs often lessen the desirability of and lower property values in an area, especially residential ones. A transportation facility becomes a building form in its environment. It should be a "good neighbor" for those who must live with it.

Following is a list of five frequently encountered aesthetic consequences of the "view of the highway" (*1-13*).

1. Edge, barrier, wall, boundary.—Heavily traveled and limited-access highways tend to form a visual barrier. Sight lines are halted or interrupted by the view of the traffic stream, the highway structure, an enclosing chain link fence or traffic barrier. Dead-ends on adjacent rights-of-way, lacking traffic or maintenance, may become weed-grown, littered, or otherwise unsightly.

2. Views.—Scenic views may be opened or closed by the highway. Elevated and at-grade highways may have the effect of closing off or replacing views of scenery, local landmarks, and distant vistas. It substitutes its own less scenic structure and pavement, signs and appurtenances, and traffic. The viewer's pleasure in his property and its value may suffer.

In other instances, the highway, if depressed or well-designed, landscaped, and sited, may succeed in opening up scenic views, eliminate unsightly features, and provide an attractive visual scene in itself.

3. Scale.—Limited-access highways, especially in urban environments developed to pedestrian or "human" scale, frequently clash with their environment. Built to accommodate machines that are extra-human in scale, highway structures and rights-of-way, through their mass, height, and expanse, visually dominate and overwhelm.

There is a social and psychological cost in juxtaposition of structures of super-human scale and areas of pedestrian use or structures built to human scale. Man, made to feel small, is unable to relate to the larger structure. The reaction may be unease and alienation. The reaction is similar to that of a child attempting to cope mentally and physically with objects and surroundings scaled for adults.

4. Design.—Designed to engineering specifications and functions, highways have sometimes lacked application of the principles of art— proportion, balance, unity, rhythm, variety—that would make them amenable additions to the visual scene. Abstraction and lack of detail that leads to nondistraction for the highway user may appear monotonous to the stationary viewer. Interprofessional design coordination and consultation may often improve highway design at an added cost justified by the relative permanence of the facilities, the enhancement of property values in the vicinity, and satisfaction of current public demand for highway beautification.

5. Spillovers.—The highway's presence sometimes creates unintended visual side effects. According to the time of day, abutting properties may receive the glare of sunlight reflecting off pavements and car surfaces or that of headlights or the roadway's lighting system. Conversely, elevated highways, structures, and earth fill may block sunlight from abutting properties.

The same spillovers may have also positive effects in lighting off-highway areas where safety from crime and accident are desired and in providing shaded areas as a relief from the sun in hotter climates.

Gains and Utilities

1. To nonusers:

a. Aesthetic pleasure and satisfaction, plus community pride from a visually attractive highway facility in the community.

b. Added recreational facilities from parks and recreation space created in remainder parcels and in air-rights space under elevated facilities.
c. Increase in land value due to visual enhancement of highway from the nonuser's standpoint (*1-14*, p. 7).
d. Visual enhancement through replacement of visual blight by the right-of-way.

2. To users:
   a. Visual enhancement intended for nonusers jointly enjoyed by users.

Costs and Losses

1. To nonusers:
   a. Dissatisfaction and alienation arising from highway designs, scales, barriers, views, and spillovers that violate principles of good design, create visual pollution, and blight the environment.
   b. Property value declines traceable to visual disharmony of a highway with its surroundings.
2. To highway agency and users:
   a. Added cost of design, right-of-way taking, and construction necessary to make the highway aesthetically satisfying to nonuser viewers.
   b. Added user running costs necessitated by adjustments in route location or design to accommodate nonuser visual enhancement.

Decision-Making Factors

1. Inventory.—Opportunities for visual enhancement and potential problems of visual pollution for nonusers along the alternative route alignments in regard to:

a. Edge, barrier, wall, boundary:
   (1) Opportunities:
      (a) Separation of incompatible land uses, clarify urban pattern with a boundary.
      (b) Screening of unaesthetic views.
      (c) Excess right-of-way taking to close dead-end views with a park, overlook, house in a cul-de-sac; ivy-covered fencing, planting for screening, and/or maintenance to avoid weeds and litter.
      (d) Alignment of facility with grid to clarify street pattern.
      (e) Visual and physical access across right-of-way where desirable aesthetically or to facilitate a functional linkage or to provide continuity.
   (2) Problems:
      (a) Separation of similar uses and breaks in street pattern with ensuing confusion.
      (b) Separation of areas with functional linkages.
      (c) Separation of areas with visual continuity.
      (d) Unattractive dead-ends.
      (e) Street grid crossed at angles.

b. Views:
   (1) Opportunities:
      (a) Opening of scenic views.
      (b) Elimination of unsightly features.
      (c) Making the highway a scenic asset by: providing visual sequences and unity of form, landscaping roadsides and medians, use of a light silhouette, terracing hillsides, integrating with terrain and ecology, and using aesthetically designed structures, appurtenances, bridges, and signs.
      (d) Harmonizing highway with the scale, color, and texture of materials found in the abutting architecture.
      (e) Removing abandoned structures and pavements.
      (f) Creating highway as a landmark and source of local pride, aesthetic satisfaction, and land value enhancement.
   (2) Problems:
      (a) Closing of scenic views.
      (b) Blending a man-made highway into natural scenic landscape.

c. Scale:
   (1) Opportunities:
      (a) Reduction of number and mass of supports.
      (b) Condensation and concentration of rights-of-way.
      (c) Designing of compact interchanges.
      (d) Tunneling, depressing, or covering over roadway in area of intense pedestrian activity or where the gross differences in scale would aesthetically destroy a significant scenic, natural, or historic area.
   (2) Problems:
      (a) Lack of agreement between scale of highway and structures and "human-scale" structures and pedestrians in the highway's environs.

d. Design:
   (1) Opportunities:
      (a) Designing aesthetically the underside of overhead structures, drainage and other structures, lighting standards, bridge forms, medians, roadsides, curvature, signing, texture of materials, retaining walls, abutments, and tunnel entrances.
   (2) Problems:
      (a) Highway design in areas having large numbers of nonuser viewers and/or where land values would be adversely affected by inharmonious design.

e. Spillovers:
   (1) Opportunities:
      (a) Providing lighting to areas needing it for nighttime visibility to prevent crime and accidents.
      (b) Shading abutting and air-rights recreation areas in hot climates.
      (c) Screening out glare, where it is a nui-

sance, by use of structures and vegetation.

(d) Eliminating shade, where undesired, by excess right-of-way taking, depression of highway, or adjustment of structures or right-of-way.

(2) Problems:

(a) Nuisance effect from glare of sunlight, headlights, or highway lighting.

(b) Elevated highways, structures, and fill shading properties from sunlight.

2. Factors for consideration.—In judging how much weight to give to adjusting route location and design to favor enhancement of the nonuser's "view of the road" the following considerations are relevant:

a. Community and highway agency goals.—Identify potential conflicts between individuals, groups, and levels of government as perceived in discussions, hearings, and goals statements related to:

(1) Land-use planning and community character. Highways that are attractive to both user and nonuser enhance the prestige and satisfactions of living in a community. Community goals relative to its visual character and "image" represent both economic and social values to residents. An evaluation of the magnitude of such values is the basis for justifying marginal expenditure to align highway design with the community's aesthetic goals.

The renewal of declining areas, particularly central-city areas, may also justify added visual enhancement. Coordination with urban renewal programs through joint development could be desirable.

(2) Traffic planning.

(3) Highway engineering.

(4) Costs of total highway facility.

(5) Visual goals. Highways that are well designed and visually enhanced for the user frequently satisfy the nonuser also. How much additional enhancement is necessary to satisfy community goals and values will depend on the visual goals the highway agency sets for the highway:

(a) A unified work of art.

(b) A unified visual experience.

(c) A harmonious environmental element.

(d) A roadway with intrinsic visual merit.

At the higher level of design goals, probably little marginal cost will be required to strike agreement between highway and community visual goals. At a lower level, more may need to be spent to achieve an acceptable solution from the community's viewpoint.

b. Characteristics of the highway improvement.—The characteristics of the highway improvement will alter the type and degree of aesthetic enhancement required to satisfy nonusers.

(1) Type of improvement. Access limitation is an important variable in determining the highway's visual impact for users and nonusers. Unlimited access coupled with high traffic volumes frequently brings commercial development and a proliferation of signs and billboards. An access-controlled highway, even when not visually enhanced, usually preserves more of the natural environment and presents more pleasant views for user and nonuser than does a nonaccess-controlled design.

The design traffic capacity of the improvement influences the width of right-of-way, the number of lanes and size of structures, which, in turn, determine scale effects: expanse and bulk. The greater the magnitude of these variables, the greater the amount of the nonuser's field of vision that is occupied by the highway. As the highway begins to dominate the visual scene, the more important it is that it be a visually harmonious element.

(2) Location of the improvement. The amount of attention that needs to be given to the nonuser's "view of the road" will vary by the location of improvement.

In open countryside, the highway is a relatively minor part of the total scene and is regularly viewed by comparatively few nonusers. Except where it forms part of a vista in an especially scenic area, there is likely to be little need for visual enhancement for nonusers, aside from fitting it into the terrain harmoniously.

In urban areas, particularly as the highway passes into areas of higher and higher population density, it becomes an ever-larger part of the visual environment of increasing numbers of people. Its scale becomes more and more disproportionate to the increasingly "human scale" of persons and buildings in the environment. Pedestrian orientation and the "human-scale" architecture of bygone eras progressively increases toward the urban center. Also, it is in these areas that the right-of-way is likely to pass proximate to significant historic, scenic, and symbolic areas, landmarks, buildings, and sites. Some may be tourist attractions familiar to many.

(3) User versus nonuser viewpoint. In some instances there may be varying degrees of compatibility and incompatibility between user and nonuser viewpoints. Visual enhancement of a highway often satisfies both user and nonuser who see the same scenery from slightly different viewing points.

Incompatibility arises, first, due to their seeing the same scene at different speeds. Traveling at high speeds, the user better appreciates aesthetic features of large scale and abstract design. A stationary or slow-moving viewer probably will find these features out of proportion and monotonous, preferring ones of smaller scale and more detail. In turn, detailed small-scale objects are distracting and incomprehensible to high-speed viewers.

Second, opening views for users may close it for nonusers whose vista is preempted by the highway.

Third, exposing users to a view of some attractive feature reciprocally involves exposing those living in, near, or visiting the feature to a view of the highway. The user gain may be counteracted by a nonuser loss if the latter do not wish to view the highway in return. A loss of the nonuser's privacy or amenity may also be involved.

The "view from the road" should be contrasted with the "view of the road" to test their mutual desirability and compatibility.

3. Synthesis and analysis.—Conduct an analysis matching that proposed under the topic, "The View From the Highway," or add to that analysis a nonuser dimension. Expand the "Inventory" portion of the analysis ("Highway-Mode-Induced Aesthetic Effects") to include aesthetics relative to the road's: (1) edge, barrier, wall, boundary, (2) views, (3) scale, (4) design, and (5) spillovers. Also, add the "factors for consideration" contained in the foregoing section.

4. Decision rules:

a. Degree to which the highway is a compatible visual element in the environment from the nonusers' point of view. Extent that highway design has accounted for the problems and opportunities relative to the highway's edge or boundary, views, scale, design, and spillovers. Criteria contained under "The View From the Highway" also apply.
b. More specific guidelines and criteria relating to aesthetic details of freeway design as regards the "view of the highway" appear in *The Freeway in the City* (*1-22*, pp. 37-46).

CATEGORY: 1. Aesthetics
VARIABLE: C. Highway-Mode-Induced Aesthetic Effects

Area:	Urban and Rural
Type of Consequence:	Economic and Social
Location of Impact:	Right-of-Way
	Corridor
	Community or System
Timing of Impact:	After Construction—Short Term
	After Construction—Long Term

Consequences

Although they are not attributable to a particular highway improvement or type of improvement (although design speed and degree of access limitation play a part), certain aesthetic consequences have emerged as the result of popular adoption of automobiles as the major U.S. transportation mode.

The main motive of highway improvement is to lower the cost of automotive transportation. The highway program has promoted higher volumes of auto use by these means and contributed to its popularization. It is therefore partially responsible for the aesthetic effects that represent reactions and accommodations to near-universal automobility.

The visual consequences or automobile-induced aesthetic effects include:

1. Low-density residential development.—The range, speed, and flexibility of the automobile and the ubiquity of streets and highways and their progressive improvement have continually expanded the workplace-accessible land area available for residential settlement around cities and towns. Abundant land supply relative to demand has meant settlement could occur at low population densities. Consumer preference for the privacy and amenity of a semi-rural setting has made low-density residential suburbs (commonly called "urban sprawl") the typical form of auto-induced development. The balancing of traffic demand (with highway capacities) has abetted this form of development. The growing unattractiveness of central cities, rising incomes, freeway development, and other forces have provided a further basis for the proliferation of low-density residential development.

The visual environment so created is typified by:

a. Single-family detached dwellings; usually in a limited number of styles (e.g., "ranch," "colonial").
b. A semi-rural natural setting with openness, landscaping, and greenery.
c. Often, an absence of sidewalks and street lights.
d. Large yards substitute for fewer parks and less open space in agricultural use; no clear break between urban and rural occurs.
e. Industrial parks with single-story plants and landscaped grounds.
f. Shopping centers with large parking lots.
g. Ribbon commercial developments along unlimited access highways.
h. As more land is absorbed, central cities become more unattractive, freeway systems grow, and highway construction requirements rise, more apartment and townhouse developments are appearing in the outlying areas.

The aesthetic faults of the pattern appear to be:

a. The monotony of the residential pattern and architectural styles.
b. The destruction of open space and trees.
c. Lack of definition between urban and rural.
d. The arid open spaces of parking lots filled with cars.
e. The chaos, gaudiness, and tawdriness of "string streets" of stores, signs, and billboards.
f. The injection of monumentally scaled urban architecture (high-rise offices, apartments, and town houses) into a rural setting.

Its aesthetic merits revolved around:

a. Its openness, modernity, greenery, and generally well-kept landscaping.
b. The attractiveness of architecturally designed and

landscaped industrial plants in contrast to the utilitarian factories of previous decades.

c. The generally well-designed churches, schools, and shopping-center buildings and malls.

2. Parking lots.—The provision of automobile storage capacity by any activity must balance with its peak-hour traffic-generating propensity. The ratio of floor space to parking space for various land uses has been a subject of research. Shopping centers often use a 3:1 ratio—the parking space occupying an area three times as large as the building coverage.

The visual results of the parking requirement have been:

a. "Islands" of development (apartment houses, shopping centers, offices, plants) surrounded by extensive parking lots.
b. Dispersed, free-standing buildings separated by parking areas in office building and shopping districts.
c. Multi-storied and underground parking garages in intense traffic-generating areas where ground space is scarce and expensive.
d. Taller buildings due to less ground space available due to parking requirements.
e. Formerly dense clusters of development with continuous facades (especially in business districts) now interrupted by open gaps for parking lots.
f. Green open space, plazas, squares, and parks preempted for parking.
g. Railroad sidings replaced by truck loading areas and parking lots in goods terminals and industrial areas.

The aesthetic demerits have been:

a. Lack of pedestrian visual amenity due to inattention to sidewalks.
b. Lessening of ground-floor activity in buildings.
c. Littering, oil staining, and asphalt covering of walking areas.
d. Inattention to the texture and design of the "urban floor."
e. Loss of vegetation, parks, and plazas.
f. Lack of unity, continuity, and harmony in the spatial relationship of building in violation of "urban design" principles.
g. Practice of moving among nearby buildings by car rather than on foot.
h. Creation of activity-less "dead spaces," reducing the visual variety and increasing the monotony of urban areas.

The aesthetic merits are:

a. The architecture of freestanding buildings has become more sculptural and three-dimensional in place of the two-dimensionality of the flat facade.
b. Some parking garages have architectural merit.
c. Depletion of ground-floor green open space has led to landscaped building roofs that provide outdoor overlooks of urban vistas.

3. Scale.—The space-consuming propensity of the automobile and its own extra-human scale has meant that spaces designed to accommodate it must be in proportion. In contrast with the scale of distances, structures, and spaces required for transit and pedestrian modes, the enlargement of environmental scale for auto traffic is on the order of several magnitudes.

The visual consequences have been:

a. Wide, straight streets without visual termination.
b. Large highway and parking structures.
c. Extensive open spaces for parking and rights-of-way; lack of enclosed articulated spaces; discontinuities in urban form.

The visual demerits are:

a. A departure from "human scale," which man finds difficult to relate to; large scale symbolizes a hostile environment outside his control; open spaces afford no protection.

The visual merits are:

a. Open spaces of monumental scale are required that occasionally work well in environments with buildings of matching scale (e.g., Brasilia, Washington, D.C.).

4. Speed.—The speed of automotive movement reduces the amount of visual detail that can be observed and comprehended. Messages and objects meant to be seen by vehicle occupants therefore tend to be abstract, brief, simple, and of large scale. Competition among messages for the driver's attention increases their number, color intensity, and size, and tempts the addition of lights—stationary, moving, and flashing.

The efficiencies of auto travel at high speed also promote highway design that permits straight-line travel with a minimum of interruption.

The visual consequences are:

a. Growing abstraction and lack of detail in the visual environment.
b. Increase in the scale of signs and in their brevity and gaudiness of design.
c. Longer blocks, straighter streets, limited access, depressed and elevated highways lighted by vapor lights with daylight-like glare.
d. Unclosed vistas on thoroughfares.

The visual demerits include:

a. Chaos of images; absence of interesting detail; deterioration of design quality leading to monotony, confusion, lack of sense of beauty.
b. Sense of diminishment through the pedestrian's lack of ability to relate to the extra-human scale.
c. Massive, utilitarian, unnatural environments created.

The visual merits are:

a. For automobile drivers and passengers, the environment contains appropriately scaled objects and messages that can be absorbed, appreciated, and comprehended at high speeds with a minimum of

distraction from the task of vehicular guidance; safety is increased.
b. Orientation and travel information are enhanced by the sequence of visible forms and messages related to the roadway and its design speed.
c. Safer, more efficient auto operation is achieved by highway design and sight lines adjusted to the vehicles' speed characteristics.

5. Separation from environment.—The separation of auto drivers and passengers from their immediate environment and the transiency of their stay in it apparently produces a lack of concern for its appearance and maintenance. Typically, areas devoted to pedestrian travel possess more detail and amenity; less evidence of litterbugging. Where automobiles move or are parked, the opposite tends to be the case: less detail and amenity; more litter (*1-21*, pp. 217-18).

Aesthetic merits are apparently none.

Aesthetic demerits are:

a. Areas are underdeveloped and ill-maintained for appearance.
b. Litter is spread by those for whom separation from environment produces unconcern for it.

6. Mechanical properties and performance characteristics.—Certain mechanical properties and performance characteristics of the automobile have effects on aesthetics, with these visual consequences:

a. Smog, where it is prevalent, sometimes obscures distant views and produces local haze; vegetation sometimes suffers or dies due to concentrations of exhaust fumes.
b. Headlights and vapor lamps project light into adjacent properties.
c. Screening to reduce light and noise blocks views.
d. Dust is generated by auto passage on some roads, obscures vision, settles on nearby surfaces.
e. Oil drips from car engines, stains street, sidewalk, and other surfaces.

The aesthetic merits include:

a. Lights form interesting patterns viewed from a distance.
b. Screening to shield properties from unaesthetic effects is sometimes attractive.

The aesthetic demerits are:

a. Blocking and screening of desirable views.
b. Annoyance of glare.
c. Unattractive appearance of dust- or oil-laden surfaces.

7. Auto market, auto use, auto disposal.—The facilities set up to sell, service, and dispose of automobiles have rarely been cited for good design or aesthetic appearance. Emphasis is placed on eye-catching displays that are showy and often gaudy—large, abstract, colorful, and neon-lighted. Copious quantities of signs are used. As more autos and auto use are generated, more of the visual environment is preempted by such facilities and displays.

The visual consequences are:

a. "Auto rows"—roadways lined with new- and used-auto dealers and car lots.
b. "String streets" or "ribbon development"—lines of roadside development in motels, gas stations, garages, billboards and signs, parking lots, and drive-in restaurants, churches, banks, etc. (*1-21*, pp. 208-14).
c. The number of automobiles converted to scrap tends to lag behind the number disposed of each year, meaning a growing number held in auto graveyards and junkyards or turned to alternative uses such as rip-rap to deter erosion along watercourses (*1-21*, pp. 214-17).

The visual demerits include:

a. Often standardized, chaotic, unrelated, unorganized visual environment.
b. Abstract imagery, lacking in detail; using pure colors, coarse detail, broad delineation, large scale, repetitive patterns, simplistic symbolism; the antithesis of aesthetic effects usually sought and achieved at "human-scale" and pedestrian speeds.

The visual merits include:

a. A new "aesthetic" may be being produced by the auto environment and is perhaps reflected in the "abstract," "op," and "pop" art movements that rely on blurrings or omission of detail, the optical illusion of movement, and small detail seen at outsize scale, respectively; effects typical of visual images seen at auto speeds and in auto-oriented environments.
b. Modern architecture, with its stress on repetitive modular geometric patterns, unadorned simplicity, and abstract design may also be showing the influence of the automotive environment where aesthetic comprehension and appreciation from a fast-moving vehicle demands such treatment. Although lacking detail, fine texture, variety of color, complexity, interest, and ambiguity that have been found aesthetically appealing by past standards, much such architecture has been praised by expert judgment.

Gains and Utilities

1. Users and nonusers:
   a. The visual merits of highway-mode-induced aesthetic effects result in:
      (1) Intangible benefits—the pleasures and satisfactions of living or traveling in a visually attractive environment.
      (2) Tangible benefits—increased property values due to demands to locate in high-amenity areas; and income from tourist services from added recreational travel to scenic areas.

Costs and Losses

1. To users and nonusers:
   a. The visual demerits of highway-mode-induced aesthetic effects result in:
      (1) Intangible costs—the displeasures and dissatisfactions of living or traveling in a visually unattractive environment.

(2) Tangible costs—lowered or foregone potential property values due to lack of demand for locations in low-amenity areas and lowered or foregone income from lack of recreational travel.

Decision-Making Factors

1. Highway-mode-induced aesthetic effects.—Such effects correlate with the number of automobiles (auto registration) and the miles they travel. The higher the number of automobiles, the greater their use, the more the environment, visual and otherwise, must be shaped to accommodate them. The improvement of highways, by lowering the cost of travel on them, increases the demand for automobiles and highway use, an inducement to further rounds of accommodation. The visual consequences of accommodation follow.

Low-density residential development occurs in proportion as the amount of vacant land that is placed within time-distance accessibility of major employment centers by highway improvements grows.

Parking lots proliferate according to the increase in accessibility to major trip generators created by highway improvements and the extent lowered cost of auto travel induces the auto to substitute for other modes of travel.

The *scale* of distances and sizes of structures in the environment expands to provide the capacity needed to accommodate the rising automobile population and the demand for its use.

The *speeds* made possible by highway improvements, geared to the higher horsepower and speed capabilities of the modern automobile, cause the visual environment to adjust by limiting the visual scene mainly to what can be seen and comprehended at those speeds.

The *separation from environment* inevitable to auto travel produces litter and unkempt areas. Substitution of auto for other modes, including walking, lessens the number of points of immediate contact with the environment and therefore concern for its upkeep.

Mechanical properties and performance characteristics of motor vehicles produce smog, glare, noise, dust, and oil stains. These effects increase where the incidence of car ownership and travel grows under the impact of highway improvement.

The amount of the environment occupied by facilities for *auto sales, service, use, and disposal* increases proportionately to the demand for autos and auto travel.

The analysis of the foregoing consequences may be summed up in statements concerning: (1) the degree to which each of the foregoing effects is estimated as likely to occur as a result of the highway improvement contemplated, and (2) the extent to which such occurrences are in harmony with the nature, goals, appearance, quality, and beauty of the community or environment. Expert opinion may be applied to the task of prediction and evaluation based on local trends, conditions, and the judgments of designers, planners, landscape architects, architects, and similar persons trained in aesthetic evaluation.

Often, no one highway improvement can be identified as casual in producing a visual environment having certain aesthetic demerits productive of losses and costs. Costs are a cumulative effect stemming from the popularization of auto ownership and travel to the point of near-universal use in land passenger transportation. This is the result of a variety of mutually supportive and complementary trends: rising incomes, rising population, sales promotion by the auto industry and related industries (oil, asphalt, concrete, trucking, etc.), rising auto registration, improvement of highway facilities, expansion of parking supply, decentralization of urban areas, and deterioration of public transportation under the impact of competition from a more popular mode. The continued working of these trends in concert produces more of that visual environment that is the natural result of an accommodation to society's set of preferences.

2. Decision rule.—Compare and evaluate the degree of agreement between community goals, character, design, appearance, and values concerning its visual/aesthetic environment and highway-mode-induced aesthetic effects. Determine whether the appearance of the latter as a joint product of highway improvement would produce a net community benefit or detriment over all (e.g., whether, on balance, an over-all improvement or a deterioration in the nature, quality, and beauty of the community's appearance is to be expected as a result of the improvement). In other words, do the gains in user efficiency exceed the long-term community costs?

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CATEGORY: 2. Agriculture
VARIABLE: A. Access to Improved Road

Area:	Rural
Type of Consequence:	Economic and Social
Location of Impact:	Corridor Community or System
Timing of Impact:	After Construction—Short Term After Construction—Long Term

Consequences

Rural highway improvements in the form of new or surfaced roads generally have the following consequences:

1. Economic effects.—Accessibility to farmland makes possible its productive use—a development effect. Improved access makes possible the bringing of new land into the market or into production. Further improvements in accessibility may make possible even more productive use through encouraging specialization or extending the farm's market area (*2-18*, p. 129). Crop rotation and timing can be adjusted more freely where all-weather roads exist. Other gains and some costs to farm production and farm life have been found to result from highway improvement, particularly in the upgrading of road surface from dirt, to gravel, to pavement.

In that farm productivity is highly correlated with land value, value increases frequently occur as a result of rural highway improvements (*2-2*). Farmland value has a variety of determinants. The main ones are soil fertility and farming practices that determine the abundance of the crop, and relative prices of farm products that determine its value per unit of measure. Buildings and utilities on the land are added value considerations. This has made separating out the marginal increment in value due to road improvement difficult in some instances. On the basis of farm value studies in Washington State, Garrison concluded, "The best estimates of the true magnitude of road and property value relationships are only a small part of the composition of property value" (*2-9*).

Also characteristic of the relationship between value and road improvement appears to be a diminishing returns effect from added improvement once the road system has reached a high level of development. Michigan studies by Vargha and Anderson (*2-19*) revealed that there appeared to be no significant effect on farmland values related to distance from hard-surface roads, their number or improvement, perhaps because such roads were nearly ubiquitous in the study area. This appears confirmed by a Maryland attitude study (*2-17*) that showed rural residents found dirt roads unsatisfactory and would be willing to pay for their improvement, whereas persons living on surfaced roads of all types found them generally satisfactory and were less willing to pay for further improvement.

Simple access in the form of a dirt road gives the land its basic value by permitting it to be brought into production. From the evidence, further significant value increases occur as a result of improvements in the form of road surfacing (i.e., laying either gravel or pavement over the original dirt road). The upgrading of a road from dirt to pavement appears to cause almost double the increase that results from going from dirt to gravel.

Studies in a variety of locations confirm this land value effect:

A New York study (*2-7*) showed that in 1935 farmers believed that an improvement from a dirt to a hard-surface road would increase property values about 21 percent, whereas a dirt to a hard-surface road improvement would approximate a 48 percent increase. These results were consistent with a 1928 study in which it was reported that farmers felt that a road improvement from a dirt to a hard-surface road would generally increase the value of farm property by 25 percent.

A more recent New York study (1951) (*2-3*) estimated improvement of a road from dirt to gravel would increase the value of farm property by 18 percent. Dirt to hard surface would increase property values by 52 percent, and gravel to hard surface would result in an increase of 28 percent.

Similar results were obtained from a 1958 Texas study (*2-2*) that showed that farms along gravel roads averaged 48 percent higher in value than farms along dirt roads. Farms along all-weather roads had an average value of 50 percent higher than those along dirt roads and 9 percent higher than those along gravel roads. The market value of land along another Texas road improved from dirt to all-weather paving increased an average of 58 percent (*2-1*, p. 3).

Table B-3 gives the average price per acre for various types of farming land nationwide and the influence of road improvements in producing a value premium above the price of land having basis access. It again illustrates that the price per acre tends to be higher on hard-surfaced roads than on gravel roads, and higher on gravel than on dirt roads. The price differential between dirt and gravel roads is usually considerably more than between gravel and hard-surfaced roads (*2-18*, p. 143).

Studies have revealed these additional consistencies in farmland value change resulting from highway improvement:

a. Prices per acre are generally higher for large tracts than for small ones (*2-18*, p. 137).
b. Tracts nearer an urban center usually show higher per-acre values than those farther away (*2-18*, p. 137).
c. Increases are greater in areas where a large proportion of the roads are unimproved or where the farm business relies heavily on roads (*2-18*, pp. 142-43).
d. Largest premiums for improved roads have been found in the general farming and cotton-producing areas (*2-18*, p. 143).

2. Social effects.—Increased accessibility causes altered patterns of social life for farm families and communities.

Farm isolation and the necessity for a degree of self-sufficiency have largely ended. Farmers have become more urban in their activities with the social, recreational, educational, religious, and employment opportunities in cities or towns made more accessible by highway improvements.

Some farm families have moved to town and commute to their dispersed holdings. Even those who remain on the farm have a wider variety of services available than heretofore, partly due to improved roads. School busing has permitted the consolidation of rural schools into larger, more efficient units (*2-18*, p. 131). Mobile services (mail, fuel deliveries, supply deliveries, medical and health services, bookmobiles, fire and police protection) have become more widely available to farm populations (*2-18*, pp. 132-35).

Accessibility improvements coupled with technological advances have made farming a part-time activity in many cases. More farmers are taking off-farm jobs in local industry. In the vicinity of the Connecticut Turnpike 40 percent of the farmers in a sample area earned over half their income from off-farm sources. In Iowa, 50 percent of a survey sample of farm families had nonfarm employment (*2-18*, p. 133). A North Carolina study (*2-12*) trip generation in a rural area found highest travel values and largest number of trips were for industrial work purposes.

Gains and Utilities

1. To farmers:
   a. Increase in real estate values (*2-17*).
   b. Decreases in vehicle operating costs (*2-17*, *2-1*, p. 12).
   c. Reduced travel time (*2-17*).
   d. Better, more timely marketing conditions for farm products (*2-17*, *2-1*, p. 9).
   e. Greater ease in obtaining farm supplies (*2-17*).
   f. Increased accessibility to public facilities and utilities, including schools, and to trade centers and social activities (*2-17*).
   g. Encouragement to farmers (*2-17*).
   h. Helps in going between separate fields operated by one man (*2-18*, p. 134).
   i. Eliminates dust in farmyards and buildings (*2-18*, p. 134).
   j. Better use of pastures because dust does not settle on grass (*2-18*, p. 134).
   k. Higher weight loads are possible, meaning more tonnage to market and supplies obtained in larger bulk with discount savings possible (*2-18*, p. 129).
   l. Increased competition for local merchants so they give better service (*2-18*, p. 134).
   m. Easier to commute to college and to part-time nonfarm jobs (*2-12*, *2-18*, p. 134).
   n. More progressive people will move into the area (*2-18*, p. 134).
   o. Opens up rural recreation areas for city or town dwellers for cabins or day use (*2-1*).
   p. No en route damage to produce and livestock (*2-1*).
   q. Opportunity for more profitable land uses (*2-1*).
   r. Opportunity to supplement income from nonfarm work (*2-1*).
   s. Traffic increase due to better road and new development boosts trade of roadside stands (*2-1*).
   t. Encourages new home building and renovation of older ones (*2-1*, p. 8).
2. To community:
   a. Healthy community, state, national farm economy (*2-17*).

TABLE B-3

AVERAGE PRICE PER ACRE BY TYPE OF ROAD ON WHICH PROPERTY WAS LOCATED, BY TYPE OF FARMING AREA, 1958–59 [a]

	SALES OF FARM REAL ESTATE [b]						
		PROPERTIES LOCATED ON:					
		DIRT ROADS		GRAVEL ROADS		HARD-SURFACED ROADS	
TYPE OF FARMING AREA	ALL SALES	SALES	AVERAGE PRICE ($)	SALES	AVERAGE PRICE ($)	SALES	AVERAGE PRICE ($)
Northeast	121	16	49	27	70	78	159
Eastern dairy	589	88	120	136	160	365	166
Lake states dairy	939	104	92	420	139	415	185
Lake states cut-over	217	21	57	110	108	86	94
General farming	1,269	223	59	522	103	524	130
Eastern corn belt	1,108	49	364	550	279	509	353
Western corn belt	2,309	239	95	1,614	179	456	194
Spring wheat	584	160	35	333	44	91	33
Winter wheat	642	258	97	224	103	160	112
Eastern cotton	447	144	64	74	82	229	99
Central cotton	413	73	99	223	115	117	151
Western cotton	566	174	75	180	85	212	107
Burley tobacco	198	10	88	78	119	110	289
Eastern tobacco	198	65	99	27	110	106	153
Northern range livestock	746	192	33	303	48	251	55
Southern range livestock	298	86	30	92	66	120	70
Western wheat	121	12	23	68	131	41	109
Northwest dairy	155	8	120	58	26	89	50
California specialty	351	31	195	33	121	287	322
Gulf Coast	88	19	96	28	169	41	127
Florida	93	29	337	8	102	56	202
United States	11,452	2,001	58	5,108	108	4,343	132

[a] Source: (*2-18*, p. 142).
[b] Sales reported by farm real estate reporters in March surveys. Most of the sales probably occurred in the 6 months preceding the date of the surveys.

Costs and Losses

1. To farmers:
   a. More difficult to move livestock on foot when road hard-surfaced (*2-18*, p. 134).
   b. Taxes might be increased (*2-18*, p. 134).
   c. More danger to children (*2-18*, p. 134).
   d. More hunters and fishermen (*2-18*, p. 134).
   e. Right-of-way grows to weeds that spread seed to fields (*2-18*, p. 134).
   f. Dissipation of close family relationships due to access to off-farm diversions (*2-18*, p. 132).
   g. Increased costs of taxes for governmental services extended to farmers (*2-18*, p. 132).

Decision-Making Factors

1. Amplitude and frequency of traffic generation of centers and areas of economic and social activity. Desire lines indicating linkages between centers; traffic counts indicative of travel demands.

2. Economic base of the farm community; potential for increased investment in resource development; location, exploitation or renewal of potentials as disclosed by surveys of soil capabilities, resource and market locations, local economic conditions, land use, land valuation.

3. Data on road costs and probable land value increments; established design standards that reflect the anticipated type and volume of traffic. Estimates of land value increments may be guided by historical data on roads providing comparable economic and social service to the occupants of the land served (*2-11*, pp. 10.01-.02).

CATEGORY: 2. Agriculture
VARIABLE: B. Economic Units (Size of Farm Unit)

Area: Rural
Type of Consequence: Economic
Location of Impact: Right-of-Way
Corridor
Timing of Impact: During Construction
After Construction—Short Term
After Construction—Long Term

Consequences

Highway right-of-way location, especially for limited-access facilities, has three major effects on economic farm units:

1. Farm size reduction due to partial taking.—Right-of-way taking reduces the amount of land held by an owner and may tend to make the remaining tract of an uneconomical size.

A Minnesota study found that a limited-access highway right-of-way taking altered the size and shape of farms. Larger units eventually resulted from the increased buying, selling, and renting of land to reestablish optimum patterns of land use (*2-18*, p. 127).

Research on an Interstate route in Kansas revealed that losses in market values of remainder lands exceeded gains in values except at interchanges (*2-15*).

Iowa studies of Interstate effects on farm operating units found:

a. Farm sizes decreased along the Interstate route (*2-18, 2-21*).
b. More farms affected by right-of-way taking were later involved in real estate transactions than farms unaffected, the figures being 40 percent and 30 percent, respectively (*2-21*).
c. Retirement rates among affected farmers were slightly higher than for those unaffected. This may have been due either to the creation of uneconomic units or to the inducement to retirement stemming from age and/or right-of-way compensation payment (*2-18*, p. 127).

Partial takings that tend to create uneconomic farm units have been offset in a variety of ways:

a. Purchase of additional land with right-of-way taking compensation.
b. Selling of additional land made more valuable by the highway, usually land adjacent to interchange locations.

2. Severance of holdings.—Right-of-way taking may sever and divide holdings requiring the farmer either to reorganize his ownership pattern or to incur either personal expense to truck machinery and animals among his divided parcels or highway department expense to provide a livestock pass or machinery pass (*2-18*, p. 127).

Severance of farmland has been offset in these ways:

a. Trading, buying, and selling of land so as to consolidate a farmer's holdings on one side of the highway.
b. Payment of severance damages. A Vermont study (*2-20*) found, however, that, in general, appraisers have been too generous in assessing damages for severance. Resale of isolated and/or severed parcels has seldom if ever occasioned real fiscal loss to owners. Quality of improvements, rather than strict areal extent is a better guide to resale value so long as lot size is relatively adequate for use. Severed farm parcels generally find ready buyers even though their market is limited to abutting farm owners. Improved access, particularly to previously land-locked parcels, has greatly enhanced parcels. Interchange areas' land values increase astronomically, making damage payments superfluous at times.

   The Vermont findings regarding the value of land at interchanges are confirmed by a Kansas study (*2-15*) which also observed interchange land value increases.
c. Highway agency provision of livestock and machinery passes where justified by cost-benefit analysis where the cost of building the pass is less than the farmer's costs of transferring his livestock or machinery between the halves of his severed holdings over time.

3. Inconvenient field shapes.—The highway right-of-way may cross holdings at an acute angle, making machinery turning maneuvers difficult, creating inefficient tillage patterns, or wasting space left in acute corners. Farmer protest has been aroused in Iowa and elsewhere where the grid section pattern is used and a highway route crossing the pattern at an angles has aroused concern over this effect.

Gains and Utilities

1. To farmers:
   a. Compensation for right-of-way taking and/or severance damages.
   b. Enhancement of land value due to the highway, especially at interchanges.
   c. Provision of livestock or machinery passes between severed holdings.
   d. Reconstitution of economic farm units by trading, buying, and selling of farmland among affected owners.
   e. Increased farm values and incomes from change in land holdings that forces reconstitution of such holdings into more economical or productive patterns.
2. To community:
   a. Increased property tax revenues where highway right-of-way taking increases land values by encouraging formation of more economical farm units or farmers to sell interchange locations for commercial uses.

Costs and Losses

1. To farmers:
   a. Loss in income or land value due to partial taking of farm holdings for right-of-way, leaving a farm unit of an uneconomical size.
   b. Cost to transfer livestock and equipment between parts of a farm severed by right-of-way taking.
   c. Cost and inconvenience of tilling odd-shaped fields made so by right-of-way taking.
2. To community:
   a. Reduced property tax revenues where highway right-of-way taking lowers land values by creating uneconomical farm units.
3. To highway agency:
   a. Added cost of livestock or machinery passes and severance damages where justified.

Decision-Making Factors

1. Right-of-way taking effects in producing nonuser costs from partial takings that reduce farms to uneconomic unit size, sever holdings, or create inconvenient field shapes.

2. Offsetting actions or compensations (e.g., severance damages, payments for right-of-way land, livestock and machinery passes, land value increases, and avoidance of anticipated costs by route location and design adjustments).

3. The net or trade-off costs to the highway agency or users (e.g., adverse distance) to avoid or compensate for costs to nonusers due to the creation of uneconomic units.

CATEGORY: 2. Agriculture
VARIABLE: C. Productivity

Area:	Rural
Type of Consequence:	Economic
Location of Impact:	Corridor
	Community or System
	Region or Nation
Timing of Impact:	After Construction—Short Term
	After Construction—Long Term

Consequences

Productivity is the amount of output produced per unit of input, including labor, capital, entrepreneurship, and raw materials. Highway improvement affects farm productivity in the following ways:

1. Higher crop yields.—The enlargement of the market area accessible to the farm over improved roads increases demand for its products and encourages higher levels of production to meet the demand so created. All-weather roads allow the farmer to time his deliveries to meet peak demand and best price periods.

The shortening of the time-distance from farm to market allows the farmer to spend more time engaged in farm production and less time on the road.

The provision of hard-surface roads over which farm machinery and trucks can conveniently move in all weathers allows farmers to enlarge and disperse their holdings and employ efficient mechanized methods for increasing yields.

Paved roads cause less produce to be spoiled by bruising and breakage formerly caused by roads or road-generated dust.

2. Flexibility in crop types and changes.—All-weather year-round transportation allows the farmer greater latitude in choosing crop rotation. He can deliver to market in all seasons. He also can (1) raise higher weight products without fear of bogging down in mud or exceeding bridge weight limits (*2-18*, p. 128); (2) more easily recruit and transport added local or migrant farm workers at periods of peak activity (*2-18*, p. 130); (3) farm more intensively, assured that he can deliver all the added product and added weight to market at the proper time; and (4) specialize in those products for which the soil and climate are best suited due to the enlargement of the market that can be reached over high-speed highways (*2-18*, p. 128).

3. Flexibility in occupation.—Mechanization and accessibility to urban centers means farmer income can be increased by part-time farming and holding of a nonfarm job. Added farm incomes have led to a general rise in the standard of living in rural areas (*2-18*, p. 131). More than 60 percent of farm families receive some income from sources other than the farm they operate (*2-18*, p. 132). At the same time, improved transportation has enabled and encouraged the location of industries in rural and small-town locations, making jobs more accessible to farmers (*2-18*, p. 132).

4. Gross national product.—The net result of highway improvement, added to advances in farm technology and biological research, has been to increase farm productivity and the gross national product. Agricultural productivity increased 100 percent during the 1947-58 period, while productivity of non-agricultural industries increased only approximately 38 percent (*2-18*, p. 123).

The increased productivity has meant an increasing farm output at the same time farmer population and number of farms were falling. Rapid growth of cities relative to the rural sector was made possible. Migration of surplus farm and rural trading center populations added to the urban growth. The cities have, in turn, stimulated farm productivity through providing a growing market for farm products (*2-18*, p. 124).

Gains and Utilities

1. To farmers:
   a. Higher crop yields possible, with correlated increase in farm income and land values.
   b. Lower costs of farm production through mechanization and economy in transportation.
   c. Increased market area and demand for product resulting in higher prices and ability to specialize.
   d. Greater latitude in crop type and rotation.
   e. Added income possible through access to nonfarm employment.
2. To community:
   a. Higher property tax yield from more productive farms.
   b. Availability of seasonal farm employment for local population.
   c. Prosperity of rural trading centers for which agriculture forms the economic base; increase in farmers living in town.
3. Region or nation:
   a. Growth of gross national product.
   b. Enabled urbanization of the population and the growth of industry through increased farm productivity to feed an urban population and migration of farm workers to fill urban jobs.

Costs and Losses

1. To farmers:
   a. Passing of the family farm and farming as a way of life, being replaced by more urban life styles and diversions, and farm industrialization and incorporation.
2. To community:
   a. Demise of the small-town, rural trading centers—dependent on farm population and income for survival—with the decline in farm population.

b. Lower tax yield from in-town properties where small-town business declined in trade and prosperity.

Decision-Making Factors

1. Prospective marginal increases in farm productivity based on highway improvements that permit:
   a. Larger markets and increased demand.
   b. Higher weight loads and vehicles.
   c. Less time en route.
   d. Less damage to farm produce en route.
   e. Lower operating costs.
   f. Better timing of deliveries.
   g. Off-farm employment.
   h. Increased mechanization.
   i. Ease in obtaining seasonal farm workers.
   j. Flexibility in crop type and rotation.
   k. Specialization of farm product.

2. Highway construction and maintenance costs necessary to procure these marginal increases in farm productivity compared in a benefit/cost framework over the improvement's service life, and with the marginal gains procurable from alternative projects.

CATEGORY: 2. Agriculture
VARIABLE: D. Dislocation

Area:	Rural
Type of Consequence:	Economic and Social
Location of Impact:	Right-of-Way Corridor
Timing of Impact:	Before Construction During Construction After Construction—Short Term After Construction—Long Term

Consequences

Two dislocation effects stem from highway improvement: (1) dislocation due to right-of-way taking, and (2) dislocation due to urbanization and commercialization.

1. Right-of-way taking.—Taking of land for right-of-way removes farmland from production, and results in possible changes in: (1) gross wealth or productivity of an area, (2) total gross income of the affected farmers, and (3) property tax revenues on the affected farmland. The changes will be influenced to varying degrees by specific locations that cause the amount and type of productive farmland taken to differ (*2-7*).

On a national scale, the conversion of farmland to highway use is likely to cause no threat to the nation's food supply, considering the trend of increasing farm productivity and the possibility of bringing unused land into production (*2-18*, p. 125). The U.S. Department of Agriculture has programs to reduce the amount of land in production to overcome surpluses, so productive is present land.

In spite of an insignificant national or regional impact, there may be significant localized losses, costs, and hardships as a result of farm dislocation. Even on a local basis, however, the impact is mixed, disallowing generalization. One California study (*2-18*) showed considerable differences in productivity change from alternative route locations. Another (*2-8*) found the freeway impact to be negligible. A study (*2-21*) of Iowa farms dislocated by Interstate right-of-way acquisition found that such farms decreased more in size and showed a substantially higher rate of farm disappearance than a control group of farms unaffected by the highway. Alternately, right-of-way takings of farmland for the Connecticut Turnpike had "relatively little impact" on agricultural production, according to another study (*2-13*). A Minnesota study (*2-10*) revealed that awards for right-of-way exceeded the estimated market value of the farmland taken. According to a Kansas study (*2-15*), losses in market values of remaining lands were estimated to exceed gains in values, except at interchanges.

2. Urbanization and commercialization of farmlands.—Industry, housing, and commerce decentralizing from nearby urban centers are added sources of farm dislocation. The amount of farmland absorbed by urbanization greatly exceeds that lost to right-of-way taking (*2-18*, p. 131). High-speed highways lower time-distances between urban job, commercial and industrial locations, and nearby farmlands. They encourage decentralization by opening the prospect of low-cost land obtainable at little or no sacrifice in relative accessibility to desired destinations.

Dislocation of farmland for urban uses produces an opposite set of effects from that usually produced by highway right-of-way dislocation: (1) the gross wealth or productivity (other than agricultural) of an area increases, (2) farmers' total gross incomes increase (from sale of farmland for urban uses), and (3) property tax revenues increase (due to higher value land uses). Raising of tax rates on farmland in urbanizing areas frequently abets and accelerates the rate of conversion by lowering the net income of farmers.

One study (*2-8*) of agricultural land on an urban fringe found freeway construction accelerated changes in land values to ultimate development levels five full years sooner than would have been the case in the freeway's absence.

Although there is usually a mutual benefit to farmer and farm buyer when farmland is sold for urban uses, there may be private and community costs in the form of: (1) depletion of farmland with unique and irreplaceable characteristics best for certain crops, (2) costs of relocating perennial plants (vines, shrubs, trees) elsewhere, with a long lag in time before full production is reached (e.g., urban development of orange groves near Los Angeles; grape-growing areas in Napa Valley, Cal.), (3) extending the distance urban dwellers must travel to find unurbanized countryside for recreation and aesthetic pleasure, and (4) any residual uncompensated relocation and readjustment costs for farm families forced to relocate, buy or sell added farmland, or leave farming.

Gains and Utilities

1. To farmers:
   a. Right-of-way payments, relocation adjustment payments, moving costs to the extent they equal or exceed the farmer's relocation costs.

b. Higher sales prices from land purchased for urban and commercial uses decentralizing from central cities as a result of highways improving relative accessibilities. Gains in farmers' gross incomes.

2. To community:
   a. Added supply of low-cost rural land for urbanization.
   b. Property tax increases due to conversion of farmland to decentralizing urban and commercial uses.

Costs and Losses

1. To farmers:
   a. Reduction in gross agricultural wealth (value of product) due to right-of-way taking removing land from production.
   b. Relocation, farm sale price, and moving costs exceeding compensation payments.
   c. Lowering of gross farm incomes through reductions in land available for farming.
   d. Depletion of farmland with unique characteristics or especially suited for certain crops.
   e. Costs in money and lag time to relocate and bring to full production perennial plants (vines, shrubs, trees, and new cropland).
2. To community:
   a. Reduced property tax revenues due to taxable land converted to right-of-way.
   b. Greater travel required by urban dwellers seeking natural countryside for recreation and scenic pleasure.

Decision-Making Factors

1. Net gain computed as the difference between gains and costs from farm dislocation, to the extent they can be evaluated in monetary terms; and utilities and losses stated in quantitative or qualitative terms where they cannot.

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CATEGORY: 3. Commercial
VARIABLE: A. Commercial Sales Receipts or Incomes: Change Due to Dislocation and Relocation

Area:	Urban
Type of Consequence:	Economic
Location of Impact:	Right-of-Way Corridor
Timing of Impact:	Before Construction During Construction After Construction—Short Term

Consequences

Highway improvements involving rights-of-way taking may remove commercial outlets. Such businesses may suffer losses before, during, and after relocation. They will either go out of business or reestablish elsewhere by finding an alternative market having an adequate threshold to generate profits. For the customers and employees in the area of the former site there is a loss; for those in the vicinity of the relocation site, a gain. Business quitting incur losses for proprietor, employees, and customers. The alternative sources of supply may gain from the additional sales and reduction in competition (*3-50*).

Gains and Utilities

1. To commercial proprietors:
   a. Compensation that offsets losses (*3-64*).
2. To employees:
   a. Employees hired in new location.
   b. Possibly more convenient access to employment.
3. To customers:
   a. Convenience of facility for consumers in trade area of relocation site.
4. Alternative supply sources:
   a. Gain of added sales from former customers of dislocated enterprises.

Costs and Losses

1. To commercial proprietors:
   a. Loss in sales *before* dislocation due to population decline or income group change in right-of-way.
   b. Loss in sales *during* dislocation due to being out of business until relocated.
   c. Loss in sales *after* dislocation due to period needed to build up a clientele in new location, to extent uncompensated.
   d. Moving cost of relocating business, to extent uncompensated. Firms moving prior to time compensation legally authorized incur loss to full extent of moving and relocation expense.
   e. Loss on stock and equipment, if quitting business.
2. To employees:
   a. Cost of finding new employment when establishment quits business or cuts staff, or relocates in a location inconvenient to former employees, causing them to terminate employment.
   b. Cost may be incurred for travel to more distant relocation site or alternative employment.
3. To customers:
   a. Cost of added travel to alternative sources of supply.

Decision-Making Factors

1. Cost burdens on properties, employees, and customers of commercial facilities unreasonably in excess of compensation and offsetting benefits.
2. The relative merits of each alignment based on its agreement with the following conditions or criteria.
3. Displacement of commercial firms in various categories; weighted by gross sales and employment.
4. Displacement of obsolescent older stores with less modernity, adequacy, and utility, compared to newer ones with these qualities.
5. Displacement of younger compared to older proprietors, with the former's greater likelihood of reestablishing rather than quitting business.
6. Displacement of stores with intentions of reestablishing in area.
7. Displacement of businesses intending to quit if displaced.
8. Displacement of stores intending to reestablish in any area.
9. Total property value displaced.
10. Disturbance cost and inconveniences to community.
11. Number of employees affected, especially in the following categories that are usually least able to bear the added cost of job seeking, unemployment, and added commutation or relocation, and that have the most difficulty being rehired after losing a job: (1) unskilled and semiskilled occupations—due to automation, low pay; and (2) older workers and those who have spent most years employed in same occupation—due to obsolescence of skills and impending retirement.
12. Involvement of local residents—for whom a shift in employment location probably would involve commutation or relocation cost burden.
13. Aggregate payroll loss (buying power loss) with least second-round impact on the retail trade sector's sales, payrolls, and employment.
14. Impact on local area employee-residents in terms of changing income levels, degree of anticipated unemployment, and added commutation and relocation cost.

Each route alternative probably will vary in the degree to which these criteria are favorable or unfavorable. A ranking of the alternative route locations by these criteria will afford one means of comparing them. See the varieties of rating systems in Chapter Eleven.

CATEGORY: 3. Commercial
VARIABLE B. Commercial Sales Receipts or Incomes: Change Due to Barrier

Area:	Urban
Type of Consequence:	Economic
Location of Impact:	Right-of-Way Corridor
Timing of Impact:	During Construction After Construction—Short Term

Consequences

Highway improvements involving limitation of access may create a barrier between enterprises in the vicinity not dislocated and their former trade areas. This may be particularly true of enterprises having a considerable walk-in trade due to the physical and psychological costs of walking added distances to find access across the highway barrier. For drive-in customers the longer distance traveled to find a crossing point adds travel time and vehicle running cost. Costs to some users of either mode may be sufficiently great to discourage travel to the enterprise. Alternative sources may appear more convenient under the changed set of accessibilities. The consumer suffers the added costs of the accessibility change. Commercial outlets may suffer gains or losses of business sales according to whether the barrier has subtracted from or added to their trade area (*3-63*, p. 95).

Gains and Utilities

1. To proprietors of alternative source of supply:
   a. Gain in sales from restructuring of trade areas due to barrier effect of limiting access: customers find alternative source relatively more accessible than former source of supply during and after construction of the improvement.

Costs and Losses

1. To proprietors of former source of supply:
   a. Loss in sales due to barrier effect of limiting access that isolates an enterprise from a portion of its former trade area.
2. To customers:
   a. Added travel cost to alternative source of supply or around barrier to former source.

Decision-Making Factors

1. Isolation of commercial enterprises from their trade areas due to the barrier effect of limiting access.

2. Number of establishments affected, their sales volume, and value of stock inventory.

CATEGORY: 3. Commercial
VARIABLE C. Commercial Sales Receipts or Incomes: Change Due to Population Change

Area:	Urban
Type of Consequence:	Economic
Location of Impact:	Corridor
Timing of Impact:	After Construction—Short Term After Construction—Long Term

Consequences

Population change, in terms of numbers of persons or households, induced by the highway will have a loss or gain effect on the amount of demand or buying potential in the trade area of existing or potential enterprises. Rights-of-way takings of residential structures act to diminish the population of the local trade area. The new population change is the total number of displacements less the number that relocate within the trade area. This is the short-term effect and implies losses. Existence of the highway improvement may generate added short-run out-migration from certain neighborhoods by (1) those who find they can better their residential environment without suffering loss of access to workplace or other locations due to the highway improvement, and (2) those moving out to avoid the nuisance aspects of the improvement (noise, air pollution, etc.). The lowering of density in either instance would lessen local demand for goods and services.

A long-run loss of population may occur from the displacement of residential land use by nonresidential uses willing to bid more for the accessibilities offered by the improvement. Manufacturing and commercial uses frequently preempt residential space in advantageous locations.

Offsetting these losses are the gains in sales that may ensue from the improvement's impact on increasing housing demand in its vicinity—superior facilities offering higher capacities or improved access have often attracted higher-density development in the form of apartments or development of previously vacant land. Such new building, or the subdivision of existing space into more units, would increase the local population. If the income group remained the same or had higher incomes, there would be gains in the sales of present or potential outlets in the vicinity. The only population change possible to predict with assurance is that due to right-of-way displacement: exactly equal to the number displaced less the number estimated likely to relocate in the vicinity according to local vacancy rates.

Gains and Utilities

1. To proprietors:
   a. Gains in sales receipts or sales potential from increases in population: new building at higher densities or on vacant land to capture the accessibility benefits of the improvement.

Costs and Losses

1. To proprietors:
   a. Losses in sales receipts due to (1) displacement of trade area population for right-of-way, (2) out-migration to better residential choice at no sacrifice in accessibility, and (3) out-migration to avoid nuisance aspects of the facility. Long-term loss due to change in land use to "non-residential" induced by the facility.

Decision-Making Factors

1. Relationship of residential neighborhoods to one or a group of commercial enterprises if they are not also displaced.

CATEGORY: 3. Commercial
VARIABLE: D. Commercial Sales Receipts or Incomes: Change Due to Income Group Change

Area:	Urban
Type of Consequence:	Economic
Location of Impact:	Corridor
Timing of Impact:	During Construction After Construction—Short Term After Construction—Long Term

Consequences

Total purchasing power in a trade area is the product of total number of households in each income bracket times the average income for that bracket; summed for all brackets in the trade area. Therefore, sales will change as a result of population change as well as of change in the income composition of the population due both to the replacement of one income group by another and to the rise in incomes within a group. Highway improvements frequently affect the first type of income group change. The improvement may make more desirable alternative locations (e.g., suburban homesites) accessible to higher-income groups who may migrate to them, leaving their former (now less desirable) residences to be occupied by lower-income groups. The nuisance aspects of the facility may have a blighting influence that may cause out-migration and succession by lower-income groups. Migrations may also entail changes in the ethnic or racial composition of neighborhoods, thus reinforcing migrations begun on the basis of income group betterment stemming from both increased accessibility and increased income. The resulting pattern is further solidified by propensities toward segregation by both race and income.

Commercial enterprises in areas experiencing such migratory shifts of income groups may experience either a loss in sales where the in-migrants are lower in income than the former occupants or an increase where they are higher. Groups with different tastes and preferences may change the quality or quantity or types of goods demanded.

Highway-induced changes in buying power or in the clientele for certain specialized goods will cause outlets in the associated trade areas to lose or to gain income; to locate, relocate, or quit business according to the nature and direction of the change.

Gains and Utilities

1. To proprietors:
   a. Gains due to in-migration of higher income group.
2. To employees:
   a. Conveniently located commercial employment; lower commutation costs.
3. To customers:
   a. Conveniently located sources of supply; lower transport costs.

Costs and Losses

1. To proprietors:
   a. Losses due to in-migration of lower income group.
2. To employees:
   a. Lowered local employment opportunities; costs of seeking other employment and commuting to it.
3. To customers:
   a. Inconvenience of travel further to sources of supply when outlets close due to lower receipts.

Decision-Making Factors

1. Blighting effects of design that would lower neighborhood residential values and lead to out-migration of higher income and succession by lower-income groups, thus lowering the sales potential of the trade area for enterprises serving it.

2. Tendency of urban radials to encourage decentralization of higher-income residents and their replacement by lower-income household in "filter-down" fashion. Lower receipts for commercial enterprise serving the abandoned area ensue, while higher incomes produce potential sales increases in the receiving area.

CATEGORY: 3. Commercial
VARIABLE: E. Commercial Sales Receipts or Incomes: Change Due to Traffic Volume Change (Bypass Effect)

Area:	Urban
Type of Consequence:	Economic
Location of Impact:	Community and System
Timing of Impact:	After Construction—Short Term After Construction—Long Term

Consequences

Bypass routes have long been used for the purpose of improving highway efficiency by diverting traffic around route segments made congested or hazardous by roadside development. At first, bypasses merely formed an alternate route around a town or "string street." Without access limitation, the bypass roadside would often develop to the point where it matched the bypassed segment in congestion and hazards due to turn movements and visual distractions. The present practice of limiting access has avoided this tendency, but has made limited-access highways "continuous bypasses" of both rural towns and urban arterials.

Numerous studies of bypass impacts on commercial trade have been conducted in towns and cities of all sizes. The results of a large sample of them were summarized in *NCHRP Report 18* (reporting NCHRP Project 2-2 research) (*3-20*). The tables summarizing the findings are reproduced here as Tables B-4 through B-8.

The following impacts can be predicted on the basis of these tables and the specific findings of the referenced studies:

1. Change in traffic flows and volumes.—An improved highway, offering superior service, attracts traffic from parallel routes, thereby reducing their ADT volumes in the process of route substitution. At the same time, the new facility, if access-controlled, limits the number of crossover points and interchanges with existing lateral routes, usually channeling increased volumes onto the crossing and intersecting streets. These effects have been documented by the Chicago Area Transportation Study (CATS) which reports (*3-7*, p. 69):

> The expressways cause a significant change in traffic usage of arterial streets. The ramps leading into the expressways represent a new focal point of trip attraction. Traffic flows are reoriented to expressway ramps. The arterial streets which run parallel to new expressways tend to sustain the greatest losses, whereas traffic on streets leading to and from ramps have the greatest gains. The effect is a substantial redirection of flows.

The CATS findings are supported by those of a study of the Capital Beltway (Washington, D.C.). Local industrial

TABLE B-4

SALES CHANGE IN BYPASSED TOWNS[a, b]

POPULATION CATEGORY	AVG. CHANGE IN RETAIL SALES (%)	NO. OF TOWNS WITH GAIN IN SALES	NO. OF TOWNS WITH LOSS IN SALES	RANGE (%)	AVG. GAIN (%)	AVG. LOSS (%)	NO. OF TOWNS WITH CON-TROL AREA	NO. OF TOWNS WITH MORE GAIN OR LESS LOSS THAN CONTROL	AVG. GAIN OR LOSS OVER CONTROL (%)
				(*a*) TOTAL RETAIL SALES					
Under 5,000	+ 5.6	16/20	3/20	− 6.4 − +22.5	+ 8.2	− 6.6	18	6/18	− 3.5
Over 5,000	+12.2	12/16	4/16	−13.0 − +49.0	+20.4	− 7.5	14	11/14	+ 3.7
5,000-10,000	+16.9	5/6	1/6	−13.0 − +38.0	+17.7	−13.0	6	4/6	+ 0.85
10,000-25,000	+ 7.3	5/7	2/7	− 3.1 − +40.5	+12.5	− 4.8	7	6/7	+ 4.1
25,000-50,000	−11.4	0/1	1/1	—	—	−11.4	—	—	—
50,000-100,000	—	—	—	—	—	—	—	—	—
100,000 & over	+22.6	2/2	0/2	+ 4.3 − +49.0	+22.6	—	1	1/1	+19.0
All towns	+ 8.5	28/36	7/36	−13.0 − +49.0	+12.9	—	32	17/32	− 0.30
				(*b*) HIGHWAY-ORIENTED SALES					
Under 5,000	+20.8	3/6	3/6	−14.7 − +60.9	+51.8	−10.3			
Over 5,000	+21.2	3/4	1/4	−11.8 − +50.4	+32.3	−11.8			
5,000-10,000	+41.5	1/1	0/1	—	+41.5	—			
10,000-25,000	+50.4	1/1	0/1	—	+50.4	—			
25,000-50,000	−11.8	0/1	1/1	—	—	−11.8			
50,000-100,000	—	—	—	—	—	—			
100,000 & over	+ 4.9	1/1	0/1	—	+ 4.9	—			
All towns	+21.0	6/10	4/10	−14.7 − +60.9	+42.5	−10.6			

[a] 16/20 indicates "16 of 20."
[b] Source: (*3-20*, p. 9).

executives, when interviewed, complained that "[T]he traffic congestion at the interchanges was costly, frustrating, and disappointing. . . . [A]ccess onto a major arterial was hurt when a Beltway interchange was constructed (nearby). . . ." (*3-62*, p. 69).

Therefore, whereas traffic-sensitive commercial enterprises located on the bypassed route segments may suffer sales losses, those located adjacent to interchanges, on their approaches, or on cross streets whose volumes have been increased probably will enjoy sales gains. Demand does not disappear but is redistributed geographically to locations with visual and physical access to the changed traffic flows. Found usually most adversely affected are marginal enterprises, for which even a slight diminution in traffic volume is sufficient to change profit to loss (*3-67*).

2. Highway-oriented commerce.—Roadside commercial

TABLE B-5

SERVICE STATION SALES CHANGE IN BYPASSED TOWNS[a, b]

POPULATION CATEGORY	AVG. CHANGE IN RETAIL SALES (%)	NO. OF TOWNS WITH GAIN IN SALES	NO. OF TOWNS WITH LOSS IN SALES	RANGE (%)	AVG. GAIN (%)	AVG. LOSS (%)	NO. OF TOWNS WITH CON-TROL AREA	NO. OF TOWNS WITH MORE GAIN OR LESS LOSS THAN CONTROL	AVG. GAIN OR LOSS OVER CONTROL (%)
Under 5,000	− 0.47	8/17	9/17	−33.0 − +39.4	+14.3	−13.6	11	5/11	− 0.86
Over 5,000	+ 5.5	7/15	8/15	−21.0 − +39.0	+20.0	− 7.3	10	6/10	− 5.75
5,000-10,000	− 1.8	2/4	2/4	−21.0 − +17.0	+11.3	−15.0	3	2/3	−20.0
10,000-25,000	− 4.2	3/7	4/7	−10.0 − +33.9	+19.1	− 7.5	6	3/6	− 6.1
25,000-50,000	− 4.8	0/2	2/2	− 7.0 − − 2.5	—	− 4.8	—	—	—
50,000-100,000	—	—	—	—	—	—	—	—	—
100,000 & over	+30.3	2/2	0/2	+21.5 − +39.0	+30.3	—	1	1/1	+21.0
All towns	+ 2.3	15/32	17/32	−33.0 − +39.4	+16.9	−10.6	21	11/21	− 3.2

[a] 9/17 indicates "9 of 17."
[b] Source: (*3-20*, p. 10).

TABLE B-6

RESTAURANT SALES CHANGE IN BYPASSED TOWNS[a, b]

POPULATION CATEGORY	AVG. CHANGE IN RETAIL SALES (%)	NO. OF TOWNS WITH GAIN IN SALES	NO. OF TOWNS WITH LOSS IN SALES	RANGE (%)	AVG. GAIN (%)	AVG. LOSS (%)	CON-TROL AREA	NO. OF TOWNS WITH MORE GAIN OR LESS LOSS THAN CONTROL	AVG. GAIN OR LOSS OVER CONTROL (%)
Under 5,000	−16.1	4/15	11/15	−50.0 − + 4.6	+ 2.2	−22.8	9	1/9	−10.6
Over 5,000	− 8.9	3/11	8/11	−26.0 − +14.0	+ 9.1	−13.1	6	5/6	− 0.25
5,000-10,000	− 9.2	1/4	3/4	−26.0 − + 2.4	+ 2.4	−13.0	3	2/3	− 5.8
10,000-25,000	− 7.3	1/3	2/3	−21.0 − +11.0	+11.0	− 8.3	2	2/2	+ 1.5
25,000-50,000	− 8.3	0/2	2/2	−14.6 − − 2.0	—	− 8.3	—	—	—
50,000-100,000	—	—	—	—	—	—	—	—	—
100,000 & over	− 1.1	1/2	1/2	−16.2 − +14.0	+14.0	−16.2	1	1/1	+13.0
All towns	−13.0	7/26	19/26	−50.0 − +14.0	+ 5.1	−18.7	15	6/15	− 6.4

[a] 11/15 indicates "11 of 15."
[b] Source: (*3-20*, p. 11).

TABLE B-7

MOTEL AND HOTEL SALES CHANGE IN BYPASSED TOWNS[a, b]

POPULATION CATEGORY	AVG. CHANGE IN RETAIL SALES (%)	NO. OF TOWNS WITH GAIN IN SALES	NO. OF TOWNS WITH LOSS IN SALES	RANGE (%)	AVG. GAIN (%)	AVG. LOSS (%)
Under 5,000	−32.4	1/4	3/4	−65.0 − + 2.0	+ 2.0	−43.8
Over 5,000	−13.9	1/4	3/4	−54.0 − +34.0	+34.0	−29.8
5,000-10,000	—	—	—	—	—	—
10,000-25,000	−15.5	0/1	1/1	—	—	−15.5
25,000-50,000	−37.0	0/2	2/2	−54.0 − +20.0	—	−37.0
50,000-100,000	—	—	—	—	—	—
100,000 & over	+34.0	1/1	0/1	—	+34.0	—
All towns	−23.1	2/8	6/8	−65.0 − +34.0	+18.0	+36.8

[a] 3/4 indicates "3 of 4."
[b] Source: (*3-20*, p. 12).

TABLE B-8

NONHIGHWAY-ORIENTED SALES CHANGE IN BYPASSED TOWNS[a, b]

POPULATION CATEGORY	AVG. CHANGE IN RETAIL SALES (%)	NO. OF TOWNS WITH GAIN IN SALES	NO. OF TOWNS WITH LOSS IN SALES	RANGE (%)	AVG. GAIN (%)	AVG. LOSS (%)	CON-TROL AREA	NO. OF TOWNS WITH MORE GAIN OR LESS LOSS THAN CONTROL	AVG. GAIN OR LOSS OVER CONTROL (%)
Under 5,000	+ 6.7	11/13	2/13	−14.8 − +32.0	+10.3	−12.6	8	6/8	+ 5.2
Over 5,000	+14.6	10/11	1/11	− 5.5 − +55.0	+16.6	− 5.5	6	5/6	+ 4.6
5,000-10,000	+11.2	4/4	0/4	+ 1.0 − +20.0	+11.2	—	2	2/2	+ 0.3
10,000-25,000	+11.2	3/4	1/4	− 5.5 − +38.0	+17.2	− 5.5	3	2/3	− 1.9
25,000-50,000	+ 6.9	2/2	0/2	+ 1.3 − +12.4	+ 6.9	—	—	—	—
50,000-100,000	—	—	—	—	—	—	—	—	—
100,000 & over	+55.0	1/1	0/1	—	+55.0	—	1	1/1	+19.0
All towns	+10.3	21/24	3/24	−14.8 − +55.0	+13.3	−10.3	14	11/14	+ 5.8

[a] 11/13 indicates "11 of 13."
[b] Source: (*3-20*, p. 12).

establishments and whole communities highly dependent on the market represented by the traffic stream often suffer loss of trade due to the diversion or "bypass effect." (See discussion of "Roadside Place—ADT Volume" in Chapter Eight.) This is particularly true of the gas-food-lodging group that often services transient rather than local trade and requires physical or visual access to through traffic. This effect is documented in Tables B-5, B-6, and B-7 which show cafes and motels usually suffer most loss of trade from diversion; service stations suffer less. The tendency appears universal, as the following sampling of research findings from various states reveals:

Alabama: "Highway oriented services such as service stations, motels and restaurants were adversely affected by the bypass" (*3-3*).

California: "Cafes and bars, a 24.4 percent decrease in business . . . service stations, a 23.2 percent decrease . . . after the freeway opened" (*3-70*).

Colorado: "The immediate effects of the highway were: an increase of 30 percent yearly in the automotive business was changed to a 25 percent decrease in the food and drink establishments" (*3-10*).

Iowa: "Cafes and service stations were adversely affected" (*3-21*).

Missouri: "Two groups showing net sales losses due to traffic removal are the restaurant, tavern and service station groups" (*3-38*).

Rhode Island: "Highway-oriented retail businesses were adversely affected by the new highway" (*3-40*).

Highway-oriented establishments were not adversely affected in all instances. A number of studies reveal the factors causing variability of gains and losses in sales of highway-oriented commercial outlets.

a. The smaller the town, the more likelihood of adverse effects. Through traffic makes up a larger share of the trade of smaller centers, whereas larger ones have a sizeable local market to fall back on (*3-42*).
b. The more dependent an outlet or center is on tourist and through-traffic trade, the greater the impact of sales losses due to bypassing. Some towns in main travel corridors, particularly in the West, have come to rely heavily on tourist expenditures to form their economic base (*3-15, 3-31*). In instances where through traffic formed only a minor portion of the traffic stream, effects were found to be minimal (*3-63*, p. 92).
c. The further removed bypassed enterprises are from the bypass, the more likelihood of adverse effects, and vice versa. Visual and physical access are important to the sales performance of roadside business (*3-63*, p. 95).
d. The growth of population and incomes in the local economy and of traffic in the corridor tend to offset the initial losses due to bypassing in some instances (*3-12; 3-49; 3-63*, p. 95).
e. Bypass impact on sales can also vary according to the actions undertaken by commercial firms or the highway department to ameliorate or prevent loss. Such actions have included:

(1) Firms:
(a) Adjustment of services to attract a larger share of the local market (*3-6*).
(b) Billboards, advertising, and signing visible from bypass.
(c) Relocating to frontage road or interchange locations (*3-11*).

(2) Highway agencies:
(a) Adjustment of distance to and visibility of bypassed enterprises.
(b) Provision of frontage roads. A number of studies have revealed successful operation of commercial enterprise in frontage road locations that minimize traffic conflicts while serving motorist needs (*3-9, 3-23, 3-24, 3-29, 3-36, 3-47*).
(c) Provision of "food-gas-lodging" signs and "business route" designation (*3-63*, p. 95).

3. Locally oriented commerce.—The ADT remaining on the "bypassed" route segment after the improvement largely reflects the traffic generated by local outlets serving their immediate market; they have therefore been observed to suffer little, if at all, from traffic diversion. Research studies, including those summarized in Tables B-8 and B-9, reveal that the nonhighway-oriented retail group often have their sales position enhanced after bypassing (*3-12, 3-14, 3-16, 3-25, 3-39, 3-45, 3-68, 3-69, 3-71*).

The causes for increased sales to this group are:

a. Such enterprises are little dependent on through traffic for trade. To the extent that they suffer trade losses, the reason is more likely to be competing shopping facilities that develop at interchanges and their approaches, thus forming "intervening opportunities" to shop (*3-18*).
b. The improved highway, in addition to bypassing, usually lowers trip time-distance and cost, thus enlarging the potential trade area of commercial firms (*3-3, 3-26, 3-48, 3-62*).

TABLE B-9

NONHIGHWAY-ORIENTED SALES CHANGE IN BYPASSED TOWNS BY SPECIFIC VARIABLE [a]

VARIABLE	NO. OF OBSERVATIONS	RANGE (%)	AVERAGE CHANGE (%)
Apparel	7	− 2.0 − +48.0	+13.1
General merchandise	8	−31.6 − +75.0	+13.2
Automotive	6	−25.0 − +30.9	− 2.8
Furniture	7	−12.4 − +42.0	+ 5.1
Lumber and building	7	−13.0 − +18.5	+ 1.7
Groceries	11	+ 1.9 − +48.0	+16.8
Drugs	2	−11.0 − +18.0	+ 3.5
Liquor	2	+10.0 − +53.0	+31.5
Hardware	1	—	+13.9
Specialty	4	−15.9 − +14.0	− 0.95
Tourism	1	—	−24.0
Service	3	+ 8.0 − +75.0	+34.2

[a] Source: (*3-20*, p. 13).

c. The diversion of through traffic makes shopping easier due to less traffic congestion, more available parking, fewer nuisance effects, and greater pedestrian safety and convenience (*3-8, 3-38, 3-58*).

4. One-way-street impacts.—Several studies have examined the impact of a variation of bypassing, one-way-street designation. Making a street one-way diverts that portion of the traffic flowing in the direction opposite from that designated. The studies uniformly show user gains in the form of increased safety and traffic-carrying capacity and no adverse nonuser effects on abutting retail businesses (*3-5, 3-22, 3-28*).

a. To road users:
   (1) Lower operating cost and reduced travel time due to less hazard and congestion through elimination of turning movements, pedestrian traffic, visual distraction. Benefits accrue to both local and long-distance users.
b. To proprietors:
   (1) Gain in sales from expanded market area due to improvement, greater safety, and convenience of shopping where through traffic volume is reduced.
   (2) Gain in sales from increased ADT on cross streets and interchange approaches.
c. To customers:
   (1) Convenience and safety of shopping in decongested area; greater accessibility to commercial centers.

Costs and Losses

1. To proprietors:
   a. Loss in sales due to traffic diversion.
2. To customers:
   a. Additional time and distance driven to seek out goods or services made less visible and/or accessible by "bypass effect."

Decision-Making Factors

1. Loss and inconvenience to highway users seeking services.
2. Trade effects on local population and trade.

CATEGORY: 3. Commercial
VARIABLE: F. Commercial Sales Receipts or Incomes: Change Due to Accessibility Change (Trade Area)

Area: Urban
Type of Consequence: Economic
Location of Impact: Corridor
Timing of Impact: After Construction—Short Term
After Construction—Long Term

Consequences

Highway improvements, in fulfilling their purpose, reduce distance and/or the rate of time or resource consumption spent on travel. This lowers the price and cost of goods for those using the improvement to reach sources of supply and increases demand at those sources made relatively more accessible by the improvement. The improved highway also increases the geographic size of the trade area, usually linearly in the directions traversed by the improvement (*3-13, 3-53, 3-54, 3-62, 3-63*, p. 70).

Thus, locations advantaged by the improved accessibility provided increase sales for the following reasons: (1) goods offered at advantaged locations will appear relatively less expensive than their substitutes or the same goods at alternative locations; depending on their elasticity of demand, more of them are likely to be purchased at the lower price; (2) lowering the cost of transportation increases the amount of money available to buy other goods and services and so increases demand for them; (3) extending the trade area increases the number of demanders whose wants can be fulfilled least expensively at the most accessible source. ("Accessibility" also includes the availability and cost of parking in addition to distance and input rates. In auto-oriented low-density communities, shopping centers without ample parking or that charge for its use appear relatively less "accessible" than centers with ample free parking. Lacking sufficient walk-in trade, the former frequently fail) (*3-33, 3-52, 3-54*).

Gains and Utilities

1. To proprietors:
   a. Gain in sales from (1) substitution effect—lower prices, (2) income effect—more goods afforded with transportation cost savings, (3) trade area expansion—larger potential market (i.e., number of demanders). Additional savings are effected by: (1) the larger market creating thresholds for additional enterprises in accessible locations, thus reducing distances and number of trip ends and making multiple-purpose trips possible, and (2) high demand creating opportunities for economies of scale (e.g., spreading overhead, quantity discounts, and bulk buying, with savings passed on to consumer).
2. To customers:
   a. Gain from buying wants and needs at lowest possible prices, thus gaining the most utility and satisfaction available from their incomes.
3. To employees:
   a. Gain from the availability of nearby employment opportunities.

Costs and Losses

1. To proprietors:
   a. Loss in sales from clientele substituting sources of supply made relatively more accessible by the improvement for those that then appear relatively less so.
2. To customers:
   a. Clientele of the disadvantaged enterprises lose by: (1) paying higher prices charged to offset declining sales volume, (2) losing a convenient (for some) store if it is forced to quit business.
3. To employees:
   a. Employees of disadvantaged enterprises may lose jobs as a result of: (1) proprietor's desire to

reduce operating cost to adjust to loss of trade, or (2) outlet's going out of business.

Decision-Making Factors

1. Accessibility of existing centers versus creating the development potential for new competing centers. Measurement is by (1) local plans and goals, (2) the ability of existing centers to cope with parking, traffic, and trade demands, and (3) potential trade loss impact on the local economy.

2. Highway capacity related to trip generation based on land-use plans, zoning, population projections, and estimates of future ADT's.

3. Features of highway design that relate to accommodating special traffic demands arising from access limitations, interchange development, roadside development, mix of auto and pedestrian, and turn movements while reducing the negative impact of these on commercial enterprise. Examples include:

   a. Local planning and zoning that balances trip generation with transportation capacity.
   b. Local regulation of ingress and egress points near interchange ramps to be observed by developers of abutting land in the interest of avoiding ramp congestion.
   c. Provision of frontage roads, signing, business routes, or other means of reducing negative impacts on commercial enterprises and their clientele due to physical and visual access limitations and bypassing.
   d. Separation of pedestrian and vehicular traffic where practicable.
   e. Reduction in turning movement conflict and hazard by one-way designation or median barriers.

CATEGORY: 3. Commercial
VARIABLE: G. Commercial Sales Receipts or Incomes: Change Due to Community Price Change (Resulting from Transportation)

Area:	Urban
Type of Consequence:	Economic
Location of Impact:	Community or System Region or Nation
Timing of Impact:	After Construction—Short Term After Construction—Long Term

Consequences

The reduction of transportation costs due to a highway improvement has these consequences depending on where the incidence of the cost reduction falls:

1. Lower freight rates to shippers.—The cost reductions induced by highway improvements for economy are first received by those engaged in producing transportation services (i.e., trucking companies). Cost savings may be captured by trucking companies in the form of increased profits and/or passed along to labor in the form of wage increases to match the productivity gain. Competitive pressures from other modes may induce a sharing of the gain with shippers in the form of a tariff reduction by requesting a lower ICC rate. In that case, the shipper would enjoy reduced shipping costs.

If the shipper was an input supplier and passed along a part of the cost reduction, a producer might be able to reduce his production costs and FOB prices.

2. Lower wholesale prices.—Should wholesalers be induced by competition to pass some of their reduced shipping costs along to the customers there is the possibility of lowering the wholesale price. The wholesaler could otherwise enjoy the possibility of increased profits.

3. Lower retail prices.—Finally, the consumer, under conditions of price competition, might receive a portion of the cost reduction in the form of lower or more stable shelf prices for retail goods and reap an increase in consumer's surplus or real income.

The incidence of the price effect of transportation cost reductions varies according to the point at which the gain falls and the willingness of the party capturing the gain—trucker, producer, wholesaler, retailer— to pass it along or to retain it in the form of increased profits or wages. This willingness will be determined in large part by competitive pressures due to the desire of entrepreneurs to maximize profits and of labor to convert productivity increases into wage gains. It is likely that most efficiency gains in transportation are being absorbed in wages and profits, with only a small portion realized by the consumer as reductions in shelf prices for consumer goods. To the extent that shelf prices do fall or tend to rise more slowly than would be the case without transportation efficiency gains, there will be consumer gains as well. Consumers, however, will also receive the transportation efficiency gains in their roles as investors reaping dividends, employees gaining higher wages, entrepreneurs reaping profits, or as private automobile owners enjoying a reduction in shopping trip cost.

The price effects are highly diffuse, variable, and difficult to measure precisely or trace in an over-all systems sense except perhaps via an input-output analysis. Such gains nevertheless exist and are being realized throughout the economy, influencing price-based purchasing decisions of producer, consumers, and middlemen and generally adding to prosperity through increased efficiency and productivity at all levels of the economy—national, regional, and local.

There is a systems effect on competing nonhighway modes when their traffic is reduced due to substitution of highway modes whose rates, fares, and time schedules appear relatively more advantageous. The competing nonhighway modes may raise tariffs and fares or reduce service to compensate for the revenue losses. This strategy may cause a further deterioration in the ability of such modes to effectively compete on a price or service basis and cause further loss of traffic in "vicious spiral" fashion (e.g., the losses of U.S. railroads in relative share of freight and passenger traffic since World War II).

Gains and Utilities

1. To trucking companies:
   a. Lower costs resulting in increased trucker profits and/or wage gains to teamsters.

b. Increased traffic and revenues from freight rate reductions that produce competitive advantages.
2. To producers and shippers:
a. Lower shipping costs due to competitive freight weight reductions enabled by transportation efficiencies.
b. Increased sales and revenues from demand induced by lower prices if all or a portion of shipping cost reductions are passed along.
3. To middlemen and consumers:
a. Lower prices resulting from lower costs to shippers passed along due to price competition but enabled by transportation economy.
b. Increased trade and profits or real income due to competitive price reductions that cause increase in demand.

Costs and Losses

1. To road users:
a. Benefit taxes levied for the purpose of procuring transportation efficiency and economy via highway investment.
2. To competing nonhighway modes and their users:
a. Loss of traffic revenue due to freight rate competition made possible by highway transportation efficiency and economy.
b. Higher tariffs and fares and service reductions due to traffic loss to highway-mode competitors.
c. Loss of sales and revenues due to higher prices of products delivered by the relatively more expensive mode, thereby inducing competitive disadvantage.

Decision-Making Factors

1. Equitable geographic distribution of transportation efficiency gains by areas and regions to maintain competition and encourage specialization through ubiquitous freight rate reduction possibilities.

2. Maintenance of inter-modal competition that encourages the use of each mode for the most appropriate purposes according to the relative efficiencies of the modes based on true costs of providing services.

3. Inter-modal substitution possibilities contributing to: (1) the ability to add paved mileage due to not having to add as much capacity (more miles as a result of fewer lanes), and (2) overcoming the diminishing returns effects from urban-expressway investment due to congestion buildup.

4. Development and redevelopment possibilities in underdeveloped regions and depressed areas as a result of lowering shipping costs for their present or potential products.

CATEGORY: 3. Commercial
VARIABLE: H. Rental Property Receipts

Area:	Urban
Type of Consequence:	Economic
Location of Impact:	Right-of-Way Corridor
Timing of Impact:	Before Construction

Consequences

Owners of income property, residential or commercial, receive less income due to (1) tenant departures, (2) lower occupancy rates, and (3) reduced rents required to attract or keep tenants as turnover steps up in anticipation of forced relocation due to right-of-way taking. Owners of commercial space suffer as a result of tenants' reduced patronage as population declines or lower-income groups occupy area, forcing owners to accept lower rents to retain tenants.

Gains and Utilities

1. To tenants:
a. Ability to rent at reduced rates.

Costs and Losses

1. To owners of rental property:
a. Reduced receipts from property rental due to vacancies or rental reductions to attract new tenants and cut losses.

Decision-Making Factors

1. Time period between route designation and actual taking of rights-of-way.

2. Probable total rental loss during the "before" period.

CATEGORY: 3. Commercial
VARIABLE: I. Employment

Area:	Urban
Type of Consequence:	Economic
Location of Impact:	Corridor Community or System
Timing of Impact:	During Construction After Construction—Short Term After Construction—Long Term

Consequences

Commercial employment in a community feels the impact of highway improvement in these ways:

1. Economic base change.—The amount of commercial employment over all is a function of an urban area's economic base or exporting activity that permits it to import goods to meet varied demands of the population. (It has been demonstrated, however, that as an urban area grows larger it becomes more self-sufficient in that it provides a market capable of absorbing more of its own product.) (*3-61*).

Highway improvements that affect the location or level of basic industry will have a multiplier effect on commercial employment. Basic industry induces changes in population and incomes, the determinants of buying power, which in turn determine the level and mix of commercial employment.

2. Market location change.—Once the basic buying power is established, where and how people spend their money relates to (1) their tastes, preferences, needs, wants, and values interacting with the types and prices of goods available, (2) the location and density of the population and spatial distribution of its various income divisions, and

(3) the relative accessibility of various commercial enterprises supplying those wants and needs. These factors, added to the amount of labor input required to achieve the desired level of sales revenues and profits for each type of commodity or service and each scale of commercial operation, determine commercial employment.

Highway improvements change commercial employment levels and locations by:

a. Causing movement of basic industries into or out of an area due to highway-induced (1) dislocation, (2) relocation to capture a highway improvement's advantages, or (3) relocation to capture other advantages that become relatively more important than accessibility once good highway service has been made ubiquitous by over-all system improvement.
b. Causing movements of population that change localized buying power; either voluntary, as in decentralization and centralization, or forced by right-of-way taking.
c. Causing population out-migration by one income group and succession by a different income group, again changing buying power in the affected area.
d. Encouraging universal use of automobiles and placing at a competitive disadvantage commercial outlets suffering traffic congestion or lack of parking space.
e. Causing centralization of commercial outlets due to trade area expansion that encompasses the trade areas of minor outlets.
f. Dislocating commercial enterprises for right-of-way (*3-43*).
g. Diverting traffic, on which some auto-oriented enterprises are dependent, to a bypass route.
h. Reducing demand for substitute modes of transportation, their suppliers, and outlets oriented to their traffic and accessibility patterns.
i. Creating a barrier between a commercial enterprise and part of its trade area.
j. Altering accessibility and thereby trade area size and shape and the competitive advantage of various centers relative to each other.
k. Creating added opportunities for sales and service enterprises catering to highway transportation needs.

Some of these effects involve only geographic shifts of employment location. Commercial enterprise seeks to maximize its share of the relevant population's buying power. There will be an ensuing change in employee commuting costs to reach relocation sites. Enterprise location and relocation results from following the market represented by the shifting residential or traffic population. Other effects involve commercial enterprises going into or out of business; adding to or cutting back on employment according to changes in over-all community buying power. Knowledge of circumstances and intentions is necessary to tell the difference.

Other factors unrelated to highways also affect the level of commercial employment and should be separated out to the extent possible. They include changing income levels, changes in tastes and preferences, technological and other innovations in products, and changes in sales organization and techniques (e.g., automated vending and self-service merchandising).

Gains and Utilities

1. To commercial employees:
   a. Increase in employment opportunities due to changes in the location or level of sales of commercial enterprises.
   b. Lower cost of journey to work for employees due to change in location of commercial employers.
2. To commercial employers:
   a. Enlarged access to the labor market.

Costs and Losses

1. To commercial employees:
   a. Decrease in employment opportunities due to changes in the location or level of sales of commercial enterprises.
   b. Higher costs of journey-to-work for employees due to change in location of commercial employees.
2. To commercial employers:
   a. Restricted access to labor market.

Decision-Making Factors

1. Potential impacts on commercial employment, beneficial or adverse, stemming from highway improvement influenced changes in the economic base or market location factors such as:

   a. Basic industry location and relocation.
   b. Population movements.
   c. Income group movements.
   d. Automobile use increase.
   e. Commercial centralization.
   f. Right-of-way dislocation of enterprises.
   g. Bypass traffic diversions.
   h. Modal substitutions.
   i. Barrier effects.
   j. Accessibility and trade area change.
   k. Growth of highway system-serving enterprise.

CATEGORY: 3. Commercial
VARIABLE: J. Land Use

Area:	Urban
Type of Consequence:	Economic
Location of Impact:	Right-of-Way
	Corridor
	Community or System
Timing of Impact:	During Construction
	After Construction—Short Term
	After Construction—Long Term

Consequences

Commercial land uses appear where there is a potential consumer market that can be profitably served. The market may be in the form of (1) a resident population with demands for personal and household goods and services, or (2) a mobile population, or traffic stream, with demands for user services (e.g., gas, food, and lodging).

Enterprises seek sites with maximum accessibility to their market. Outlets serving the resident market frequently seek a "central place" location made accessible by highways such as a crossroads, interchange, or roadside of a main commuter route. Their typical form is nucleated shopping centers. Outlets serving the mobile market usually seek a "roadside place" location where traffic volumes are highest (e.g., crossroads, interchanges, or roadsides of main through traffic routes). Their typical form is "ribbon" development. Although their market orientations and criteria differ, the two outlet types are often found in combination due to the frequent congruence of sites where their locational criteria are met.

Highway improvements have the following effects on commercial land uses:

1. Dislocates commercial uses for right-of-way, causing some enterprises to relocate, others to quit business (*3-43*).
2. Encourages migration, dislocation and relocation, concentration or dispersion of population and income groups, thereby altering the trade potential of a given "central place" site and perhaps shifting sites (*3-32, 3-67*).
3. Encourages traffic diversion onto the improved facility, thereby altering the trade potential of given "roadside place" sites and perhaps shifting sites (*3-34, 3-35*). (Traffic reduction may attract more "central place" commercial land users by increasing the safety and amenity of the shopping area.) (*3-8*).
4. Alters the trade potential of a site by changing its relative accessibility to its potential consumer area by (1) changing cost- or time-distance, or (2) creating a barrier (*3-1, 3-17*).
5. Encourages substitution of highway transportation for other modes, thereby changing the demand potential at sites related to the mode substituted for, its routes, terminals, and systems.
6. Tends to disperse commercial centers to locations where their trip-generating potential matches capacity of roadway and parking facilities serving them.
7. Tends to increase demand for automotive goods and services and land use for those purposes.
8. Tends to increase the relative share of total land in commercial use due to the necessity for providing customer parking adjacent to all outlets.
9. Provides a supply of new sites attractive to commercial enterprise (e.g., crossroads, interchanges, roadsides), thereby altering the supply-demand relationship (*3-41*).
10. Increases commercial demand and land use due to the income and substitution effects of lowering transportation costs.

Gains and Utilities

1. To commercial landowners:
   a. Increased land values and rents when highway improvement causes increased sales.
2. To commercial land users:
   a. Increased sales and profits due to highway improvement effects.
3. To consumers:
   a. Lower cost of goods and added convenience due to increased accessibility of commercial enterprises.
4. To community:
   a. Increase in community efficiency and economic and tax base due to highway-induced change in commercial land use.

Costs and Losses

1. To commercial landowners:
   a. Decreased land values and rents when highway improvement causes reduced sales.
2. To commercial land users:
   a. Relocation and readjustment costs in excess of those compensated for when dislocated for right-of-way.
   b. Decreased sales and profits due to highway improvement effects.
3. To consumers:
   a. Higher cost of goods and inconvenience when accessibility to commercial outlets reduced by highway improvement.
4. To community:
   a. Decrease in community efficiency and economic and tax base due to decline or relocation of commercial uses.

Decision-Making Factors

1. Potential impacts on commercial land use, beneficial or adverse, stemming from highway improvement impacts on:
   a. Commercial dislocation for right-of-way.
   b. Population and income group migration.
   c. Traffic diversion.
   d. Accessibility change.
   e. Modal substitution.
   f. Decentralization.
   g. Demand for automotive goods and services.
   h. Parking demand.
   i. Supply of sites suitable for commercial use.
   j. Retail demand effect from road-user savings.

CATEGORY: 3. Commercial
VARIABLE: K. Land Value

Area:	Urban
Type of Consequence:	Economic
Location of Impact:	Right-of-way Corridor Community or System
Timing of Impact:	During Construction After Construction—Short Term After Construction—Long Term

Consequences

Land values are based on the productivity of land capitalized over time and reduced to its present net worth. Land is usually sold to the highest bidder, that party who expects to make most productive use of the land. Commercial land values are based on the sales volume that can be realized in a given location. Highway improvements influence commercial land values by changing the sales volume potential realizable at a site served by the highway.

Studies have revealed percentage changes in commercial land-use values ranging from 90 percent reductions to 1,583 percent increases (*3-63*, pp. 28-29). The high degree of variability reflects the variability of local conditions that affect the sales volume potential of a site. The relevant variables include:

1. Community economic base, the industrial or other "export" activities that determine the basic population and income characteristics of a community on which buying power is based (*3-63*, p. 30).
2. Local trade area population and income characteristics that determine sales volumes in given locations (*3-67*).
3. Accessibility of a site to its trade area, including time-distance, trip cost, parking availability, and degree of congestion (*3-60*).
4. Volume of traffic, and visual access, especially for highway-oriented commercial outlets and outdoor advertising. Ease of physical access is also important to highway-oriented outlets (*3-1*, *3-41*, *3-46*).
5. Number of commercial outlets dislocated for right-of-way whose clientele increase the demand experienced at alternative remaining outlets.
6. Sales volumes at sites oriented to alternative modes of transportation whose clientele are diverted by substituting auto travel over the improved highway for travel by the former mode.
7. Amount of available commercial land and its desirability according to amount made newly accessible by highway improvement, local zoning policies, competition from other existing or planned commercial outlets.
8. Added demand for commercial land created by auto-oriented commercial enterprise to service increased demand for highway transportation and by requirement for parking space.
9. Increase in consumer demand resulting from road-user savings on the improved highway.

Commercial land value increases have been shown to occur or be largest:

1. At interchanges and on their approaches.
2. At intersections.
3. On roadsides or frontage roads of high-volume arteries (*3-2*).
4. Along highways central to and serving high-population or high-income areas.
5. Close to and/or in view of the roadway.
6. Where commercial dislocation sends consumers to alternate outlets.
7. Where highway improvement has caused increases in the amount of basic industry and employment.
8. Where demand for commercial land is unsatisfied by the supply created by the highway improvement. Limited-access facilities create fewer potential commercial sites than unlimited-access arterials. Interchange locations thus tend to have higher values and to be used more intensively.

Commercial value decreases have occurred:

1. On bypassed route segments.
2. Where highway improvements have encouraged out-migration of industry, population, and/or higher-income groups.
3. Where right-of-way has dislocated population or formed a barrier across a trade area.
4. Where commercial sites were oriented to another mode or to less traffic and parking demand and lose trade to competing sites more advantageously located.
5. At sites farther removed from and/or not visible from the highway improvement.
6. Where the supply of commercial land created by a highway improvement considerably exceeds effective demand.

Gains and Utilities

1. To commercial landowners:
   a. Higher land values resulting from increased commercial sales potential resulting from highway improvement.
2. To real estate industry:
   a. Higher commissions from turnover of higher-value properties.
3. To community:
   a. Higher tax revenue income resulting from appreciation of commercial land value.

Costs and Losses

1. To commercial landowners:
   a. Lower land values where the result of highway improvement is to displace demand and commercial sales potential.
2. To commercial land users:
   a. Higher rents for commercial land.
3. To consumers:
   a. Higher costs of goods and services due to shifting of some of the rent and tax burden.
4. To community:
   a. Lower tax revenues where the result of highway improvement is to depress the value of commercial land. Gains may balance or offset losses, depending on circumstances.

Decision-Making Factors

1. Potential impacts on commercial land values, beneficial or adverse, resulting from highway improvement impacts on:
   a. Population and income levels.
   b. Industrial growth and locations.
   c. Number of commercial outlets displaced.
   d. Supply of commercial land.
   e. Demand for commercial land.
   f. Inter-modal substitution and sites serving each mode's users and its operating needs.
   g. Accessibility, extent of trade area.
   h. Traffic volumes.
   i. Competing enterprises and centers.
   j. Volume of road-user savings.
   k. Visibility of and physical access to enterprises.
   l. Degree of congestion and amount of available

parking and pedestrian hazard proximate to the outlet(s).

2. A variety of nonhighway factors also enter into the attraction to and therefore the value of commercial land. They include magnitude of the enterprise or center, diversity and prices of goods and services offered, modernity of facilities and their aesthetic appeal, advertising and sales promotions, and effectiveness of management.

CATEGORY: 3. Commercial
VARIABLE: L. Effect on Public Transportation

Area:	Urban
Type of Consequence:	Economic and Social
Location of Impact:	Corridor
	Community or System
Timing of Impact:	After Construction—Short Term
	After Construction—Long Term

Consequences

Use of public transportation, especially rapid transit, rail and streetcar modes (once predominant), have declined in U.S. urban areas since the automobile came into widespread use in the 1920's. After a temporary recovery during World War II, the decline has continued (*3-53*).

A variety of factors have contributed to this trend (*3-4*):

1. The popularity of the automobile as a transportation mode due to its speed, range, flexibility, privacy, comfort, and the driver's independence of choice of routes, destinations, and schedules.

2. Affluence, that has extended the opportunity for car ownership, and mass production, which has lowered its cost.

3. Highway investment, which has stabilized or lowered the cost of operation and extended the feasible range of trips, the capacity of routes, and the satisfaction of auto travel.

4. Dispersed land-use patterns, related to automobile operating and system characteristics, which cannot be economically or feasibly served by transit.

5. Transit's "vicious spiral" in which reduced patronage caused by auto-for-transit substitution leads to lower revenues. Lower revenues lead to increased fares and to reduced service, maintenance, and reinvestment. These actions lead to further patronage reductions and successive rounds of fare increases, accompanied by service and plant deterioration, and patronage loss. By contrast, highway investment has secured successive improvement in highway transportation service at progressively lower cost (prior to congestion's reversal of the cost curve).

Systems effects have included (1) deterioration of those areas of cities best served by transit whose relative accessibility has declined, (2) inconvenience and added expense for those in the population dependent on transit (e.g., low-income households, noncar owners, those too young or too old to drive, the nonlicensed, the handicapped, residents of high-density housing areas, and CBD workers and shoppers), (3) increased public expense to subsidize transit operations, and (4) increased cost of highway transportation and parking due to lack of an alternative mode to relieve congestion and parking demand.

That public transportation and automobiles are substitutes for one another and that rises in the use of one are matched by declines in the use of the other are revealed by numerous statistics of which those for Southeastern Wisconsin are typical:

> In the combined Milwaukee, Racine, Kenosha, and Waukesha areas, which accounted for all but a very small part of the total mass transit utilization within the Region, the total number of revenue-passengers carried annually decreased by 45.2 percent, from 171.0 million in 1953 to 93.8 million in 1963.
>
> . . . .
>
> Contrasting to the approximately 45 percent decrease in mass transit revenue passengers within the Region from 1953 through 1963 was the increase of approximately 46 percent in auto registration within the Region, from 387,987 in 1953 to 566,139 in 1963 (*3-59*).

Therefore, the improvement of highways, by lowering the cost while raising the comfort and convenience of highway travel, further encourages the auto-for-transit substitution which, in extreme cases, has led to the dissolution or subsidy of public transportation services.

Gains and Utilities

1. To public transportation users:
   a. Faster ride and lower cost where bus transit operates more efficiently over improved highways or reserved express lanes.
2. To public transportation authority:
   a. Increased revenues, profits, and plant use where better bus service over improved highways increases patronage.
3. To community:
   a. Less expenditure for highways and transit subsidy, fewer tax losses and nuisance effects as better bus service and improved highways increase transit-for-auto substitution.
4. To auto users:
   a. Less congestion, user operating cost, chauffering, and more modal choice where transit-for-auto substitution is encouraged by bus operation on improved highways.

Costs and Losses

1. To public transportation users:
   a. Erosion of service, obsolescence of facilities, higher fares when auto-for-transit substitution occurs.
   b. Limitation on employment, social, educational, and recreational opportunities for those who do not own or cannot drive a car.
2. To public transportation authorities:
   a. Loss of revenues, excess capacity, and under-utilization of plant, and decline of profits (where privately owned).
3. To community:
   a. Increased taxes and expenditure for highways, streets, parking, traffic control, police, and courts to meet added demand for highway travel transferred from transit.

b. Loss of alternative transportation mode or expense of its subsidization where it is considered essential.
c. Tax and business losses from space transferred from private use to public for highway rights-of-way and parking; migration or failure of enterprises and functions oriented to public transportation and its use and users for operating thresholds (e.g., downtown department stores, metropolitan newspapers, high-density housing and specialized enterprises and functions requiring a metropolitan-wide clientele that cannot find an operating threshold off-center and none on-center due to central area congestion and cost of auto travel and parking); and de-intensification of land use.
d. Increase in "nuisance" effects of automobile use (e.g., air pollution, noise, vibration, pedestrian hazard, aesthetic demerits, and barriers due to modal substitution of auto-for-transit).

4. To auto users:
   a. Lack of an emergency back-up system in periods of car failure or inclement weather.
   b. Higher cost of travel and parking in congested areas where former transit users have substituted travel by auto.
   c. Increased time spent chauffering nondrivers.
   d. Lack of modal choice.

Decision-Making Factors

1. Highway improvements that cause private automobile transportation to appear to have competitive advantage over public transportation, thereby encouraging auto-for-transit substitution, should be examined in the light of the systems effects, costs and benefits, occurring from the substitution. Factors for evaluation include:
   a. Public transportation revenues, patronage, plant, profits, and subsidies.
   b. Public transportation user characteristics, costs, numbers, comfort and convenience, and opportunities.
   c. Community revenues and expenditures, form, environment, land uses, activities and functions, and space consumption.
   d. Highway user operating costs, travel-time use, parking costs, and modal choice.

CATEGORY: 3. Commercial
VARIABLE: M. Parking

Area:	Urban
Type of Consequence:	Economic
Location of Impact:	Right-of-way
	Corridor
	Community or System
Timing of Impact:	During Construction
	After Construction—Short Term
	After Construction—Long Term

Consequences

Highway improvements that cause increased trip demand, either by encouraging more trips at the lower trip price or the development or intensification of trip-generating land uses, create an increase in the joint demand for parking.

Trip generation volumes of a land use, or the number of trip ends within a traffic zone, may or may not be an indication of the correlated parking demand. Trip generation of office and industrial uses and work-trip ends are likely to closely approximate parking demand due to the all-day nature of their use. Shopping, social, cultural, and recreational trip ends and trip generation of land uses devoted to these purposes will have a lower correlation with parking demand due to the short-term nature of the space occupancy and the relatively light turnover rate. The same amount of parking space can thus absorb a far higher volume of trip ends in the latter instance than in the former.

The magnitude of the difference made in parking demand by trip purpose is revealed by these study findings (*3-44*):

> Study of meter feeders in Easton, Pa. revealed a single meter feeder uses up curb parking space that could otherwise handle from 15 to 18 parkers (customers) each day. This is based on the fact that each meter in Easton is used by 1.94 cars each hour. Easton finds that about 8% of all spaces are hogged by meter feeders. Thus a total of between 900 and 1,080 other drivers are unable to find parking room.

Parking demand relates to a variety of factors:

1. Trip attraction of various uses (location, size, floor area, type).
2. Peaking characteristics of demand.
3. Urban area population.
4. Trip purpose and related turnover rates.
5. Availability of public transportation.
6. Price of parking and cost to provide it, and supply relative to demand.
7. Necessary and tolerable walking distances.
8. Trip volumes, prices, and capacity of highway improvement.

The following relationships between parking demand and these variables have been established (*3-55, 3-56*):

1. Average parking space required for downtown establishments per 1,000 sq ft of floor space varies by use. Examples include: banks—5.4; bus depots—5; libraries, medical buildings, and governmental buildings—4; department stores and post offices—3; offices—2; and furniture stores and hotels—less than 1.

2. Parking accumulation in downtown areas generally peaks between 11:00 AM and 2:00 PM. Peaking periods of other activities (shopping centers, sports arenas, theater districts, recreation areas) should also be studied and accounted for in adjusting parking supply to demand.

3. Total CBD parkers increase with urban population but at a diminishing rate. Cities of 100,000 have about 14,000 daily parkers; cities of one million, 36,000 daily parkers. A population increase of ten times results in only a 2.5 times increase in daily parkers.

As urban population size increases, the proportion of CBD trips for work and business increases proportionately, whereas those for shopping and all other purposes declines, meaning parking turnover declines also.

4. When trip purposes are known, approximately 0.50

parking space should be provided for each work trip and 0.15 parking should be provided for each nonwork trip.

5. Public transportation provides trips with no associated parking demand. Parking demand need be computed only on that portion of trips generated that use automobiles. Where public transportation does not exist, the proportion using automobiles will necessarily be higher.

6. Price of parking rises nearer to high-trip-generating land uses accounting for (1) the necessity to ration space through the pricing system so as to achieve supply-demand equilibrium, and (2) the opportunity cost of land that could be devoted to other high-value uses. The cost of providing parking varies according to the means used. A survey by the Secretary of the International Municipal Parking Congress reports these statistics on cost per space of constructing parking: open parking lots, $719; open deck garages, $2,270; and underground garages, $4,250. These are averages that are indicative of costs (*3-44*).

7. The average walking distance from place of parking to destination has been found to vary according to urban area population. The distance increases at higher population levels, ranging from about 400 ft in cities of 100,000 up to 650 ft in cities of 1 million and 800 ft in urban centers of 4 million. These figures reflect how far parkers *have* to walk. They would naturally prefer to walk the least distance necessary. How far they *will* walk probably matches the transit industry's rule of thumb that people will walk no further than ⅜ mile (1,980 ft) to a bus stop or presumably any other destination. This sets a size limit to parking lots serving any trip-generating land use. It also specifies an upper limit to the volume of cars that can be parked and, therefore, the upper level of trip-generating intensity of a land use (*3-4*).

8. Highway improvements, by lowering trip prices and increasing capacity, tend to increase trip volumes to high trip-generating areas such as CBD's and shopping centers. The effect is to increase the demand for parking. Simultaneously, the added accessibility will cause added land users to desire to locate there. Land values will rise due to (1) intensified land-use productivity, (2) competition for space by potential land users, and (3) demand for parking. Some open parking lots will be demanded for building, thereby reducing the supply of parking. Parking garages will be necessary to satisfy the demand. Their higher cost, parking demand, and competition for space producing higher land values will cause parking prices to rise, discouraging travel to the CBD and lowering demand. Equilibrium between supply and demand and a stabilization of trip generation eventually will occur. It is this interplay of forces that has (1) discouraged downtown shopping, (2) encouraged high-rise buildings that can justify the high price paid for land, (3) caused the amount of trip generation to stabilize or decline as auto travel is substituted for transit travel to the CBD, (4) led to demolition of buildings to satisfy parking demand, and (5) encouraged decentralization of enterprises and functions from the CBD.

Providing parking is a necessary concomitant to doing business or conducting any public or private enterprise in an auto-oriented society. The additional cost of providing incremental amounts of parking to accommodate added traffic generation encouraged by highway improvement, whether publicly or privately funded, should be considered as a marginal joint cost of the improvement. The systems effects of the improvement on parking prices, land use, decentralization, urban form, and aesthetics are other relevant considerations.

Gains and Utilities

1. To land owners:
   a. Higher land values if parking puts land to more productive use or increases productivity of land uses it serves.
2. To land users:
   a. Revenues and profit increases to operators of parking enterprises as demand rises due to highway improvement's traffic generation.
3. To community:
   a. Higher tax revenues due to more productive use of land in parking facilities or to nearby land because of the provision of parking.
4. To auto users:
   a. Provision of additional parking due to increased demand.

Costs and Losses

1. To landowners:
   a. Cost of providing parking or additional parking to satisfy increase in demand generated by highway improvement.
2. To land users:
   a. Higher rents to cover owner's cost of providing parking to serve land use.
3. To community:
   a. Potential taxes lost due to use of land for parking; generally a less profitable and productive use than others such as stores and office buildings.
   b. Tax loss due to decentralization encouraged by rising parking fees when a relocating land user locates outside its former jurisdiction.
   c. Subsidization of public parking to halt decentralization.
   d. Aesthetic effect of a discontinuous urban form broken by parking lots. Added walking distances.
4. To auto users:
   a. Increase in parking fees due to increased competition for parking space and cost of creating additional space.

Decision-Making Factors

1. Highway improvements that increase trip demands generate a joint demand for increased parking. Factors for evaluation include:
   a. Benefits and costs of providing additional parking in terms of both dollar costs and land required, especially in space-scarce areas such as the CBD, are basic considerations. Meyer, Kain, and Wohl (*3-37*, p. 298) have graphed the percentage of CBD land area required for parking and streets,

assuming parking on lots and in structures for various traffic levels. The correlated land values and property tax levels are also relevant.

b. Parking fee levels and their probable effect on user costs and impetus for decentralization should be examined.

c. On-street parking demand and maneuvering to enter such spaces reduces street capacity and efficiency; raises user operating costs while parkers usually avoid higher off-street fees.

d. The space required for all trip-generating land uses is increased in that parking space matching the generation levels must usually be provided.

e. Aesthetically, a dispersed and discontinuous urban form is created in which isolated individual buildings or building clusters are separated by or interspersed with the parking lots serving them. Walking distances are increased.

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CATEGORY: 4. Community Government
VARIABLE: A. Community Services and Facilities

Area:	Urban
Type of Consequence:	Economic
Location of Impact:	Right-of-Way Corridor
Timing of Impact:	During Construction After Construction—Short Term

Consequences

The efficiency of operation of community facilities and services may gain or lose from the effects of a highway improvement according to (1) the pattern of population movement responding to the improvement's effect on accessibility of residential area, (2) the amount of displacement resulting from rights-of-way takings, and (3) the relative accessibility of the service or facility to its service area, considering the expanded accessibility offered by the improvement and contracted accessibility due to the barrier effect.

1. Population movement may occur as a result of the improvement's increasing access to more desirable residential areas. Migration may occur to lower the population of the area or change its socio-economic composition. The demands placed on community facilities in the area receiving the population influx will cause them to appear inadequate, diminish their efficiency by overloading, and call for capital investment to expand their capacity. The out-migration area may lose population or have a change in socio-economic characteristics that results in more or less use of the services and facilities demanded by the former population. If services and facilities in an area lose patronage, they may become under-utilized and be left with excess capacity.

2. Population displacement may also reduce the efficiency of some services and facilities by reducing their patronage. On the other hand, the patrons of displaced facilities may increase patronage of the remaining ones, and overload them, thus creating inefficiency from that source. New facilities may be required where population increases.

3. Relative accessibility to various services and facilities is changed by the improvement, thereby changing service area boundaries.

Access may be expanded by the lesser time and cost to reach the facility over the improvement, thus enlarging the service area and patronage, perhaps to the point of overload.

The barrier effect of limited-access improvements may cut off patrons of former service areas, reducing patronage for some facilities while increasing it for others. The new level of patronage may, according to circumstances, settle at the efficient optimum, or be inefficient due to overloading or under-utilization.

The provision of new facilities or their relocation or replacement through joint development may help overcome disparities between patronage and optimum operating levels. Inefficiency, and economic and social costs could be reduced thereby.

Gains and Utilities

1. To government:
   a. Change in population or accessibility resulting from the highway improvement may raise or lower patronage of community services or facilities to their approximate optimum levels where they operate most efficiently.
   b. Removal of obsolete facilities.

Costs and Losses

1. To government:
   a. Change in population or accessibility may cause a service or facility to become inefficient either through losing patronage excessively (under-utilization, excess capacity) or gaining excessive patronage (congestion, volume exceeds capacity).

Decision-Making Factors

1. Effects on the community facilities and services and their patrons and employees due to dislocation of facilities, changed accessibility, changed levels of patronage, and inefficiencies due to improvement-induced population change.

2. Net cost to community to restore services to their former level.

3. Opportunity afforded by the highway improvement to increase or to improve the use and accessibility of community services.

CATEGORY: 4. Community Government
VARIABLE: B. Park, Recreation, and Open Space

Area:	Urban
Type of Consequence:	Economic and Social
Location of Impact:	Right-of-Way
Timing of Impact:	During Construction After Construction—Short Term After Construction—Long Term

Consequences

Rights-of-way takings may involve taking of park, recreation, and open space. The taking of such space is rational from the highway agency's viewpoint for a number of reasons: (1) it incurs none of the economic or social costs of dislocating households and businessess, (2) it avoids the cost of demolishing structures, and (3), being in the public domain, it can be acquired at little or no cash cost and without condemnation proceedings. On the other hand, some urban freeways create a corridor of open space by the removal of buildings that are replaced with a wide depressed highway or low-level highway compared with the height of the structures removed.

From the viewpoint of residents of the vicinity, and the city government, however, the taking may represent social and economic costs that loom large alongside these economies. One column in Table B-14 gives the amount of public open space in Chicago in 1956 by two-mile rings outward from the Loop. It is evident that open space is scarcest toward the center where residential densities are greatest. It grows in abundance toward the periphery where the densities are progressively lower. Taking of parkland in various locations will therefore have a differential impact according to its degree of scarcity relative to the user population, having greater impact toward the center, less toward the periphery.

Where encountered in built-up areas, green open space is a *scarce resource* desirable for the health and well-being of residents for its recreational and aesthetic values. Its depletion represents a social cost in terms of limiting the opportunities of urban dwellers to enjoy these benefits. Taking scarce and often irreplaceable urban public open space may have a higher long-run social cost than taking an equivalent amount of built-up land that is not relatively scarce and whose occupants can usually find alternative space in vacancies available in the real estate market or provided through new building. Their temporary discomfort must be compared with that of generations of future residents deprived of open space.

The economic cost of supplying urban open space is extremely high. Some land users can offset land scarcity through intensifying the use of available space through high-rise buildings. Use of green open space, however, can be intensified only by crowding its users at the expense of diminishing its primary qualties—greenness, openness, and spaciousness. Its true economic cost is the cost to replace it for, at least, its user population. (Its "replacement" for another set of users in another location causes it to appear that no compensation was made to the user group.)

The low cost of parkland to the agency acquiring it for highway use thus understates its true "cost" in resource, social, and economic terms. Its proper social cost is a combination of (1) the deterioration in mental and physical health that attends the absence of physical exercise and infrequent contact with nature, (2) the extra effort and cost of travel to the nearest alternative open-space facility if one is removed, (3) the atmospheric deterioration that occurs without the presence of vegetation to absorb nitrogen oxide and generate oxygen in creating a symbiotic atmospheric balance, and (4) the loss of amenity and property values to the extent that the presence of open space had contributed to both for abutting residents.

In support of the foregoing interpretation of the economic cost of parkland the Committee for Economic Development has proposed the following guideline for the evaluation of public or semi-public land taking for rights-of-way (*4-3*, pp. 43-44):

> Where public or semi-public lands not normally transferred in the free market are condemned for transportation rights-of-way, they should be valued at a full opportunity cost, that is, the full cost of replacing the values destroyed by the transfer of property. Only in this way is it possible to make sure that the use of eminent domain does not result in a less valuable use replacing a more valuable use.

Gains and Utilities

1. To park users:
   a. Parkland purchased to compensate for any taken; offsetting only if the same user group is affected.
2. To highway agency:
   a. Right-of-way cost economization by avoiding residential dislocation, structure demolition, and purchase of private property.
3. Creation of open space in the freeway corridor.

Costs and Losses

1. To park users:
   a. Social cost of reduced space or opportunity for recreation and aesthetic enjoyment: reduction in physical and mental health.
   b. Social cost of atmospheric deterioration due to lack of vegetation to create symbiotic balance between oxygen and nitrogen oxide.
   c. Economic cost of added time, energy, and money of seeking alternative open space to use.
2. To government:
   a. Economic cost of replacement by government purchase and development of additional open space to replace that taken.
3. To landowners (abutting):
   a. Land value loss to extent increased by the presence of open space.

Decision-Making Factors

1. Recreation and open space taking for right-of-way. Replacement cost.
2. Recreation and open space taking that:
   a. Creates costs of replacement or added accessibility costs in excess of alternative nonopen space land (*4-4*).
   b. Creates drastic discrepancies between after-taking

open space availability and accepted standards of open space requirements (*4-2, 4-4*).

3. The U.S. Code and Department of Transportation Act as amended by the *Federal-Aid Highway Act of 1968* (*4-11*):

PRESERVATION OF PARK LANDS

Sec. 18. (a) Section 138 of title 23, United States Code, is amended to read as follows:

§ 138. Preservation of parklands

It is hereby declared to be the national policy that special effort should be made to preserve the natural beauty of the countryside and public park and recreational lands, wildlife and waterfowl refuges, and historic sites. The Secretary of Transportation shall cooperate and consult with the Secretaries of the Interior, Housing and Urban Development, and Agriculture, and with the States in developing transportation plans and programs that include measures to maintain or enhance the natural beauty of the lands traversed. After the effective date of the Federal-Aid Highway Act of 1968, the Secretary shall not approve any program or project which requires the use of any publicly owned land from a public park, recreation area, or wildlife and waterfowl refuge of national, State, or local significance as determined by the Federal, State, or local officials having jurisdiction thereof, or any land from an historic site of national, State, or local significance as so determined by such officials unless (1) there is no feasible and prudent alternative to the use of such land, and (2) such program includes all possible planning to minimize harm to such park, recreational area, wildlife and waterfowl refuge, or historic site resulting from such use.

(b) Section 4(f) of the Department of Transportation Act (80 Stat. 081; Public Law 89-670) is amended to read as follows:

(f) It is hereby declared to be the national policy that special effort should be made to preserve the natural beauty of the countryside and public park and recreation lands, wildlife and waterfowl refuges, and historic sites. The Secretary of Transportation shall cooperate and consult with the Secretaries of the Interior, Housing and Urban Development, and Agriculture, and with the States in developing transportation plans and programs that include measures to maintain or enhance the natural beauty of the lands traversed. After the effective date of the Federal-Aid Highway Act of 1968, the Secretary shall not approve any program or project which requires the use of any publicly owned land from a public park, recreation area, or wildlife and waterfowl refuge of national, State, or local significance as determined by the Federal, State, or local officials having jurisdiction thereof, or any land from an historic site of national, State, or local significance as so determined by such officials unless (1) there is no feasible and prudent alternative to the use of such land, and (2) such program includes all possible planning to minimize harm to such park, recreational area, wildlife and waterfowl refuge, or historic site resulting from such use.

4. Bureau of Public Roads *Policy and Procedure Memorandum 50-9-67, Urban Transportation Planning*, dated June 21, 1967 (*4-10*, p. 8):

j. Social and community value factors

(1) In the development of transportation plans, it is important that full consideration be given to the possibility of utilizing these facilities to raise the standards of the urban area. Open space, parks, and recreational facilities are important environmental factors. It is becoming more and more important in our transportation planning that additional attention be given not only to the preservation and enhancement of existing open space, but also to the providing of additional open space in anticipation of future development. Similarly, conscientious attention should be given to the preservation of historical sites and buildings.

CATEGORY: 4. Community Government
VARIABLE: C. Nonhighway Government Revenue and Expenditure Changes

Area:	Urban
Type of Consequence:	Economic
Location of Impact:	Right-of-Way
	Corridor
	Community or System
Timing of Impact:	Before Construction
	During Construction
	After Construction—Short Term
	After Construction—Long Term

Consequences

Highway improvements have these impacts on local government tax revenues and expenditures:

1. Revenues:
   a. There is a direct loss of tax revenue from properties condemned for right-of-way.
   b. There are indirect losses due to decline in market values and associated assessed values and tax revenue due to:
      (1) Deterioration in property condition due to uncertainty concerning timing and location of right-of-way taking.
      (2) Property values may decline within the proposed right-of-way taking line due to deterioration and out-migration in anticipation of demolition.
      (3) Blighting effect of highway on property in proximity.
      (4) Out-migration of a higher-income group due to new suburban accessibilities and replacement by a lower one.
      (5) Trade losses in commercial properties due to population or income group out-migration, which commerce follows.
      (6) Lower-order uses substituting for higher ones encouraged to migrate to more advantageous land supply, land prices, markets, property taxes, and accessibility elsewhere. Wealth-producing industrial uses and wealth-distributing commercial ones may be reduced in central areas by decentralization following highway improvements.
      (7) Parking demand in urbanized areas may change land from higher- to lower-order values represented by parking lots and garages. Limitation on available parking space reduces accessibility and intensity of land use to match parking capacity; limited parking space is rationed among those willing to pay for it at high cost. Cost is relatively high due to the existence of higher-value alternative uses of the land.

(8) The growing predominance of tax-free institutional and public uses in the tax base as wealth-producing and -distributing enterprises and high-income consumers migrate to outside the central jurisdiction. Institutions can afford to bid for convenient central space deserted by taxpaying uses with the savings in operating costs produced by their tax-free status.

c. There may be some direct recovery of tax-ratable land loss from:
   (1) Joint use of air-rights space over or under highways that can be taxed by the jurisdiction.
   (2) The substitution of high-value for low-value uses in the process of joint development projects. There may be added spillover effects as neighboring areas upgrade to match the new development.

d. There are indirect gains due to rise in market values and associated assessed value and property tax revenue due to:
   (1) The enhancement of property in the vicinity of the highway due to improved transportation service and its aesthetic treatment (e.g., landscaping, parkway, beautification).
   (2) Improvement and refurbishing of areas due to being exposed to the view of traffic using the facility.
   (3) In-migration of higher-income groups due to accessibility change.
   (4) Trade gains in commercial properties due to population or income group immigration that commerce follows, locating, relocating, and expanding to match buying power and demand.
   (5) Higher-order uses substituting for lower ones, encouraged to migrate in due to more advantageous land supply, land prices, markets, and accessibility. Additions in outlying areas of wealth-producing industrial uses, and wealth-distributing commercial ones.
   (6) Parking demand that changes land from a lower- to a higher-order use—the usual case in rural areas in the process of being urbanized.
   (7) The low incidence of tax-free institutional and public uses relative to the predominant tax-producing production and distribution enterprises and housing.

2. Expenditures:
   a. Increases in local government expenditures arising due to highway construction include:
      (1) Increase in public services (police, fire, building inspection and code enforcement, health, refuse collection) due to rise in vandalism to vacated structures, crime, debris and rubbish accumulation, and unsanitary conditions. These result from accelerated deterioration and numerous vacancies in the right-of-way in the period prior to demolition.
      (2) Expenditure increases to adjust public service areas and levels to the new demand conditions and patterns created by the highway improvement. This includes shifts in population and income groups due to displacement, altered densities and settlement patterns, and changed accessibilities, plus the effect of the highway in creating a barrier and in displacing former public service facilities.
      (3) Expenditure increases to serve the added trip generation induced by the highway improvement (e.g., for street and highway maintenance, lighting, police patrols and traffic courts, public parking, air pollution control agencies, aerial traffic surveillance, traffic information broadcasting, electronic traffic monitoring, public transportation subsidies, and emergency services to accident victims).
      (4) Long-term expenditures arise from decentralization of industry, commerce, and population.

Peripheral expansion of urbanizable land is made possible by high-speed, high-capacity highways. Capital expenditures increase in the urbanizing areas to provide needed public facilities (e.g., streets, parks, sewers, water, fire protection, schools). In the older central-city areas expenditures increase to service the lower-income groups that have replaced the decentralizing higher-income ones. The increased expenditures are for welfare; special health, poverty, and education programs; employment services; added fire and police protection; sanitation services, code enforcement; public housing; and urban renewal. According to *The Municipal Year Book 1968* (*4-8*), the urban functions for which expenditures showed the greatest percentage change from 1956 to 1965-66 were housing and urban renewal (241 percent); general public buildings (142 percent); airports (129 percent); education (122 percent); public welfare (119 percent); and libraries (109 percent). With the exception of airports, the changes reflect the changing population composition of cities and the rising need for services for a lower-income population.

Gains and Utilities

1. To government:
   a. Increased revenues from highway-influenced changes in land use and the demand levels for same; increased productivity of existing land use due to increased access or efficiency of operation; and air space and joint development projects.
2. To residential taxpayers:
   a. Highway-influenced introduction of high-value land uses (e.g., industrial and commercial) that lowers, or reduces the rate of increase in, taxes or residential property.

Costs and Losses

1. To government:
   a. Reduced revenues from: loss of taxable property to highway right-of-way; out-migration of high

tax-producing land users influenced by highway-induced changes in accessibility; increasing share of nontaxable or low-tax uses in the total tax base due to such migration; deterioration of property in proposed rights-of-way.
   b. Increased expenditures due to changing socio-economic composition of population; blighting effect of prolonged period between route selection and right-of-way taking; services to increased traffic generation; and adjustment of public services and facilities to account for new accessibility patterns and right-of-way takings.
2. To taxpayers:
   a. Increased taxes or diminished services to compensate for highway-influenced losses in tax base and increased demand for traffic services.

Decision-Making Factors

1. Net balance between highway-influenced revenue and expenditure increases and reductions, whether positive or negative.

CATEGORY: 4. Community Government
VARIABLE: D. Public Policy and Laws

Area:	Urban and Rural
Type of Consequence:	Economic and Social
Location of Impact:	Right-of-Way
	Corridor
	Community or System
	Region or Nation
Timing of Impact:	Before Construction
	During Construction
	After Construction—Short Term
	After Construction—Long Term

Consequences

Highway improvement has accommodated growing traffic demand by both a growing number of highways and their increased physical scale. The accommodation has, in turn, encouraged still further increases in traffic demand. Inevitable conflicts have arisen over various impacts of improvements. Such conflicts have often been relegated to the political arena for settlement. Public policy and laws have resulted from these conflict resolutions. Highway planners use such laws and policies to guide route location choices and execution of improvement programs.

Typical of the consequences of highway improvement that have become the subject of public policies and laws is the following partial listing:

1. Community impacts:
   a. Joint development projects.
   b. Joint use of right-of-way (air rights).
   c. Parkland taking restrictions.
2. Household and business impacts:
   a. Relocation assistance.
   b. Moving cost compensation.
3. Environmental impacts:
   a. Air pollution controls.
   b. Highway beautification.
   c. Noise controls.
4. Rural impacts:
   a. Appalachia highway program.
5. National defense impacts:
   a. Civil defense route designations.
6. Localized impacts:
   a. City planning.
   b. Zoning ordinances.
   c. Public parking.

Gains and Utilities

1. To community:
   a. Resolution of conflicts or problems raised by highway improvement impacts via public laws and policies that provide remedial actions.

Costs and Losses

1. To community:
   a. Additional taxes and adjustments necessary to comply with or support remedial actions called for by public laws and policies.

Decision-Making Factors

1. What laws and policies are available to resolve conflicts, supply alternative solutions, guide route location choice, and provide compensation to those paying an inordinate share of the costs without offsetting benefits should be considered in making route location choices and framing strategies for their implementation.

CATEGORY: 4. Community Government
VARIABLE: E. Community Goals

Area:	Urban and Rural
Type of Consequence:	Economic and Social
Location of Impact:	Right-of-Way
	Corridor
	Community or System
	Region or Nation
Timing of Impact:	Before Construction
	During Construction
	After Construction—Short Term
	After Construction—Long Term

Consequences

Community goals express a vision of some desired future state of a community—economic, social, physical, and aesthetic. Goals are an expression of community values, those values held in common by a majority of the members of the community. Together they determine the community's collective behavior expressed usually through their political representatives or in public hearing assembled, when faced with choices, challenges, and changing conditions.

Goals are highly variable from community to community—differing according to the values of citizens, the scale of the community, its historical and geographical perspectives, present condition, and future prospects.

In an attempt to define the precise nature of community values, a literature search was undertaken as part of NCHRP Project 2-1 (*4-1*) at the University of Washington. The intent was to explicitly identify and gauge the relative weight of various community values as viewed by "experts" from specializations dealing with urban communities. The values were identified and measured according to the frequency of their mention in the literature generated by these experts. From this review, the following ten major value categories and their definitions were drawn:

1. Community—human interaction, face-to-face contact, a general sharing among friends and neighbors, a sincere interest in the welfare of the area, and an attitude of civic pride and responsibility.

2. Aesthetics—values that relate mainly to the visual experience of the city or community, civic order, art, nature, general aspects of urban beauty, and other statements and remarks on the city that pertain to the fine arts and indigenous culture.

3. Free choice—the opportunity to choose; it implies the right to select from among a broad range of both public and private goods and services, involving many facets and situations of urban life (place and type of residence, employment, recreation, etc.).

4. Identity—the value of identifying oneself with, of belonging, of relating, and of orienting to an area in such a fashion as to have a satisfactory sense of self.

5. Economic base—employment, business, industry, taxes and revenues, the market, and any statements that bear directly on an area's economic well-being.

6. Convenience—value statements that relate primarily to access and accessibility, and expressions such as "readily available" and "human scale" (walking distance).

7. Administration—values pertaining to government or control of the community, and any statements implying organization, planning, or social regulations (e.g., such value statements as "efficiency of urban government," "physical organization," and "good laws").

8. Community facilities—value statements that relate to municipal public services, including schools, parks utilities, and roads and streets, but excluding housing, shopping, and industrial plants and other "private sector" facilities.

9. Accommodation for future growth—value statements dealing with accommodating to future development, "growth," and "change."

10. Optimum life style—values that denote maximizing the "good life" on a personal, individual scale such as "privacy," "prestige," "personal reward," and "residential living space" (*4-1*).

Lacking the more precise estimation of the relative weighting of urban values, frequency of mention in the two bodies of literature reviewed was taken as an index of each value's relative importance. The two classes of works were: (1) "critical 'Utopian' literature concerning the human values significant for life in the urban context, and (2) the value premises stated by planners in the presentation of actual urban plans" (*4-1*). The resulting table is reproduced as Table B-10.

The previous listing is not exhaustive but forms an example of some of the more universal community values encountered. Other listings have appeared in highway literature. "Transportation and Community Values" was the subject of a 1969 conference arranged by the Highway Research Board, which published the proceedings (*4-6*). The conference stressed the desirability, if not the necessity, of aligning transportation goals with community goals, causing the two to be complementary where possible and not to seriously violate the latter where conflicts arise.

Conflicts between transportation and goals and between goals themselves inevitably occur. Means proposed for their resolution have been varied. They have included:

1. Conducting attitudes surveys to anticipate and avoid potential conflict (*4-5*).

2. Communication and negotiation with local governments and citizen groups (*4-6*).

3. Comparison of transportation capabilities and effects with community goals to determine the degree to which the goals are affected positively or adversely by a transportation mode or route location (*4-9*).

4. Rating and weighting of goals to determine their relative significance in the decision process (*4-7*).

Gains and Utilities

1. To community:
    a. Fulfillment of community goals where highway improvements are supportive or complementary.

Costs and Losses

1. To community:
    a. Nonfulfillment of community goals where highway improvements are in conflict or are non-complementary.

Decision-Making Factors

1. Community goals, as revealed by attitude surveys, hearings, city plans, leaders, etc., considered relative to the effect of highway improvements on such goals—whether in conflict or in harmony. Hill (*4-7*) proposes three sets of community goals as relevant: (1) those affecting the highway user, (2) those affecting persons in proximity to the improvement, and (3) those affecting the system or community as a whole. The following are some typical considerations:

    a. User goals:
        (1) Efficiency of motor vehicle operation.
        (2) Dependability of travel time and route.
        (3) Flexibility of trip planning and execution.
        (4) Orientation and directness of route.
        (5) Safety of travel.
    b. Neighborhood goals:
        (1) Environmental factors (noise, vibration, light, pollution).
        (2) Aesthetic contribution.
        (3) Social exchange.
        (4) Neighborhood activity.
        (5) Access to community facilities.
    c. Community goals:
        (1) Economic growth.
        (2) Community development.
        (3) Master plan implementation.

TABLE B-10

FREQUENCY OF MENTION AND INDEX OF RELATIVE EMPHASIS OF VALUES EXPRESSED IN URBAN "UTOPIAN" LITERATURE AND URBAN MASTER PLANS [a]

	FREQUENCY OF MENTION		INDEX OF RELATIVE EMPHASIS	
VALUE CATEGORY	"UTOPIAN" LITERATURE	MASTER PLANS	"UTOPIAN" LITERATURE	MASTER PLANS
Community	89	9	2.0	0.3
Aesthetic	79	24	1.8	0.7
Free choice	65	2	1.4	0.1
Identity	61	19	1.4	0.6
Economic base	56	70	1.2	2.1
Convenience	53	33	1.2	1.0
Administration	36	28	0.8	0.8
Community facilities	27	88	0.6	2.7
Accommodation for future growth	13	34	0.3	1.0
Optimum life style	13	23	0.3	0.7
Total	492 [b]	330 [b]		
No. of documents	45	33		

[a] Source: (*4-1*).
[b] Two hundred and eighty value statements were identified in the 45 "Utopian" documents. Some of these were coded into more than one value category, thus producing the 492 figure used in the analysis. Two hundred and fifty-five value statements were identified in the 33 master plans, and these were coded into the 330 figure.

(4) Traffic pattern improvement.
(5) Opportunities for jobs, housing, shopping.

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CATEGORY: 5. Construction
VARIABLE: A. Community Social and Economic Effects During Construction

Area:	Urban
Type of Consequence:	Economic and Social
Location of Impact:	Right-of-Way Corridor Community or System
Timing of Impact:	During Construction

Consequences

During highway construction, local residents, businesses, and industrial plants may suffer costs, lost trade, and inconvenience due to access limitations and detours. A Texas study (*5-2*, pp. 4, 12) showed "Many businesses were hurt during the construction period" (of a highway median).

The dust, noise, dirt, vibration, and congestion created by machinery and trucks serving the construction site may lower environmental quality.

Gains and Utilities

1. None known.

Costs and Losses

1. To neighborhood and community:
   a. Costs and inconvenience due to detours, access limitations, and nuisance effects.

Decision-Making Factors

1. Number of those residents or enterprises temporarily bearing costs of inconvenience and nuisance of highway construction.
2. Effects on transportation costs by all modes.

CATEGORY: 5. Construction
VARIABLE: B. Immediate Effects on Highway Construction Industry

Area:	Urban
Type of Consequence:	Economic
Location of Impact:	Community or System Region or Nation
Timing of Impact:	During Construction

Consequences

Highway improvements produce immediate and direct economic benefits to the highway construction industry in the form of contracts and employment, wages and profits.

A Vermont study (*5-1*) attempted to determine the initial respending pattern of monies paid out for Interstate highway construction in that state. It was proposed that this first round of spending represented the immediate economic benefits from highway construction. The study concluded that, of every million dollars expended for constructing the Interstate highway system in Vermont, 72.7 percent will go into the state's economy (*5-1*, p. 20).

There is doubtless a multiplier effect as the injection of highway construction money goes through second and third rounds of spending. Expenditures may relieve local depressed economies.

Inflationary effects may be experienced if the amount of money released into the community by construction expenditures sets up demands in excess of those the market has the ability to supply.

Gains and Utilities

1. To construction industry:
   a. Wages and profits from highway improvement expenditures.
2. To state and local economies:
   a. Sales of consumer goods and construction materials due to construction industry spending of funds received for highway construction.

Costs and Losses

1. To road users:
   a. Revenues to support road improvement programs.

Decision-Making Factors

1. Impact of highway improvement expenditure on the construction industry and on state and local economies should be considered a primary economic benefit.
2. Other impacts to be considered: multiplier effects due to second-round spending, possible inflationary effects and impact on economically depressed regions.

CATEGORY: 5. Construction
VARIABLE: C. Long-Run Effects on Nonhighway Construction Industry

Area:	Urban
Type of Consequence:	Economic
Location of Impact:	Community or System Region or Nation
Timing of Impact:	After Construction—Short Term After Construction—Long Term

Consequences

In the long run, highway improvement has a continuing effect on the construction industry under conditions of population and/or economic growth by: (1) making accessible undeveloped land for industrial and commercial location and residential settlement, and (2) the users of the facility forming a market for roadside gas-food-lodging services. The construction of buildings locating or relocating to capture the advantages of improved access created by the new highway brings employment, wages, and profits to the construction industry and its suppliers.

Gains and Utilities

1. To construction industry:
   a. Wages and profits as the development potentials the highway improvement created are realized in new construction.

Costs and Losses

1. None known.

Decision-Making Factors

1. Development potentials created by the highway improvement that will result eventually in construction.

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CATEGORY: 6. Employment
VARIABLE: A. Employment Change Due to New Land-Use Development

Area:	Urban and Rural
Type of Consequence:	Economic
Location of Impact:	Corridor Community or System
Timing of Impact:	During Construction After Construction—Short Term After Construction—Long Term

Consequences

Changes in the level of employment, related to highway improvement, can occur due to the influence of changed accessibility on land-use development.

Extractive and agricultural employment may be increased by roads offering access to resource-rich land areas (e.g., mining roads, forest roads, farm-to-market roads) (*6-7*, pp. 148, 152).

Industrial employment has been enhanced by facilitating access to inputs (raw materials, labor, land) or to markets for the output. Theoretically, a plant producing a product whose shelf price includes a significant amount of transportation costs will select a median location where total shipping costs for both inputs and the output are at the feasible minimum. Industries with bulk-reducing processes will often locate near their raw material source (e.g., metals). Bulk-adding industries usually locate near their markets (e.g., soft-drink bottlers).

As shipping costs and times have been progressively reduced by highway improvements, transportation costs have shrunk as a proportion of the final price of many goods. Other inputs, such as labor costs, have grown in proportion, leading to plant migrations to where the most expensive inputs could be economized (e.g., the movement of northern industry to the South). This "footlooseness" was previously available only to industries with no or few transportation costs, such as research and development and electronics. With widespread "footlooseness," location decisions are increasingly being based on human factors such as quality of housing; public services and schools; availability of cultural, recreational, and educational opportunities; and climate.

The most obvious influence of highway improvement on employment has been the attraction of industrial and commercial firms to metropolitan radial and circumferential expressways and freeways and their interchanges. Linear employment corridors are being formed alongside such facilities. These locations offer the advantages of: (1) access to a diverse and skilled labor market; (2) access to sources of inputs and services; (3) access inward to the local metropolitan market and outward, over the Interstate system, to regional and national markets; (4) an abundance of relatively inexpensive land needed for space-extensive plant layouts, employee parking and future expansion; and (5) plant visibility from the highway for advertising and "image" enhancement (*6-1, 6-4, 6-6*).

Commercial employment relates to the location of a resident population or a mobile one using the highway for commutation, tourism, or other purposes. The attraction of improved highways to basic industries has brought about residential development for industrial employees. Residential development has, in turn, created opportunity for commercial development to serve residents and highway users and increased employment in the retail, wholesale, and service sectors.

Construction, government, and automotive sales and service employment are other beneficiaries of new land-use development and the ensuing traffic generation.

Lowered travel times have enabled farmers to become employed part- or full-time in industrial plants by extension of the urban commuter radius or plant relocations away from the urban center or in small towns.

Lower travel times also have opened some rural areas to tourism and recreational developments and their attendant employment opportunities (*6-7*, pp. 154-63).

Gains and Utilities

1. To employers:
   a. Access to a large labor market with varied skills.
   b. Ease of commutation by employees over improved highways with beneficial effects on morale and productivity (*6-7*, p. 66).
2. To employees:
   a. Increased employment opportunities.
   b. Lower commutation costs.

Costs and Losses

1. To employers:
   a. Difficulty in attracting low-skill, low-wage employees in noncentral locations unserved by public transportation (*6-7*, p. 66).
2. To employees:
   a. Loss of nearby employment opportunities offered by firms relocating to capture highway improvement advantages.

Decision-Making Factors

1. Land-use development potential and trends in areas to be made more accessible by highway improvements can be examined. Attention is in order to untapped resources, labor availability, buildable land supply, access to input suppliers and output markets, and attractiveness of "human factors" (amenities, climate, etc.). Land-use development, in turn, produces employment whose levels can be estimated on the basis of the type and intensity of land use predicted for the impacted area. Employment is enhanced by highway improvements in areas having the most development potential (*6-5*).

CATEGORY: 6. Employment
VARIABLE: B. Employment Change Due to Dislocation and Relocation

Area:	Urban and Rural
Type of Consequence:	Economic
Location of Impact:	Right-of-Way Corridor Community or System
Timing of Impact:	Before Construction During Construction

Consequences

Changes in local employment levels occur due to geographic shifts by employing plants or firms within a localized area such as a city or metropolitan area. In this case there is no over-all increase in area employment as there is when highway improvement attracts new industry or taps new resources. In fact, the tendency is toward over-all employment reductions in that employers often use a move as an opportunity to introduce new labor-saving machinery and processes. There is a further loss from firms that are influenced by dislocation to quit business. Offsetting these losses are firms that increase capacity and employment on relocation (*6-1*).

Highway improvements induce this sort of employment change through (1) dislocation of enterprises by right-of-way takings, (2) firms relocating voluntarily to capture the access advantages offered by the highway improvement, and (3) firms moving to follow their decentralizing residential market or a mobile market that bypasses the former location.

Relocation of enterprises changes the money cost and travel time of the journey-to-work for employees and may discourage some from following the firm to its new location where costs or time en route rise. This condition creates particular hardships for low-income workers whose incomes do not permit residential decentraliaztion or long commuting to follow places of employment.

Decline in central-area job availability may mean unemployment, unemployment compensation, underemployment, or employment at a lower-skilled job than the worker's training and ability warrants, resulting in lower income to the worker. To the economy, there is a loss of potential productivity from human resources.

Employers, too, are handicapped by the restriction of their labor markets. Some decentralized enterprises employing large numbers of blue-collar workers find few such employees can reach them conveniently or economically (*6-3*, pp. 69-70).

Obversely, decentralizing commerce and industry lowers, by proximity, the travel time and cost of some suburban residents. Increasing suburban job availability spells more and better job opportunities for those residing there in that suburban employers often are the sort offering white-collar and skilled labor employment (*6-3*, pp. 63-64). Improved highways typically increase the commuting radius and further broaden the job market for suburban residents (*6-3*, p. 79).

Gains and Utilities

1. To employers:
   a. Opportunity to modify operations, capacity, and employment in the process of dislocation, and/or relocation due to highway improvement.
   b. Accessibility to skilled and white-collar labor in suburban locations.
2. To employees:
   a. Increased employment opportunities due to relocating enterprises.
   b. Lower commutation time and travel costs to relocated employment opportunities.

Costs and Losses

1. To employers:
   a. Difficulty of hiring low-wage workers in non-central locations following decentralization.
2. To employees:
   a. Increased commutation time and cost to relocated employer, or cost of moving residence to be near employment.
   b. Decreased job availability where dislocation or relocations have reduced the number of employers within commuting range.
   c. Unemployment or underemployment where unable to find replacement job opportunity after migration of former employer; plus cost of seeking a new job.

Decision-Making Factors

1. To be considered are the number and employment levels of firms likely to be dislocated or influenced to relocate due to a highway improvement and the impact likely to accrue to local-area job markets as a result.

2. Type of employees (white/blue collar), their wage and skill levels, and what difficulties and costs they are likely to experience in finding and commuting to alternative employment are added considerations.

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CATEGORY: 7. Environment
VARIABLE: A. Noise

Area:	Urban and Rural
Type of Consequence:	Economic and Social
Location of Impact:	Corridor
Timing of Impact:	During Construction After Construction—Short Term After Construction—Long Term

Consequences

Vehicular noise is a nuisance effect of highway improvements that increases as traffic volumes and speed of traffic increase. The effects include disturbed sleep, reduced efficiency, frayed nerves, dampened dispositions, interrupted conversations, and possibly deafness. Public health, economic productivity and the quality of private and community life are adversely affected (*7-7*, pp. 75-77).

Research findings have revealed the following highway-related sources and characteristics of traffic noise:

1. Sound from trucks is the most objectionable highway disturbance (*7-1*, p. 2).

2. A sound-disturbance threshold level exists above which more people living near expressways will find the noise disturbing than not. This threshold level occurs at about 68.5 dBA (*7-1*, p. 35). The threshold for farmers is about 10 dBA lower because the background sound level is 10 dBA lower (*7-1*, p. 71).

3. Highway depression and elevation markedly affect sound levels emanating from highways. Highway depression is the most effective reducer of sound level. Landscaping reduces sound only slightly (*7-1*, p. 2).

4. Dwellers in high-rise apartment houses adjacent to limited-access highways found sound disturbance most objectionable. Apartment owners usually lowered the rent of units facing the highway in compensation (*7-1*, p. 2).

5. No significant correlation was found between land values and highway noise by two studies that investigated this aspect (*7-1*, p. 22; *7-2*, pp. 185-98). Many persons made expenditures for air conditioners, insulation, and landscaping to deaden the noise from nearby expressways, however (*7-1*, pp. 167-88).

6. People living in more expensive houses tended to find highway-related disturbances less acceptable than did persons living in older, less-expensive homes (*7-1*, pp. 2, 35).

7. Noise levels tend to increase with increase in traffic volumes (*7-2*, p. 247).

8. Trucks with defective mufflers caused 40 percent of the "excessive" noise in New York City in 1965. High speeds and rapid acceleration are other causes of vehicular noise (*7-7*, p. 77).

Gains and Utilities

1. To apartment tenants:
    a. Reduced rents for apartments facing nearby expressways.
2. To residents near highways:
    a. Increased attractiveness and utility of property where noise levels of highway in proximity are reduced by depressing or landscaping.

Costs and Losses

1. To residents near highways:
    a. Detriment to health, economic productivity, and environmental quality caused by highway noise.
    b. Expenditures for sound-deadening devices to insulate dwelling from highway noise.
2. To highway department:
    a. Cost to depress or landscape highway to reduce sound levels for nearby properties.

Decision-Making Factors

1. Number and location of residential units likely to suffer disturbance from highway noise exceeding the threshold levels (68.5 dBA—urban; 58.5 dBA—rural).

2. Cost to alleviate highway noise through (1) private expenditure for sound-deadening devices, (2) public expenditure for depressing grade or landscaping.

CATEGORY: 7. Environment
VARIABLE: B. Air Pollution

Area:	Urban
Type of Consequence:	Economic and Social
Location of Impact:	Corridor
	Community or System
	Region or Nation
Timing of Impact:	After Construction—Short Term
	After Construction—Long Term

Consequences

Highway-transportation-related air pollution is the result of the exhaust emissions of automotive vehicles' internal combustion engines. Motor vehicles accounted for an estimated 60.6 percent of total U.S. air pollution in 1966 (*7-8*, p. 11). The components of automotive emissions contributing to air pollution include carbon monoxide, nitrogen oxides, hydrocarbons, sulfur oxides, lead compounds, and particulates.

Individually and in combination these chemical gases and solids have the following effects on:

1. Human health.—Reduced cognitive and psychomotor performance; eye and respiratory tract irritation; chronic respiratory disease; possibly liver and kidney malfunctions; disturbed enzyme activity; and even death (*7-3, 7-4, 7-8*, Pt. I, pp. 14-15).

2. Vegetation.—Crop damage and blighting with air pollution caused cash crop losses of from $6 million to $10 million annually in California alone (*7-8*, Pt. 1, p. 15).

3. Property damage.—Deterioration of materials, including building materials, rubber, textiles, and dyes, occurs from air pollution (*7-8*, Pt. I, p. 15).

4. Weather modification.—Burning of fossil fuels as in automotive vehicles raises the level of carbon dioxide in the atmosphere. Carbon dioxide absorbs infrared light, trapping radiant heat near the earth's surface and raising atmospheric temperatures. The most dramatic consequence of this effect, over time, could be the melting of polar ice, thereby raising the sea level and submerging the world's coastal areas. A counteractive effect is produced by the particulate matter released by burning. Such matter reflects sunlight away from the earth and could result in atmospheric temperatures being lowered. In that case the ice caps could increase and a new ice age could be ushered in. Which of the two effects will occur or whether the two might cancel each other out is speculative at this time (*7-8*, Pt. I, pp. 15-16).

5. Other consequences.—Additional nuisances and costs resulting from air pollution are objectionable odors; soot that dirties exposed surfaces; and petro-chemical smog that reduces visibility, thereby restricting sunlight and scenic views.

The impacts of highway improvement on air pollution are as follows:

1. Air pollution is increased by highway improvements that increase the number of vehicles using the highway and

the number of vehicle-miles driven by such inducements as lowering the cost or increasing the attractiveness of highway use.

2. Air pollution is further increased as highway improvements increase modal substitution from low- or non-polluting mass transportation vehicles to automobiles.

3. The forms of development encouraged by automobility and improved highways (i.e., urban sprawl) add to the problems of air pollution by adding to the geographic size of the polluted air mass and encouraging longer and more frequent and dispersed trips due to low density. Filling in of upwind areas with development hinders the process of dilution of polluted air and its dispersal. The pollution problems of metropolitan areas are thus exacerbated as they expand.

4. On the other hand, with expressways, air pollution is lower than with an identical volume of traffic using arterial streets. The higher speeds and lack of frequent starts, stops, and slow-downs means the engines of expressway-using vehicles operate with greater fuel efficiently and thereby emit less pollutants. This conclusion appears confirmed by data from 14 cities that show generally higher concentrations of carbon monoxide on arterials than on expressways (*7-8*, Pt. II, p. 16).

Gains and Utilities

1. To road users:
   a. Reduced cost of motor vehicle operation where not required to install or maintain pollution control devices on auto engines.
2. To air pollution control device manufacturers:
   a. Profits and sales of air pollution control devices for automobiles.

Costs and Losses

1. To persons:
   a. Impaired health and medical expense due to air pollution.
   b. Nuisance effects of objectionable odors, and restriction of sunlight and scenic views.
2. To property owners:
   a. Lowering of property values in areas having high concentrations of pollution.
   b. Crop losses due to blighting effect of air pollution.
   c. Deterioration and dirtying of buildings by air pollution.
3. To community:
   a. Decrease in community attractiveness and amenity due to smog.
   b. Adverse weather modification effects.
   c. Lower tax base due to out-migration to avoid highly polluted areas.
   d. Cost of governmental air pollution control enforcement, research, and monitoring.
4. To road users:
   a. Cost of air pollution control devices on automobiles (e.g., initial cost and maintenance).

Decision-Making Factors

1. Levels of concentration of air pollution induced by highway improvement due to:
   a. Inducement of increased traffic by lowered trip cost and increased travel attractions engendered by highway design.
   b. Higher local concentrations of air pollution due to increased roadway capacity.
   c. Higher trip generation levels and longer trip distances due to sprawl development pattern encouraged by highway model characteristics and system configurations.
   d. Lower pollution levels for equivalent ADT on expressways versus arterials.
   e. Outer expansion of urban areas (encouraged by efficient radial and circumferential highways) that inhibits dispersal and diffusion of the polluted air mass by adding to its geographic extent.

CATEGORY: 7. Environment
VARIABLE: C. Vibration

Area:	Urban
Type of Consequence:	Economic
Location of Impact:	Corridor
Timing of Impact:	During Construction
	After Construction—Short Term
	After Construction—Long Term

Consequences

Vibration appears to be a minor nuisance effect from highways. Of 459 interviews conducted in various parts of the U.S. as part of research on NCHRP Project 2-9, vibration was mentioned as annoying only 16 times by owners of property abutting major highways (*7-1*).

Urban highways are more likely to possess this nuisance effect due to proximity to buildings. The density of development in urban areas will cause the costs of vibration to be greater and to be felt by more persons. The costs are: (1) annoyance to persons feeling the vibrations, and (2) damage to structures in the form of loosening, cracking, or settling of walls and foundations due to vibrations set up by traffic, especially truck traffic, on nearby highways.

Vibration levels can be detected by seismic sensors. Increasing right-of-way distance from buildings and prohibition of truck traffic on certain routes where vibration and other highway-originated nuisances would be unwelcome (e.g., in residential areas) are possible correctives.

Gains and Utilities

1. None known.

Costs and Losses

1. To residents and property owners near highways:
   a. Annoyance from vibration.
   b. Property damage to structures due to vibration.

Decision-Making Factors

1. Character of environment—whether vibration annoy-

ance or damage, probably based on past experience in similar environments.

2. Means of avoiding potential annoyance or damage by increasing distance between highway and structures, structural design to reduce vibration, and prohibitions on truck use.

CATEGORY: 7. Environment
VARIABLE: D. Drainage Patterns

Area:	Urban and Rural
Type of Consequence:	Economic
Location of Impact:	Right-of-Way Corridor
Timing of Impact:	During Construction After Construction—Short Term After Construction—Long Term

Consequences

There are four possible effects on environmental water drainage patterns from highway improvement:

1. Runoff.—In that the highway and highway-induced construction replace water-absorbing earth, the volume of runoff, particularly in urban areas, is increased. In the absence of adequate drainage channels, and/or storm sewers, flooding may occur.

Runoff from bare earth cuts during or after construction may create problems of erosion and sediment until corrected by planting. Removal of ground cover from slopes during construction may induce the danger of slides where unstable subsoil conditions exist.

2. Drainage channels, damming, borrow pits.—Highway drainage channels may change local drainage patterns. Ponds may be created by borrow pits. The highway subgrade may cross and dam former natural channels unless adequate culverts are provided. The changed drainage patterns may work to the advantage or disadvantage of nonusers in the locale who have organized their land use on the basis of the former drainage patterns. Flooding, ponding or lack or same, erosion, or sediment collection may occur.

One-third of 48 farmers surveyed in a Kansas study (*7-5*) of an Interstate highway's impacts reported drainage, erosion, and sediment problems due to the highway.

3. Water pollution.—Highway-induced activity such as industrial, agricultural, or commercial land uses may contribute to downstream water pollution by discharge of untreated wastes into local streams or through water runoff from pesticide-sprayed croplands.

4. Natural ecology.—Highway damming or diversion of streams may adversely affect the local natural ecology (e.g., prevent fish migration to spawning grounds, erode soil that supports flora, create marshes). Beneficial effects are also possible (e.g., creation of ponds, checking of erosion).

Gains and Utilities

1. To nonusers:
   a. Correction of local drainage problems.
   b. Creation of ponds from borrow pits.
   c. Aids to natural ecology through provision of watercourse pattern beneficial to wildlife.
2. To users:
   a. Aesthetic or recreational value of water areas and natural scenery created or preserved by highway improvements.
   b. Avoidance of occasional impassability due to flooding.

Costs and Losses

1. To nonusers:
   a. Creation of local drainage problems (e.g., erosion, sediment, ponding, flooding) with subsequent costs to adjust or restore the drainage patterns, correct problems, adjust land-use organization to the new conditions, or compensate for damage.
   b. Water pollution costs due to the untreated waste discharge of highway-induced economic activities.
   c. Disturbance of natural ecology related to watercourses, with adverse effects on wildlife.
2. To users:
   a. Unaesthetic vistas where revised drainage patterns induced by highway improvement cause adverse change in or removal of scenic features of the natural landscape.
   b. Occasional impassibility due to flooding where location or design, especially of culverts, does not account for revised drainage pattern or the range of local conditions of climate or hydrology.

Decision-Making Factors

1. Costs to avoid, compensate for, or correct drainage problems or provide benefits stemming from highway construction due to (1) runoff; (2) damming of watercourses, creation of ponds, or change of drainage patterns; (3) inducing water-polluting land uses; and (4) effects on natural ecology.

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CATEGORY: 8. Industrial
VARIABLE: A. Industrial Development

Area:	Urban
Type of Consequence:	Economic
Location of Impact:	Corridor Community or System Region or Nation
Timing of Impact:	After Construction—Short Term After Construction—Long Term

Consequences

Industrial development in a particular area or location takes place for many reasons. The reasons vary among industry types according to the nature of their inputs and outputs and their relative share of production costs, and the nature of the productive processes. Extractive industries must naturally locate at the raw material source, and bulk-reducing industries often locate near the source of their raw materials to cut high transportation costs. Industries with high labor inputs frequently gravitate to low-cost labor areas. Industries in which timely response to market trends or customer orders is important usually centralize. Those with processes requiring extensive plants may attempt to decentralize to find low-cost land.

Studies have shown that no one set of location criteria can be applied uniformly in all industries (*8-13, 8-15*). However, the following factors are considered to some degree in practically every plant location decision: markets; labor; transportation; raw materials; power, fuels, and water; community factors; and site factors (*8-15*).

Profit-seeking industrial managers probably will weight each factor according to its relative share of total production cost and the degree to which it can be economized in alternative locations. The optimum location is that one from which a plant can serve the largest market potential with the greatest efficiency possible.

Numerous studies have noted the propensity for industrial development to be attracted to main transportation facilities and corridors, especially, in recent years, to the vicinity of superhighways. Sample study conclusions:

1. Virginia—Capital Beltway.—"An observer need only see the many new industries bordering the circumferential to be convinced that this surge of industrial construction in Fairfax County and Alexandria has in some part been caused by the addition of the Beltway" (*8-7*, p. 63).
2. Massachusetts—Route 128 Circumferential.—"Growth in industrial development has followed every improvement in Route 128, after a lag of two or three years for zoning changes to permit industrial uses" (*8-3*, p. 189).
3. Texas—Interstate Highway 30.—"As a result of the new facility, new manufacturing firms have located in Rockwall County" (*8-6*, p. 67).
4. California—Eastshore Freeway.—"The new growth and expansion of industry within the freeway zone of influence has far exceeded the industrial activity throughout the remainder of a county (Alameda County), whose greatest source of income is from industry" (*8-10*, pp. 19-22).
5. Minnesota—Belt Line Highway T. H. 100.—"Belt Line Highway T.H. 100 encouraged development of 431 acres of land for commercial purposes in the study strip during the 14 years 1945-1959. . . . This is a substantial part of the increase which occurred during that period in the Twin Cities metropolitan areas as a whole" (*8-4*, p. 12).

A number of studies have probed for the specific reasons why industrial plants have been attracted to areas adjacent to improved highways. Most of these have used the interview method to elicit the leading reasons for selection of a highway-oriented site. The top four reasons, in order of the number of responses from the sampling of the surveys, are given in Table B-11.

From this analysis emerge seven main reasons for industrial development near improved highways. Listed in order of number of times mentioned, they are:

1. Customer or market accessibility.
2. Sufficient land for desired plant size and/or future expansion.
3. Employee access.
4. Labor supply.
5. Highway proximity.
6. Land price.
7. Avoidance of congestion.

This list agrees closely with the results of a nationwide survey of 1,363 plants locating or relocating between 1955 and 1959 concerning their leading location decision factors. The survey did not discriminate among plants locating near main highways and ones not so locating. The four most frequently mentioned location factors were, in order:

1. Proximity to good highways.
2. Abundant labor supply.
3. Availability of suitable land.
4. Proximity to markets (*8-13*).

Highway improvements can have positive effects on all these variables:

1. Market accessibility.—Highway improvements that lower the dollar and time costs of moving products to market improve competitive advantage, provide efficiency, lower product cost and related price, and raise profits.

When asked what benefits they expected to derive from the (Virginia Capital) Beltway, 24 of 48 firms responded, "Efficient transport of staff and materials to and from the plant" (*8-7*, p. 68).

A study to determine the effect of the Santa Ana Freeway on industrial business in the Los Angeles metropolitan area concluded (*8-11*, pp. 19-22):

> The freeway is (1) distinctly an appreciation factor to adjoining property; (2) the freeway is an asset from the standpoint of advertising, convenience, and time saving in the distribution of goods; and (3) industrial location

TABLE B-11

INTERVIEW SURVEY RESULTS OF FOUR STUDIES SHOWING LEADING LOCATION DECISION FACTORS OF INDUSTRIAL PLANTS NEAR IMPROVED HIGHWAYS

LOCATION FACTOR	INTERVIEW SURVEY RESULTS, BY HIGHWAY STUDIED			
	DALLAS EXPRESSWAY (*8–1*)	VA. CAPITAL BELTWAY (*8–7*)	MD. CAPITAL BELTWAY (*8–22*)	MASS. ROUTE 128 (*8–3*)
1.	Accessible for employees	Proximity to highways	Availability of a large parcel of land or building at a reasonable price or rent	Commercial accessibility
2.	Avoid areas of traffic congestion	Access to clients and local markets	Good access to clients and customers	Land for expansion
3.	Need a location to expand business	Price of land	Close to labor supply and easily accessible by same	Employee accessibility
4.	Accessible to more customers	Availability of large land parcel	Good highways or anticipation of same	Labor market

on frontage accounts for additional business which is entirely attributable to prospective customers using the freeway.

2. Sufficient land for desired plant size and/or future expansion.—Under the impress of changes in the technologies of production many industries find one-story plants most efficient. The dynamics of population and economic growth argue for surplus land availability for future-year expansion. Because most employees drive to work, space for parking is needed.

The Virginia Capital Beltway study found (*8-7*, p. 66):

> Availability of a large land parcel, while not directly related to highway access, is a likely by-product of highway development that opens up a large supply of land to industrial development.

3. Employee access.—Highway improvements aid employee access by lowering the time and cost of commuting. The Massachusetts Route 128 study revealed that employees using that route managed an average work trip speed of 32 mph. Nonusers of the improved facility averaged only 24 mph (*8-3*, p. 193).

4. Labor supply.—The area of a plant's potential labor shed is increased by a highway improvement. Again, the Route 128 study revealed that users of that facility traveled further to work, an average of 15 miles. Nonusers traveled a shorter distance, an average of 8.5 miles (*8-3*, p. 193).

A study of the Connecticut Turnpike concluded: "The Turnpike is a potential major route for commuting workers, a factor in expanding some firms' labor markets, and a factor in shifting the orientation of the firms' labor markets" (*8-23*, p. 14).

5. Highway proximity.—One researcher summed up the particular advantages bestowed on industrial land near highways as follows (*8-9*):

> What an expressway does then is to restore to a plant site all those advantages of accessibility to suppliers, related industries, markets, and labor, that a similar plant used to enjoy on intown sites before congestion set in, at the same time making possible the big site, the single-story building, the room for expansion, the amenity of space for landscaping and planting. These advantages are shared by other outlying plant locations, but not to the same degree.

6. Land price.—By opening up a larger supply of sites suitable for industrial use, the price of industrial land will be initially reduced by a new highway facility. The price will rise again as sites are developed and become more scarce once again.

7. Avoidance of congestion.—New highways also provide the initial advantage of lack of congestion relative to more central sites. This advantage may be transitory as additional traffic-generating industrial, commercial, and residential users are attracted to a highway corridor, thus contributing to traffic build-up and eventual congestion.

Hence, highway improvements, along with other factors contributing to the major trends, are visible in industrial development and location—namely, decentralization, both regional and metropolitan.

Truck transportation, with its lower short-haul costs and ubiquitous mobility, has made it possible to move plants closer to markets, to downgrade transportation cost considerations in plant location, and to establish where there is no rail service. It is thus partly responsible for the trends for industry to move to:

1. The South and West;
2. Suburban rings of metropolitan areas;
3. Small towns and rural areas;
4. Where significant inputs are most economical;

and away from its former strongholds:

1. The Northeast and Great Lakes states.
2. The central city.
3. The industrial metropolises.
4. The sources of raw materials or other input supplies and major markets (*8-12, 8-15*).

Industrial development potential is thus becoming more homogeneously spread over the U.S. and over regions and metropolitan areas. An abundance of highway-oriented locations may be responsible for the indifference reported by two studies:

> In general, the network of existing roads rather than any one highway influences decisions of manufacturing firms in a metropolitan area (*8-14*, p. 114).
>
> The general influence of highways upon plant site selection is paramount, but not critical. There is recognition of the need for highways, but little demand for specific types. If the highway was paved and in good condition, it was judged adequate (*8-5*, pp. 13-28).

Development of extractive industries depends on highway access to the source of natural resources (e.g., forests and mineral deposits).

A study of forest highways found the following benefits (*8-19*):

> There is a direct relationship between the decrease in forest fires and road improvements in forest regions, which in turn saves resources, increases employment, and provides community benefits. Access to the established highway system is a basic determinant in the choice of forest land to be harvested, and influences the value of stumpage.

Although more dependent on pipelines, waterways, and railroads than on highways for transport of the product of their operations, the mineral industries have nevertheless derived some benefits from highway access. Highways have provided them with mobility of equipment, permitted smaller operators to flourish, and made remote resources accessible (*8-24*).

Gains and Utilities

1. To industrial plants:
   a. Extension of market area leading to increased volume of demand, sales, and profits (*8-16*).
   b. Larger markets mean more stable prices and demand that are less subject to the vagaries of localized conditions (*8-16*).
   c. Increased access to suppliers and lower cost of materials and other inputs (*8-16*).
   d. Reduced cost of distribution (*8-16*).
   e. Large-scale production for larger market enables added economies of scale and specialization leading to lower prices (*8-16*).
   f. Access provided to a wider labor market (*8-16*).
   g. A larger supply of developable land opened, thereby permitting large tracts for all-on-one-floor plants with their greater efficiency, room for future expansion, space for employee parking and other employee activities (*8-16*).
   h. Lower cost of land where the new supply initially outstrips the effective demand (*8-16*).
   i. Advertising benefits provided through modern plant facades, landscaping, and signing visible from the highway (*8-16*).
   j. Ability to serve wide market areas from centralized distribution centers provides savings in storage and inventory (*8-24*).
   k. More efficient trucking service obtainable at decentralized plants due to lack of congestion; more space for truck loading and maneuvering (*8-24*).
   l. Large tracts permit buffer zones to shield nuisance-producing operations from neighbors (*8-24*).
   m. Large tracts, often landscaped industrial parks, provide pleasant surroundings for workers.
   n. Gains to trucking and automotive industries and their suppliers from highway-oriented industrial development that increases dependency on highway transportation by shippers and workers.
   o. Gains to construction industry from expansion programs undertaken by industry locating or relocating due to availability of attractive sites opened up by highway improvements.
2. To extractive industries (*8-24*, pp. 148-49):
   a. Trucks more flexible in extractive operations.
   b. Greater efficiency—less transport cost.
   c. Forest-fire protection.
   d. Joint use of forest lands for recreation, livestock forage.
   e. Increases amount of salvage cutting possible.
   f. Allows small operators to flourish who cannot afford to construct their own roads or railways.
   g. Increases mobility of equipment.
   h. Opens up remote resource locations untapped by other modes.
3. To employees:
   a. Less time and expense in commutation.
   b. Timber workers can commute rather than live in logging camps.
   c. More job opportunities within driving range.
   d. Higher wages due to employer competition.
   e. Pleasant working environment in industrial parks.
4. To consumers:
   a. Lower costs of transportation tend to allow more products from more sources to come into competition, thereby reducing and homogenizing delivered prices while increasing consumer choice (*8-16*).
5. To nation:
   a. Gain in gross national product from industries that increase productivity and efficiency through development or location change made advantageous by highway improvement.

Costs and Losses

1. To industrial plants:
   a. Traffic congestion builds up at interchanges over time (*8-7*).
   b. Inadequacy of public services in outlying semi-rural locations (*8-7*).
   c. Lack of transit service for workers or cost of operating private service (*8-7*).
   d. Infrequent mail service in outlying locations (*8-7*).
   e. Access roads may be inadequate for commuter traffic volumes (*8-7*).
   f. Difficulty in retaining women employees on a part-time basis at outlying plants (*8-2*).
   g. Upward pressure on wage levels for old industries

due to competition of new ones locating in proximity (*8-2*).

h. Labor requirements, skill mix, not met as well, especially for blue collar and clerical, due to inaccessibility via public transportation (*8-2*).

i. Snow removal on approach roads and in parking lots a plant responsibility (*8-2*).

2. To employees:
   a. Lack of eating and shopping facilities near outlying plants (*8-2*).
   b. Added costs of commuting to outlying locations or of moving residence to follow an industrial plant relocating off center (*8-3*).
   c. Reduced job opportunities in central-city areas due to decentralizing industry.
   d. Difficulty in obtaining employment opportunity information and interviews due to scattering of industrial plants.
3. To road users:
   a. User taxes bear the expense of higher standards of road construction and maintenance to accommodate logging trucks.
   b. Mix of logging and other industry-serving trucks is a disbenefit to auto traffic due to trucks, slower speeds, passing hazards, poor sight lines, and potential for inflicting greater collision damage.

Decision-Making Factors

1. Distance between highway and other transport routes (*8-17*, p. 62).

2. Characteristics of adjacent land and suitability for industrial development [e.g., topography, utilities, tract sizes, lack of previous development (open land)] (*8-17*, p. 62).

3. Influence of future needs of industry on highway routing and capacities and interchange locations (*8-17*, p. 62).

4. Regional and local industrial development policies, needs, and plans.

5. Accessibility afforded to exploitable natural resources.

6. Central-city impacts of industrial decentralization (e.g., employment, tax base, transit use, and real estate market).

CATEGORY: 8. Industrial
VARIABLE: B. Industrial Dislocation

Area:	Urban
Type of Consequence:	Economic
Location of Impact:	Right-of-Way Community or System
Timing of Impact:	During Construction After Construction—Short Term

Consequences

Rights-of-way takings may dislocate industrial plants. This has the following effects: (1) forces relocation or discontinuance of the firm, with attendant expense to the extent uncompensated; (2) causes employees the expense of finding and commuting to new jobs, commuting to old job at the firm's relocation site, or relocating residence to be nearer the relocation site; and (3) incurs greater or lesser transportation costs to the firm's suppliers or customers according to their location in relation to the firm's original and relocation sites.

Gains and Utilities

1. To firm:
   a. Compensation paid for property at fair market value and for moving expenses and optional relocation payment.
   b. Advantages and efficiences from improving plant and location through relocation.
2. To employees:
   a. Lower commutation costs to the plant in its relocation site.
3. To suppliers and customers:
   a. Lower shipping costs to or from the plant in its relocation site.
4. To local government:
   a. Added tax ratable and assessed valuation for jurisdiction receiving relocated plant.
5. To retail trade:
   a. Additional purchasing power in area receiving relocated plant due to lower commuting costs, higher wage job opportunities, less unemployment, in-migration to be near relocation site.
6. To landowners:
   a. Higher land values for land sold for industrial uses due to necessity for relocation sites of displaced firms.

Costs and Losses

1. To firm:
   a. Cost of plant and moving and relocation expense to extent uncompensated.
   b. Disadvantages and inefficiencies stemming from plant in new location.
2. To employees:
   a. Cost of seeking new employment; or added cost of commutation to relocation site; or cost of relocating residence to be nearer relocation site.
3. To suppliers and customers:
   a. Higher shipping costs to or from plant in its relocation site.
4. To highway agency:
   a. Compensation paid for fair market value of property and plant, moving costs, and relocation costs.
5. To local government:
   a. Loss of tax ratables and assessed valuation for jurisdiction losing plant that quits business or relocates outside jurisdiction.
   b. Unemployment compensation for employees unable to find alternative employment after taking of employing plant.
   c. Added cost to government jurisdiction receiving dislocated industry on account of increased services for local streets, education, fire, police, health, and general community services.

6. To retail trade:
   a. Loss in sales from reduced purchasing power due to: temporary unemployment, higher commuting costs, lower wages, out-migration to be near relocation sites.

Decision-Making Factors

1. The relative merits of each alternative route may be indicated by comparison of the following criteria:
   a. Displacement of industrial firms in various categories; weighted by gross product and employment.
   b. Displacement of obsolescent older plants with less modernity, adequacy and utility, rather than newer ones with these qualities.
   c. Displacement of younger rather than older proprietors with the former's greater likelihood of reestablishing rather than quitting business.
   d. Displacement of plants with intentions of reestablishing in the area.
   e. Displacement of businesses intending to quit if displaced.
   f. Displacement of plants intending to reestablish in some area.
   g. Displacement of plants with lower assessed valuations.
   h. Route alternative involving least disturbance cost.
   i. Employees involved, especially in the following categories:
      (1) Unskilled and semi-skilled occupations—due to automation, low pay.
      (2) Older workers and those who have spent most years employed in same occupation—due to obsolescence of skills and impending retirement.
   j. Local residents involved, for whom a shift in employment location probably would involve the most commutation or relocation cost burden.
   k. Aggregate payroll loss—buying power loss—with the least second-round impact on the retail trade sector's sales, payroll, and employment.
   l. Impact on local area employee-residents in terms of changing income levels, degree of anticipated unemployment, and added commutation and relocation cost.

CATEGORY: 8. Industrial
VARIABLE: C. Industrial Relocation

Area:	Urban
Type of Consequence:	Economic
Location of Impact:	Corridor
	Community or System
Timing of Impact:	During Construction
	After Construction—Short Term
	After Construction—Long Term

Consequences

An improvement in transportation that offers an opportunity to industrial enterprise to become more efficient or productive attracts development to sites where those opportunities can be taken advantage of. The plants are relocated from sites presumably having fewer advantages and, thus, less profit potential.

Decision factors influencing relocation of industrial plants to sites near improved highways have been found to include:

1. Market and supplier accessibility related to transportation costs.
2. Desire for new plant to accommodate increased production or improved production processes.
3. Lower land costs.
4. Space for future expansion and parking.
5. Availability of labor.
6. Availability of utilities.
7. Tax advantages (*8-1, 8-3, 8-7, 8-13*).

The relative importance of each of the factors in influencing a relocation will vary among industrial land users according to its significance in the costs of production of each user.

Highway improvements in the form of high-speed expressways, both radial and circumferential, along with trucking industry progress in capacity, efficiency, and technology, have freed many industrial plants from their former dependence on proximity to railroads, ports, and central-city districts.

This "pull" effect of improved highways in inducing industrial relocation to noncentral locations has been reinforced by the "push" of central area conditions, including traffic congestion, parking shortages, obsolescent plant, and rising taxes that have had a negative impact on industrial activity (*8-3, 8-4*).

The trend in industrial relocation has been one of decentralization. A random sample survey of 611 plants moving between 1955 and 1959 showed twice as many relocations of in-city plants to suburban, rural, and small-town areas as to other in-city locations (*8-13*). Another study found that, as a result of plant relocation, industrial work trips and shopping trips had become the types highest in incidence in a rural area of North Carolina (*8-8*).

Studies of relocating plants attracted to specific highway corridors provide even more impressive indicators of the decentralization trend:

Massachusetts Route 128: Of the total plant investment along Route 128 in September 1957, 76 percent was relocated plants, with the balance in new enterprises. Most of the relocated companies came from in-town Boston; 68 percent from a radius of 2¼ miles; and 96 percent from within 4½ miles of the center of the city (*8-3*, p. 1).

Capital Beltway in Virginia: Out of a sample of 48 firms located proximate to the Washington, D.C., Capital Beltway in Virginia, 34 or 71 percent were relocated plants. Twenty-five firms or 52 percent of the sample were relocated from within the metropolitan area (*8-7*, p. 65).

These same studies have demonstrated both positive and negative effects from plant relocations apparently inspired by highway improvements:

1. Massachusetts Route 128:
   a. Positive effects:
      (1) Because relocation was for the purpose of or

provided opportunity for plant expansion there was a net gain in metropolitan employment of 11,700 jobs (*8-3*, p. i).

(2) There was also a net gain in new plant investment of $80 million (*8-3*, p. i).

(3) Increased residential building is occurring in the Route 128 corridor (*8-3*, p. iii).

(4) There is active real estate promotion of commercial and industrial sites along the highway (*8-3*, p. iii).

(5) The largest increases in net in-migration in the metropolitan area are occurring in Route 128 towns that also connect with minor radial highways (*8-3*, p. iii).

(6) Industrial development has brought new tax revenue sources to Route 128 towns without an offsetting increase in municipal service expenditures (*8-3*, pp. 189-90).

(7) Relocated enterprises realized benefits in the form of "land for expansion, accessibility for commercial purposes, attractive sites, labor market considerations, accessibility for employees, advertising value of site, and adequate parking facilities" (*8-3*, p. 90).

b. Negative effects:

(1) Assessed valuation, occupied floor space, and employment have dropped at the former sites of relocated companies—losses to the central city (*8-20*). Assessed valuation of the former site dropped by $1 million or 6 percent; employment, by 1,525 or 40 percent (*8-3*, p. 188).

(2) Old employees of relocated firms travel farther to work after the move and have longer travel times. Whereas 30 percent of old employees used public transit or walked to work, nearly all used automobiles for home-to-work travel after plant relocation (*8-3*, p. 194).

(3) Apparently some employees have been prompted to move in order to follow their relocated jobs—"an average of 18 percent of employees have moved since working for a Route 128 company" (*8-2*, p. ii).

2. Capital Beltway in Virginia:

a. Positive effects:

(1) Most plants have achieved the "efficient transport of staff and materials to and from plant" they expected from relocating near the Beltway (*8-7*, p. 68). Other stated advantages have been "access to clients and local markets, favorable land prices, and large parcels of land" (*8-7*, p. 66).

(2) Professional employees have found a Beltway plant location convenient (*8-7*, pp. 69-70).

b. Negative effects:

(1) Nine of eleven companies with more than 75 percent of employees blue-collar reported themselves not well-located for their labor supply. There is no low-cost housing in the suburbs, and minimal amounts of public transit (*8-7*, pp. 69-70).

(2) Out of 41 responses to a survey question asking employers whether a "Beltway site was more convenient for employees," 25 "No" answers were given. Hourly employee hirers were least satisfied (*8-7*, pp. 69-70).

There is some evidence that the plants relocating by decentralization tend to be large firms rather than smaller ones. In eight selected metropolitan areas 69 percent of small plants were in the central city, whereas only 45 percent of the large ones were there. Large firms have more space needs, perform more functions and services in-house, and are more established. Smaller firms cling to central locations in that they are newer, usually lease space, need less room, and enjoy the "external economies" of proximity to input supplies, services, and communications (*8-24*, pp. 51-69). They are also well-located to attract the low-wage workers many require. Other industrial plants will remain centralized due to a need for access to water and rail transportation.

Gains and Utilities

1. To industrial plants:
   a. Better access to markets and suppliers.
   b. Avoidance of central area congestion.
   c. Space expansion and modern, more efficient facilities replacing obsolete plant.
   d. Land for plant and future expansion at favorable prices.
   e. Better access to some employees, especially white-collar, professional, and salaried.
2. To employees:
   a. Better access to workplaces for some employees (i.e., lower work trip travel time and cost).
   b. More employee parking.
   c. Gains in job choice and possible wage gains as more plants relocate and wage competition increases.
   d. Pleasant working conditions in landscaped industrial park.
3. To community:
   a. Property tax revenue gain unmatched by expenditures for communities receiving relocated plant.
   b. Gain in local employment.
   c. Gains to real estate and commercial sector from sales and services to relocating industrial plants.

Costs and Losses

1. To industrial plants:
   a. Difficulty in hiring blue-collar, hourly-wage, and part-time workers at off-center relocation sites due to lack of housing at suitable rents and transit service.
2. To employees:
   a. Time and money costs of longer commuting for old employees of relocated firms.
   b. Possible cost of move to accommodate residential location to plant relocation site.

c. Inability to continue use of transit or walking to reach workplace where plant relocation site is not reachable by these means.
d. Possibility of unemployment due to not being economically feasible to follow relocating industrial employers to new sites.

3. To community:
a. Loss to property tax base and employment to community losing a relocating plant.
b. Loss of transit patronage where plants generating transit trips move out.
c. Higher expenditures for municipal services as residential and commercial units follow industry into an area.

Decision-Making Factors

1. Amount of land suitable for industrial relocation opened up by highway improvement—potential "pull" effect.

2. Conditions in local industrial zones (e.g., presence or lack of congestion, obsolete plant facilities, land for expansion)—creating a potential "push" effect.

3. Public policy concerning the encouragement of industrial decentralization due to potential community effects (e.g., employment opportunity and tax base disparities between central and suburban jurisdictions; loss of transit patronage; employee commuting and moving costs due to relocation; and ability and willingness of jurisdiction receiving relocating industries to incur capital and operating costs of public utilities and services needed to support industrial uses and the residential and commercial development that follows it).

CATEGORY: 8. Industrial
VARIABLE: D. Industrial Land Use

Area:	Urban
Type of Consequence:	Economic
Location of Impact:	Corridor
	Community or System
Timing of Impact:	After Construction—Short Term
	After Construction—Long Term

Consequences

Efficient transport of materials, products, and labor have traditionally been prime considerations in the location of industrial plants. Transportation can be a major source of profit-producing economies. This has led to the frequent observation that industrial land uses appear most intensive in ports and along rail lines, waterways, and highways.

Research has shown certain industrial land users to be more transportation oriented than others. Predictably, such users have weighty inputs and/or outputs and therefore higher transportation costs. Typical examples are printing and publishing, wholesale trade, fabricated metal products, furniture, stone-clay-glass, and warehousing (*8-13*).

There is a growing tendency to use truck transport to obtain its frequently lower short-haul costs, its flexibility in destinations, and its time savings. A random sample survey of 1,315 industrial plants revealed 67 percent shipped 90 percent or more of outbound freight by truck, whereas 58 percent received 90 percent or more of all inbound freight by truck (*8-13*). These indicators go far toward explaining the observable trend for many plants to favor sites proximate to improved highways.

Research has revealed these characteristics of industrial land use related to improved highways:

1. Location of industrial land use relative to highway.—There appears to be a variety of distances, ranging from 500 ft to 20 miles, within which industrial land use has been related to improved highways:

a. Lexington, Ky., Northern Belt Line.—"[C]onsiderable commercial and industrial development [occurred] abutting or near the . . . Belt Line. . . . In 1958, six years after opening, 40 percent of the area within 500 ft of the highway was used commercially or industrially" (*8-12*).
b. Minneapolis Belt Line Highway T. H. 100.—"Eighty-nine percent of the manufacturing and warehousing establishments, embracing 74 percent of the acreage, are within 1,000 ft of a major highway . . . ." (*8-4*, p. 41).
c. Massachusetts Route 128 (Boston Circumferential).—One hundred plants exist within one mile of the highway in a 55-mile stretch of Route 128. In 17 cities and towns along Route 128 a total of 209 companies are in operation, 17 are being built (as of 1957) (*8-24*, pp. 51 ff).
d. Pennsylvania Turnpike.—In areas within five miles of the interchanges there have been moderate increases in manufacturing and employment (*8-21*).
e. Indiana Turnpike.—"[F]orty-four percent of the 354 new industrial plants establishing in Indiana within a recent 3 year period located within a 45 mile band straddling the Indiana turnpike" (*8-24*, pp. 51-69).

2. Other factors influencing industrial land use.—Whether land accessible to improved highways is used industrially depends on a variety of other factors. Good highways are a "necessary but not sufficient" condition for industrial development. Some or all of these factors must be present to cause or permit industrial land use:

a. Economic growth of the region creates the initial demand for industrial land (*8-4*, p. 58).
b. Availability and access to other modes of transportation are important. Studies have indicated that availability of railroad facilities, and sometimes waterways or ports, is still vital to some industrial land users (*8-4*, *8-13*).
c. An abundant supply of industrial land or excess plant capacity in previously developed areas will reduce demand for outlying highway-oriented locations (*8-24*).
d. Local land-planning policies affecting the zoning of land for industrial use influence the number and location of sites available (*8-24*).
e. The degree of access control and land-use control of minor traffic generators is significant in that

congestion reduces the desirability of land for industrial uses (*8-24*).

f. Congestion and plant obsolescence in the central city produce a "push" effect on industrial land users (*8-4*, p. 58).

g. Availability of public utilities and services must usually precede or accompany development of industrial land use (*8-4*, p. 3).

h. Some industries can locate only where a variety of supporting services or complementary industries exist (*8-4*, p. 3).

3. Systems effects of industrial land use.—Development of industrial land results in the following systems effects:

a. Pressures for residential and commercial land uses within commuting distance of industrial plants (*8-10*).

b. Higher local tax ratables but higher expenditures to accommodate services demands from changed land uses.

c. Rise in commuter traffic volumes on industrial corridor routes impedes long-distance interstate traffic during rush hours.

d. Dispersal of industry and its buffering by landscape and distance in industrial parks reduces the nuisance effects (smoke, noise, vibration) of industrial concentrations and the incidence of spillover blight on surrounding nonindustrial uses.

Gains and Utilities

1. To industrial plants:
   a. Access to employees, suppliers, markets.
   b. Sufficient land for efficient plant and expansion.
   c. Advertising benefits.
2. To employees:
   a. Reduced work trip cost and time over improved highways.
   b. Easy and economical parking.
   c. Wider choice of job opportunities.
3. To communities:
   a. Increase in tax ratables not matched by expenditures for services.
4. To road users:
   a. Better access to industrial destinations removed from central-city congestion.

Costs and Losses

1. To industrial plants:
   a. Lack of access to unskilled and part-time help.
   b. Cost of employer-sponsored buses and provision of parking spaces.
2. To employees:
   a. Lack of access to noontime shopping and dining facilities.
3. To communities:
   a. Influx of residential and commercial land users whose service costs may exceed their tax revenue potential.
4. To road users:
   a. Impedance of long-distance traffic due to routes attracting industrial land use being congested with commuter traffic in rush hour.

Decision-Making Factors:

1. Local planning and development policies regarding location of industrial land uses.

2. Central-city versus suburban tax disparities resulting from industrial land use decentralization following highway improvement.

3. Economic growth of region as an indicator of industrial land use potentials.

4. Ripeness of highway corridors for industrial development according to the complex of other industry-attracting factors present (e.g., zoned land, public utilities and services, markets, labor, other complementary or support industries and suppliers).

CATEGORY: 8. Industrial
VARIABLE: E. Industrial Land Value

Area:	Urban
Type of Consequence:	Economic
Location of Impact:	Corridor Community or System
Timing of Impact:	After Construction—Short Term After Construction—Long Term

Consequences

Industrial property values are determined by (1) the productive uses to which industrial land may be put and the value of the product fabricated or the resources extracted there; (2) the comparative degree of advantage, economy, or efficiency offered by a site relative to alternative choices; and (3) the current supply-demand relationship existing between the amount of industrial land and the number of potential users bidding for the space.

Location and accessibility of land—to markets, suppliers, and labor supply—thus affect the values of industrial land. Theoretically, widespread highway improvements would lower values, because values of previously favored locations would be reduced. Confirmation of this hypothesized effect appears in the Massachusetts Route 128 study which found a 6 percent drop in assessed valuation of industrial land in central Boston locations from which industry had migrated to outlying sites near Route 128 (*8-13*, p. 188).

Low initial values of industrial land due to an improved highway's opening up of an abundant land supply is usually offset over time by reductions in the supply due to development and an increase in demand based on population and economic growth dynamics. This effect is again demonstrated in the Route 128 study, which found (*8-3*, p. 190):

> The former land value of industrial sites along Route 128 was usually very low, in a range of $1,000 to $1,500 per acre. After being developed and built upon, land values reported by companies average $18,000 per acre. . . . In one industrial area, the land value was reported as $26,000 per acre.

A number of studies confirm the long-term upward trend of highway-oriented industrial land values. Five such studies were summarized in a Bureau of Public Roads report as given in Table B-12.

In actual dollar terms, the percentages represent such typical increases in price per acre as from $500 to $10,500 along the Eastshore Freeway and $800 to $11,000 along the Atlanta Freeway in the periods shown (*8-24*, pp. 24-30). The variety in the value growth rates and dollar values probably is a function of local conditions in the factors mentioned (i.e., productivity, site advantages, and land supply-demand relationship).

Although transportation efficiency adds to the productivity of market-oriented industry it frequently creates values for extractive or resource-oriented industries. The Bureau of Public Roads has reported a study of the effects of access roads on standing timber values on public lands administered by the U.S. Forest Service in Idaho. The study indicated that "appropriation for timber access roads are closely associated with increases in the value of timber stands." Larger net returns to the U.S. Treasury and Forest Service and the State of Idaho have been among the resultant benefits (*8-24*, p. 149).

Gains and Utilities

1. To landowners:
   a. Higher values for industrial land due to improved highway accessibility.
2. To land purchasers:
   a. Initially lower prices of industrial land due to larger supply made accessible by highway improvement.
3. To communities:
   a. Increase in assessable tax base from industrial land value and use changes.

Costs and Losses

1. To landowners:
   a. Lower prices and rents for land, especially centralized, whose value has been deflated by the large supply made available by a highway improvement or the relocation of plants to noncentral highway-oriented locations.
2. To land purchasers:
   a. General upward pressure on land values of all types in industrializing areas due to accompanying demand for residential and commercial property to accommodate worker needs.
3. To communities:
   a. Lower tax revenues in areas falling in value due to departure of decentralizing industry and population that follows jobs to other jurisdictions.

Decision-Making Factors

1. Potential industrial property value changes based on highway improvement effects on:
   a. Demand for relocation sites by decentralizing plants; a function of central-city conditions such as taxes, congestion, plant obsolescence and demands for expansion, modernization, and parking by growing industries.
   b. Demands for industrial land in highway corridor, generally based on increased accessibility and capacity provided as an attraction.
   c. Land supply-demand relationship for industrial property in the area, and likely direction and rate of change of values based on changes in this and other factors mentioned previously.

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TABLE B-12

SUMMARY OF INDUSTRIAL LAND VALUE CHANGES BEFORE AND AFTER HIGHWAY IMPROVEMENTS AND RATIO OF STUDY AREA TO CONTROL AREA

State and study	Description of highway	Changes					Ratio of study area to control area
		Dates of changes	Study area		Control area		
			Total	Annual	Total	Annual	
			Percent	Percent	Percent	Percent	Percent
California:							
Alameda Co. 2/	Eastshore Freeway	---	---	---	---	---	---
High St. to city limits of Oakland	---	1941-53	836.4	69.7	---	---	---
South city limits of Oakland to Lewelling Blvd.	---	1947-53	272.4	45.4	---	---	---
Los Angeles 3/	Santa Ana Freeway	---	---	---	---	---	---
Test area A	---	1949-54	48.9	9.8	36.5	7.3	1.34
Test area B	---	1947-54	486.0	69.4	282.4	40.3	1.72
Test area C	---	1946-54	199.2	24.9	183.2	22.9	1.09
Georgia:							
Atlanta 4/	Atlanta Expressway	---	---	---	---	---	---
West side							
Band A							
Section 3							
Vacant	---	1943-54	1382.0	125.6	---	---	---
Improved	---	---	278.5	25.3	---	---	---
Average	---	---	1287.6	117.1	---	---	---
Texas:							
Dallas 5/	Dallas Central Expressway	---	(5/)	---	---	---	---
Dallas -- Stemmons Freeway	Interstate 35E	1946-55 to 1955-59	---	---	---	---	---
Trinity District	---	---	-7.0	-1.1	---	---	---
Brook Hollow District	---	---	-1.0	-0.2	---	---	---
Houston	Gulf Freeway	---	---	---	---	---	---
Group 1 6/							
Section 3							
Land	---	1940-55	285.4	19.0	---	---	---
Improvements	---	---	-17.2	-1.1	---	---	---
Average	---	---	281.5	18.8	---	---	---
Group 2							
Section 3							
Land	---	---	175.6	11.7	---	---	---
Improvements	---	---	28.6	1.9	---	---	---
Average	---	---	105.0	7.0	---	---	---
San Antonio 7/	San Antonio Expressway	1941-45 to 1952-56	---	---	---	---	---
Land	---	---	98.9	9.0	-25.6	-2.3	---
Improvements	---	---	125.1	11.4	-21.7	-2.0	---
Average	---	---	107.6	9.8	-22.5	-2.0	---

1/ The percentage changes are based on data from the pages cited in each footnote converted to constant dollars where necessary by the Consumer Price Index.

2/ Reference 20, p. 7.

3/ Industry and Frontage Roads, by John F. Kelly and Edward P. Reilly, California Highways and Public Works, vol. 33, No. 7-8, July-August 1954, pp. 2 and 3.

4/ Reference 7, table A-8.

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Source: (*8-24*, p. 25).

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CATEGORY: 9. Institutions
VARIABLE: A. Institutional Dislocation and Relocation

Area:	Urban
Type of Consequence:	Economic or Social
Location of Impact:	Right-of-Way Corridor
Timing of Impact:	During Construction After Construction—Short Term After Construction—Long Term

Consequences

Rights-of-way takings may dislocate institutions. The consequences are: (1) forced relocation or discontinuance of the institution, with attendant expense to the extent uncompensated; (2) creates employee expense involved in finding and commuting to new jobs, commuting to old job at the institution's relocation site, or relocating residence to be nearer the relocation site; (3) incurs greater or lesser transportation costs to the institution's patrons according to their location in relation to the institution's original and relocation site; (4) may cause inefficient operation of substitute institutions in the vicinity that are overloaded by the patrons of the dislocated institution. The last effect may be offset somewhat by residential dislocation also occurring in the vicinity. If residential dislocation is sufficiently great, inefficiency may arise from under-utilization, lack of patronage, and excess capacity for institutions remaining in the area but not dislocated.

Gains and Utilities

1. To institutions:
   a. Compensation paid for property at fair market value; moving expenses and optional relocation payment.
   b. Advantages from improving facilities, and service area coverage through relocation (gain of served population, its characteristics—number, class, type, etc.), lower costs of relocation facilities.
2. To employees:
   a. Lower commutation to institution in its relocation site.
3. To patrons:
   a. Greater convenience for some patrons to reach institution in its new site.
4. To substitute institutions:
   a. Increased patronage from patrons of dislocated institution who find it inconvenient to reach in its relocation site, or lose its services if it quits operation as a result of dislocation.

Costs and Losses

1. To institutions:
   a. Value of property and moving and relocation expense to the extent uncompensated.
   b. Disadvantages stemming from: reorientation of service area (loss of served population, its characteristics—number, class, type, etc.); less satisfactory relocation facilities, or higher costs for same.
2. To employees:
   a. Cost of seeking new employment; or added cost of commutation to relocation site; or cost of relocating residence to be near relocated establishment.
3. To patrons:
   a. Inconvenience of former patrons in reaching relocated institution or substitute sources of its services if it moves beyond convenient range or quits operation.
4. To substitute institutions:
   a. Inefficiencies stemming from overload due to patrons of the dislocated institution transferring their patronage to a substitute.

Decision-Making Factors

1. The relative merits of each alignment based on the following criteria:
   a. Institutions in various categories, weighted by employment and number of patrons.
   b. Institutions intending to (1) reestablish in area, (2) reestablish in any area, and (3) stop operation if displaced.
   c. Disturbance cost to institutions.
   d. Involvement of employees, especially those in the following categories that are usually least able to bear the added cost of job seeking, unemployment,

and added commutation or relocation; and/or which have most difficulty being rehired after losing a job:

(1) Unskilled and semi-skilled occupations—due to automation and low pay.

(2) Older workers and those who have spent most years employed in same occupation—due to obsolescence of skills and impending retirement.

e. Local residents employed—for whom a shift in location of employment probably would create the most commutation or relocation cost burden.

f. Aggregate payroll—buying power—loss with least second-round impact on the retail trade sector's sales, payroll, and employment.

g. Negative impact on local employee-residents in terms of lowering income levels, and added commutation cost.

h. Negative impact on institutional patrons in numbers and in aggregate cost to patronize alternative or relocated institutions.

CATEGORY: 9. Institutions
VARIABLE: B. Institutional Accessibility and Patronage Change

Area:	Urban
Type of Consequence:	Economic or Social
Location of Impact:	Corridor
Timing of Impact:	During Construction After Construction—Short Term After Construction—Long Term

Consequences

Highway improvements have a variety of effects on religious, civic, social, educational and recreational institutions:

1. Accessibility change.—By widening the service area of the institution, a highway improvement may attract added patronage. Such added patronage is a benefit if the institution is operating below capacity. If at capacity or above it, added patronage may create overcrowding of the institution's facilities, congestion in its vicinity, and modification of the amount of service it can provide each patron under the impact of increased demand. The institution would therefore bear added cost to increase its capacity or cause its former patrons to bear the cost of reduced service. Increased demand may also affect patrons' costs if parking fees are required.

On the other hand, patronage change and the institution's use of the improved highway may permit advantageous alterations in its operation. A report to the Congress states that "Highway improvements also benefit public and institutional services by promoting efficiencies and economies that could not otherwise occur" (*9-2*).

An example includes hospitals. By improved access to a larger service area, regional medical centers have replaced smaller community hospitals. The regional centers offer more completely equipped facilities and a broader staff of specialist doctors and technicians (*9-1*, pp. 86-87).

Also advantaged by highway improvements have been institutions of higher learning. They have been able to serve a wider area and a larger student body through improved highways that bring "commuter" students to campus by car. This has relieved the institution of part of the burden of providing student housing for all those enrolled (although adding to parking problems). It has also permitted an increase in evening courses, thereby extending educational opportunities (*9-1*, p. 175).

2. Population change.—The change in the relative accessibilities caused by highway improvements within the area or region served by the institution may create population migrations. According to the number of persons migrating and where they settle, the institution may experience gains or losses in patronage and may itself be forced to migrate to follow a specialized clientele.

The succession of a population with different characteristics (racial, religious, etc.), even though population numbers remain the same, may lead to this result. This has frequently been the case with inner-city churches: they have lost parishioners to either the suburbs or local population change.

A highway-influenced change in income groups within the service area is also capable of affecting the practices and prosperity of institutions.

3. Barrier effect.—As with commercial facilities and their trade areas, institutions may have their service areas revised by the barrier effect of a limited-access facility. This will be particularly true in central-city areas where much of the travel to institutions is on foot. Hindering of access may reduce patronage for some institutions, and increase it for others that become the alternative source for institutional services for those cut off from their former source. If offered no choices, patrons may have to incur added travel expense to reach the institution.

4. Practices.—Institutional practices have been influenced by the manner in which highway improvements have influenced the population toward greater auto-orientation. Examples of accommodation to the new transportation environment include the following. A group of "drive-in" churches exist in California where church-goers remain seated in their cars for the service. Physicians have largely given up the practice of the house call now that most patients have the means of coming to the office, hospital, or clinic for out-patient treatment. The doctor's ability to see more patients in a day has been a beneficial result (*9-1*, p. 86). Public health institutions have taken advantage of highway improvements through such mobile services as X-ray examination vans.

5. Employment.—The employees of institutions will be positively or adversely affected according to the fortunes of the institution as affected by highway improvement. If the effects are adverse, employees may suffer loss of employment, limitations on pay increases, and added moving or commuting costs if the institution moves and the employee desires to remain in its employ.

6. Construction.—An institution may undergo temporary disadvantage and loss during highway construction if

it is rendered relatively less accessible due to detours, street blockage, and the congestion of construction trucks and equipment.

Gains and Utilities

1. To institutions:
   a. Increased patronage from highway-induced accessibility or population changes.
   b. Efficiencies and economies gained from patronage change or practices made possible by highway improvement (e.g., mobile services).
2. To patrons:
   a. Expanded institutional facilities or services due to increased demand.
   b. Lower costs of access to institutions.
3. To employees:
   a. More employment, wages, and job security for employees of institutions advantaged by highway improvement.
   b. Lower commuting costs if via highway improvement.

Costs and Losses

1. To institutions:
   a. Decreased patronage due to highway-induced accessibility or population change.
   b. Barrier effects of highways or temporary inaccessibility due to highway construction.
2. To patrons:
   a. Lower quality or quantity of institutional services if (1) increased patronage produces an overload, or (2) decreased patronage causes the institution to increase charges to cover costs, move elsewhere, or go out of existence.
   b. Higher costs of access if institutions centralize due to highway improvement, are cut off from a portion of their service area by the barrier effect of limited-access highways, or raise parking fees due to increased demand.
3. To employees:
   a. Less employment, wages, and job security for employees of institutions disadvantaged by highway improvements.
   b. Higher commuting costs or possible moving costs for employees of institutions that change locations due to disbeneficial effects of highway improvements.

Decision-Making Factors

1. Effects of highway improvement, beneficial and adverse, on:
   a. Institutional accessibility during and after construction.
   b. Change in institutional patronage, service levels, and practices due to highway improvement.
   c. Patronage change based on population change, income group change, change in characteristics of the population, or barrier effects of a limited-access highway.
   d. Patron costs of access, parking, and institutional services after the highway improvement.
   e. Employment in institutions, costs of commutation or moving, as affected by institutional change due to highway improvement.

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CATEGORY: 10. Population
VARIABLE: A. Population Growth

Area:	Urban and Rural
Type of Consequence:	Social
Location of Impact:	Corridor
	Community or System
Timing of Impact:	During Construction
	After Construction—Short Term
	After Construction—Long Term

Consequences

Highways contribute to population growth mainly by attracting employment in the area served by the highways through the generation of office, commercial, and industrial enterprises. Industrial growth is usually thought of as basic in that it is productive of new wealth with export potential. Commercial employment has a service and distribution function and can rarely exist without basic employment being present. (Retirement and resort communities are among the exceptions.) Office employment may be either basic or nonbasic, according to whether it serves the local or a "foreign" market, thereby becoming an "exporter" of services. Basic industry sets the basic and nonbasic employment levels and thereby influences population potential.

Ample evidence exists that highway improvements are influential in the location of employment centers and therefore in setting the locus of population growth. A Connecticut study (*10-5*) concluded: "Analysis of the effect of the Connecticut Turnpike on population trends in Eastern Connecticut reveals that the build-up of population in recent years has been more intensive among the turnpike towns than among the control towns."

Similar findings emerged from case studies of the "Mohawk Corridor" of the New York Throughway and the "Piedmont Crescent" of North Carolina undertaken as part of NCHRP Project 2-2. Automated analysis of employment and population trends in the two highway corridors revealed these findings (*10-4*):

1. When changes in population are compared with changes in employment, it becomes apparent that the two tend to be consistently related.

2. "In the Mohawk Corridor the locations which ex-

perienced the highest growth rate in population and employment from 1950 to 1960 were . . . the sub-regional nodes."

3. "Satellite cities with freeway connections to the sub-regional nodal cities . . . show diversification of employment . . . general loss of economic base . . . and a probability that the remaining workers are commuting to the nucleus of sub-regional nodes where more diversified employment is available."

4. "The accessibility provided by a major highway improvement . . . is a significant influence on employment patterns within the commuter shed of large urbanized areas."

5. Economic activities along a regional corridor will become concentrated in nodal locations probably spaced at intervals relating to tolerable commuting times on the main transportation links of the corridor.

Evident is both the attraction of employment centers to the urban areas along major highway corridors and the further shift of employment and population to the suburban portions of those urban areas.

A Bureau of Public Roads study reveals that "population in the suburban portions of standard metropolitan areas has grown at a rate about seven times that of central cities" (*10-6*, p. 100). The same study traces this suburban population growth to the development of freeways into and through urban peripheral areas. For example, three Chicago expressways were found to serve "residential areas that are among the fastest growing sections of the Chicago metropolitan area" (*10-6*, p. 101).

A study of freeway system impacts on Los Angeles' urban development also conducted as part of NCHRP Project 2-2 perceived an interrelationship between freeways and population growth. The study found (*10-4*):

> Seemingly, these two factors of rapid population growth and rapid freeway development are interrelated facts. Thus it would appear that a high and increasing degree of mobility of people and goods is part of the explanation of population increase. According to this argument, highway system improvements, both in quality and extent, are an inducement to continued population growth. Reasons which may be hypothesized for this are:
>
> 1. Southern California's greatest natural resource historically has been climate and amenity for living. Spaciousness, low density development and access to the out-of-doors have been concomitants of this attraction.
> 2. Southern California's geographically extensive pattern of land development has kept land values lower than would otherwise be the case. This pattern of development has made ample land available for the requirements of space-using industries.

These attributes would not be possible without an expanding and interrelated transport service to distribute people and economic activity. Viewed in this way, freeways are the most recent and most ambitious means for sustaining and even increasing mobility in Los Angeles. To this extent, then, it may be asserted that the freeway system has induced population growth in Los Angeles (*10-3*).

Gains and Utilities

1. To communities:
   a. Population growth based on the growth of local employment centers due to highway influence.
   b. Population growth stemming from increased access to remote employment centers via improved highways.

Costs and Losses

1. To communities:
   a. Population losses based on the decline of local employment centers relocating to capture the advantage of highway improvement elsewhere.
   b. Population loss stemming from reduced access to remote employment centers as congestion builds up, over time, on the improved facility.

Decision-Making Factors

1. Desirability of population growth in areas likely to be influenced by highway improvement according to:
   a. Local development plans and policies.
   b. Open space preservation policies.
   c. Economic conditions (e.g., unemployment, depression, excess capacity versus prosperity, full production).
   d. Population conditions; saturation and high density versus vacant land and low density.
   e. Cost of infrastructure to support population growth: sewers, water, streets, street lighting, schools, etc.

CATEGORY: 10. Population
VARIABLE: B. Population Density

Area:	Urban
Type of Consequence:	Social
Location of Impact:	Corridor Community or System
Timing of Impact:	After Construction—Short Term After Construction—Long Term

Consequences

Population density is the ratio of population to area, usually measured in square miles or acres. Density may be either gross (total area) or net (area in residential land use).

Highway improvements influence population density by affecting the amount of land accessible to work places and shopping within residents' time and distance tolerances. Such land is developable for residential use. The more residential land available relative to population, the lower the density possible.

As land coverage becomes saturated, highway improvement in the form of increased capacity allows land to hold greater numbers while preserving the balance between trip generation and transportation capacity. Higher densities are thus made possible.

The density effects of highway improvement was one of the variables probed in time-phase studies of Los Angeles as its freeway system developed from 1940 to 1960. The studies were made as part of NCHRP Project 2-2 conducted at the University of Washington. Computer mapping of census data from 1940, 1950, and 1960 formed the basis for the analysis. Findings on population densities in the Los Angeles area during the period of freeway development were as follows (*10-3*):

1. There has been an increased uniformity in population per gross acre in Los Angeles County, and there has been an accompanying decrease in the very low and very high density ranges.
2. There was a moderate increase in average or over-all density between 1940 and 1950 associated with the urbanization of former open land.
3. There was a more marked such increase between 1950 and 1960.
4. There is no great correlation between changing population density patterns from 1940 to 1950 and the freeways constructed in that period.
5. The density pattern (from 1950 to 1960) does appear to reflect an influence on the part of the increased accessibility provided to outlying portions of the County by the extension of the freeway system.
6. Densities in the central portion of the County, which were largely developed prior to the construction of the freeways, have changed very little in general, although there has been some reduction in gross density near the heart of the City of Los Angeles.
7. The drop in density in these central-city tracts was the result of land clearance and subsequent freeway development.
8. In 1940, densities were concentrated in the center of the County and decreased somewhat uniformly outward, with concentrations of medium or high density in the more-established outlying communities such as Pasadena, Glendale, Santa Monica, and Long Beach.
9. By 1960 there had been a general filling up of the entire Los Angeles Basin at a fairly uniform density level, although the nodes of somewhat higher density still existed in the older popuation centers.

The major effect of freeway development on urban population density thus appears to be the allowing of an increasing population to disperse fairly uniformly over a wide area. This permits wide choice of residential location, provides the amenity features of low-density development, and discourages high-density concentrations. It may also lower existing high-density concentrations by the opportunity to decentralize, the growing congestion of such areas, and the demise of public transportation serving them. Higher densities also may be reduced by land takings for freeways and parking.

As land is saturated by low-density development out to tolerable commuting ranges, higher densities to accommodate further population increases are predictable. Congestion may also be a factor leading to density increases as employees seek to concentrate closer to workplaces and so reduce commuting time.

Gains and Utilities

1. To residents:
   a. Amenities of low-density settlement made possible by highway improvements (i.e., spacious yards, additional landscaping, privacy, quiet).
   b. Reduced development costs and private transportation costs where increased highway capacity induces higher population densities and makes public transportation feasible.
   c. Lower taxes and utilities costs, usually for urban infrastructure to service higher-density development where induced by added highway capacity.

Costs and Losses

1. To residents:
   a. Added travel distances to most destinations due to low-density settlement pattern encouraged by highway improvement.
   b. Higher taxes and utilities costs, usually to support installation of urban infrastructure (e.g., streets, water, sewer, lighting) at low densities.
   c. Reduced natural amenities and spaciousness where added highway capacity induces higher population densities.

Decision-Making Factors

1. Likelihood and desirability of various density levels according to:
   a. Amount of land made developable by highway improvement.
   b. Projected population and growth rates.
   c. Public costs of supporting urban development at various densities and agency preparedness for same.
   d. Local development plans and policies regarding densities.
   e. Trip generation potential of various residential densities versus system capacity and congestion potential.
   f. Public demand for low-density amenities.
   g. Private transportation costs induced by low-density residential patterns.
   h. Ability to serve various densities with public transportation.

CATEGORY: 10. Population
VARIABLE: C. Population Geographic Shifts

Area:	Urban and Rural
Type of Consequence:	Social
Location of Impact:	Community or System Region or Nation
Timing of Impact:	After Construction—Long Term

Consequences

Highway improvement plays a role in geographic shifts of population. The major population shifts of the post-war decades have been from: (1) rural areas and small towns to urban areas, (2) central cities to suburban areas, and (3) the East to the West.

The revolution in agricultural technology that made production of the same quantity of food with decreasing labor inputs was mainly responsible for the depopulation of the rural areas and the small towns serving them. Highways helped in this process by making mechanized farming more possible through the transference of machinery among parcels over paved roads. All-weather roads to markets helped enlarge markets, truck sizes, and accessible land areas, making large-scale farming economical and practicable. When migrations became necessary to find employment, many were encouraged by the easier move over the improved highway system. Many farmers today find part-time urban jobs possible through improved roads that put them in commuting distance of employment centers.

Central cities had, in many instances, depleted the supply of vacant land accessible via public transportation. Highways into the undeveloped urban hinterland opened up new supplies of land to accommodate the in-migrants from rural areas and small towns as well as normal population increase. Without this relief, the added population would have led to density increases and costly redevelopment of central-city housing areas. The alternative would have been to open the hinterland with extensions of the public transportation system. However, the popularity of the automobile and its concomitant low-density residential pattern with its amenities made that the preferred means of accommodation to growth.

Saturation of the land with development out to the practicable limits of the highway system related to an urban area is occurring. The inevitable saturation of the highway system is happening as well. These trends will lead, as they are leading, back to public transportation that had the capacity to handle the traffic loads induced by the rising densities that must now take place to accommodate continuing urban population growth.

Interregional shifts of population, as in the rural to urban shifts, have been abetted by good highways that have facilitated the migration. In addition, the speed, mobility, and flexibility of transportation along with its reduced cost have made it possible for industry to disperse. Transportation costs have been reduced in significance as a factor in the cost of production. Industries have thus been freed from locations near major markets to move to where their other factors of production—such as cost of land, labor, raw materials—can be economized. The westward population migration has also caused many industries to follow the migration with branches to serve it. The expanded employment opportunities draw still more migrants in a multiplier effect.

Gains and Utilities

1. To communities:
    a. Added population from geographic shifts of residents and employment influenced by highway improvements.
2. To migrants:
    a. Improvement in employment opportunities and/or residential quality as a result of geographic shift influenced by highway improvements.

Costs and Losses

1. To communities:
    a. Reduced population from out-migration of residents and employment relocating as a result of highway influence on location of industry and land suitable for residential development.

Decision-Making Factors

1. Direction and desirability of certain geographic shifts of population that may be influenced by highway improvement according to considerations of:
    a. Efficient land-use and settlement patterns.
    b. Problems generated by urbanization and depopulation of the hinterland.
    c. Problems generated by urban dispersion and decentralization.
    d. Problems of interregional population shifts (i.e., economic depression and excess productive capacity of areas suffering out-migration, and development costs in areas receiving migrants).

CATEGORY: 10. Population
VARIABLE: D. Population Distribution

Area:	Urban
Type of Consequence:	Social
Location of Impact:	Community or System
Timing of Impact:	After Construction—Long Term

Consequences

Geographic distribution of industry workplaces influences residential distribution which in turn influences commercial workplace distribution. As highway improvement affects the geographic location and/or accessibilities among any of these activities, it will generate geographic shifts in the others.

Geographic shifts in population can occur either as a result of relocation of employment centers or due to improved accessibility to existing centers that enlarges the potential commuting area.

Borchert, in a Minnesota study, found (*10-1*, p. 42):

> The traffic volume observed on the state highway system in a given county is related to local population density and also to the distribution of population potential, or potential accessibility of population, in the regional system of which the individual county is a part. . . . The changing patterns of population density and potential can be related to fundamental elements in the nation's changing economy, technology, and geography. They can also be tied to the highway traffic pattern.

NCHRP Project 2-2 made the following findings concerning the relationship of freeways to industrial land and population distribution in a case study of the Los Angeles region during the period of freeway development, 1940-1960 (*10-3*):

> [I]ndustry is highly responsive to the opportunities to minimize space friction by means of situating in close proximity to the freeways.
>
> . . . .
>
> [T]here have since been incipient signs that part of the future utility of freeways as increasing portions of the system unfold is intercommunication between centers of

employment which may become markedly intensive in both the capital outlays for their proximate resident population.

Population distribution in its other sense (i.e., the distribution in numbers of various characteristics of the population) is also influenced but indirectly by highway improvement. Age, sex, race, marital status, family size, and housing tenure are influenced more directly by the character of the basic and nonbasic labor force, the skill mix required, its turnover, and the incomes paid to its members. Sometimes, as in the case of college and retirement communities, these variables are influenced by the character of the population subsisting on transfer payments as well as that engaged in wealth-producing, distribution, or service activities.

Highways affect distribution of population characteristics by (1) their role in inducing the location of employment, and (2) their role in influencing settlement patterns wherein groups with similar age, family size, racial, marital status, income, and housing tenure characteristics will be found clustered.

Brodsky in an NCHRP Project 2-1 (*10-2*, pp. 2A7.01-.14) case study of population patterns related, in part, to highway and transportation workplace locations in Seattle found the following generalizations emerging from his data:

1. Income Group Distribution:
   a. A higher proportion of low-income residents tend to reside in central-city areas due to inability to afford a car and therefore dependence on public transportation; or, if only one car is owned, and if both spouses work, one spouse may require access to mass transportation.
   b. A higher proportion of middle- and upper-income residents reside in outer zones because they can afford one or more automobiles and the operating expense of a longer commuting distance.
2. Age Group Distribution:
   a. Central-area residents tend to include a high proportion of elderly people who cannot afford or cannot operate a vehicle.
3. Worker Residential Distribution About Workplaces:
   a. A mapping of journey-to-work patterns in the Seattle area demonstrates that a tendency does exist for people to choose their place of residence with some regard to their place of work.
   b. Workers tend to cluster about work centers, but the degree of cluster may depend on many factors, such as the average income of workers and the size and location of the employment areas.
   c. In general, people prefer to spend as little time and money as possible on transportation to work, but the attraction of cheaper land costs in the less accessible locations and the ability of wealthier workers to absorb higher transportation costs create strong centrifugal currents.
4. Travel Time Influence on Residential Location:
   a. Central-area residents, although closer to work, spend as much time as suburban residents on work trips. Congestion and the slower speeds of transit vehicles and pedestrians are partly responsible.
   b. Travel times to larger centers (CBD, large industrial areas) tended to average a greater distance (7.2 miles) and involve more travel time (30 min) than worker travel to smaller commercial centers (4.9 miles and 20 min). Possible reasons are: lower wages for commercial, as compared with industrial workers, which would not justify or permit longer trips; more females are in the commercial work force and are more likely to use transit; and smaller work places attract a smaller population to their environs, causing less competition for space.
   c. A daily total of 60,171 commuters to the CBD averaged 5.6 miles in trip distance and took an average time of 29 min. Meanwhile, 15,606 commuters to a suburban industrial plant averaged 8.8 miles in trip distance (3.2 miles longer than CBD trips) but averaged only 31 min in trip time, 2 min more than CBD trips.
   d. From these figures it appears that the higher the employment levels in a center the greater the tendency for workers commuting there to cluster to reduce trip distance and thereby compensate for the lower travel speeds in congested traffic. Conversely, the effects of highway improvement and decentralization of employment are both to reduce congestion and increase average travel speeds. The result is an increase in the feasible commuting radius and the supply of developable land followed by lower population densities and a reduction in the degree of cluster of workers about their workplaces.
   e. Distance to work may be of less significance in housing location than travel time.
   f. Where two major employment areas exist, workers can obtain cheaper land while incurring similar transport costs by locating on the far side of their employment center rather than in the area between the centers where workers from each center compete for the same space and thus drive land prices up.
   g. Where congestion exists there is a propensity for workers to cluster closer to work, where highways allow free-running the tendency is to disperse. Size of employment center and its location and average income of workers also influence these processes.

Gains and Utilities

1. To suburban residents:
   a. More residential choice and amenity without sacrifice of added travel time due to highway improvements that permit higher trip-to-work speeds, cause work-place decentralization.
2. To central-area residents:
   a. Lower housing rents as competition for space is reduced by a portion of the population decentralizing.

3. To suburban jurisdictions:
   a. Increased tax base from decentralizing residents.

Costs and Losses

1. To central-area residents:
   a. Lower land values as residential decentralization to capture advantages of highway improvement reduces demand.
   b. Loss of patronage leading to deterioration of public transportation service and increases in fares.
2. To central jurisdiction:
   a. Reduced tax base where decentralizing residents cross outside central jurisdiction's boundaries.

Decision-Making Factors

1. Desirability of accommodating population growth in the distribution pattern influenced by highway improvement according to considerations of:
   a. Land use and transportation efficiency.
   b. Relative tax position of central and noncentral jurisdictions.
   c. Public transportation service.
   d. Public demand for certain residential amenities.
   e. Housing cost and rent pattern in the urban area.

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CATEGORY: 11. Public Utilities
VARIABLE: A. Utility Joint-Use of Right-of-Way

Area:	Urban and Rural
Type of Consequence:	Economic
Location of Impact:	Right-of-Way
Timing of Impact:	During Construction After Construction—Short Term After Construction—Long Term

Consequences

Various public utilities (i.e., electric, telephone, natural gas, water, and sewer) make joint use of public road rights-of-way. The joint use provides benefits to the utilities according to three separate studies conducted in Oregon (*11-1*), Georgia (which examined utility benefits in that state and three others) (*11-2*), and Utah (*11-3*).

The studies' conclusions were:

1. Oregon study.—There is "a net monetary benefit and a net real benefit with respect to utilities and a significant combined utility and non-utility benefit from utility use of the highways" (*11-1,* p. 25).

2. Georgia study.—Both publicly and privately owned utilities receive real benefits (in the form of lower costs) from using streets and roads for placing services. These benefits seem to pass on to the public, the management, and the stockholders (*11-2,* p. 91).

3. Utah study.—The study determined that there are benefits and costs that are certain to be associated with utility use of the public rights-of-way. The costs include the marring of the landscape and reduction in traffic flow. The benefits include (1) lower rates and higher input, (2) lower maintenance costs, (3) lower construction costs, and (4) better utilization of scarce resources (*11-3,* pp. 66-68).

All states have laws permitting utilities the use of highway rights-of-way where it is not inconsistent with the public's superior right to use the highway for travel. Where, as in the case of the Interstate system, utility use appears inconsistent with the high travel standards of those highways the privilege has been withheld (*11-4,* p. 186).

Some jurisdictions levy a tax or charge for utility use of street and highway right-of-way. Utilities customarily pay owners of private property for rights-of-way across their property. Utilities enjoy free use of state highway rights-of-way where such use is permitted. Extensive use is made of highway rights-of-way. Sample surveys taken in eight states revealed the percentage of utilities in the various study areas that were located in public rights-of-way:

STATE	%
Arkansas	28
Colorado	55
Georgia	61
Massachusetts	80
Oregon	68
Texas	79
Utah	56
Wisconsin	77

The same surveys indicated that undergrounded utilities are the most frequent users of public rights-of-way, going as high as 99 percent in some instances (*11-4,* pp. 187-89).

It is obvious that the main benefit from utilities' free use of public rights-of-way is the savings in easement costs that would otherwise have to be paid private landowners. According to the Georgia study (*11-2*) of utility easement costs in four states, the savings amount to an average of $3,494 per mile for easement acquisition and $245 per mile for its use.

The averages for the individual states are as follows:

STATE	AVERAGE EASEMENT COST ($/MILE)	AVERAGE EASEMENT ANNUAL CHARGE ($/MILE)
Colorado	4,026	282
Georgia	4,011	282
Texas	4,104	288
Wisconsin	2,330	163

Costs would run higher than average in urban areas; lower in rural (*11-4*, pp. 190-92).

In addition to these monetary savings, added benefits include: (1) ease of access for service and maintenance from public roadways, (2) proximity of lines to utility users, (3) lack of necessity to clear vegetation in order to locate lines, and (4) lower rates to utility customers on higher returns to stockholders and management than would be the case if utilities had to pay for private right-of-way. The Utah study computed the savings for each customer to average $3.36 per year for electric and $2.03 per year for telephone (*11-4*, pp. 192-94, 198).

Disadvantages of public right-of-way locations for utilities to utility companies include: (1) cost of relocating lines when necessary to accommodate highway improvements, and (2) the added costs incident to maintenance performed on or adjacent to a traveled roadway (i.e., flagmen, barricades and warning signs, workman insurance, and loss of efficiency due to working in traffic) (*11-4*, pp. 195-96).

Disadvantages also accrue to road users: (1) traffic disruption for utility line installation or servicing; (2) safety hazards from poles along roadways capable of being struck by cars skidding off roadway, broken electric lines falling on highway; (3) unaesthetic appearance of utility lines along highways; and (4) unaesthetic tree trimming to avoid interference with lines (*11-4*, p. 196).

Gains and Utilities

1. To utility companies:
   a. Savings in easement costs where free use of highway rights-of-way is possible and permissible.
   b. Savings in maintenance and service costs.
   c. Proximity to users for ease of connection and savings in cost of connections.
   d. Savings in clearing vegetation from private rights-of-way.
   e. Higher returns to stockholders and management from savings.
2. To utility customers:
   a. Lower costs of service than would occur if utilities paid for all easements.

Costs and Losses

1. To utility companies:
   a. Cost of relocating lines for highway improvements.
   b. Added costs to service utility lines from traveled roadways; flagmen, signs, barricades, insurance, and efficiency losses.
2. To highway users:
   a. Costs of traffic disruption when lines are being installed or serviced.
   b. Safety hazards of poles and electric lines proximate to roadway.
   c. Unaesthetic appearance of utility lines and trees trimmed to avoid interfering with them.
3. To highway agencies:
   a. Lack of reimbursement for right-of-way use.
   b. Utility relocation costs due to highway improvement where the highway agency is made legally liable for same (e.g., under Interstate system laws).
   c. Administration of permits and plans for utilities to use rights-of-way.

Decision-Making Factors

1. Net benefit or cost accruing from utility companies' joint use of highway rights-of-way considering value of all benefits and costs to: (1) utility companies, (2) road users, and (3) highway agencies.

2. Means to ameliorate or reduce costs where found to exceed benefits (e.g., undergrounding power lines; coordination of utility and highway agency work on and under roads).

CATEGORY: 11. Public Utilities
VARIABLE: B. Utility Dislocations and Relocations

Area:	Urban and Rural
Type of Consequence:	Economic
Location of Impact:	Right-of-Way Corridor
Timing of Impact:	Before Construction During Construction

Consequences

When highway improvements necessitate the dislocation and relocation of utilities using the right-of-way, a cost is incurred for that procedure.

Whether the utility or the highway agency bears the cost of relocation varies among jurisdictions and, more recently, according to the highway program funding the improvement. For most relocations, the utility pays the cost. The scale of such costs nationwide is indicated by the statistic that utility companies paid $29.1 million in 1953 for relocation of lines on federal-aid and other state highways (*11-4*, p. 195).

According to an Oregon study (*11-1*, p. 21), utility relocation costs average less than half the value of benefits utilities receive from use of highway rights-of-way.

Under a provision in the *Federal-Aid Highway Act of 1956*, as amended, states that pay the cost of relocating utility lines necessitated by construction of a federal-aid highway can be reimbursed with federal funds for such cost in the same proportion as federal funds are spent on the project (*11-4*, p. 195). A growing number of states have passed legislation providing for payment of utility relocation costs. This will eliminate the main disadvantage to utilities of highway right-of-way locations and increase the benefits they now receive through savings in easement costs. At the same time, highway agency construction costs will be increased by the amount of unreimbursed relocation expense in those states having passed reimbursement legislation (*11-4*, pp. 195, 197).

Gains and Utilities

1. To utilities:
   a. Reimbursement for utility relocations necessitated by highway improvements in states permitting same.
2. To highway agencies:
   a. Partial reimbursement for utility relocations from federal-aid funds where program and state law permit.

Costs and Losses

1. To utilities:
   a. Cost of utility line relocations in states where reimbursement is not allowed or practiced.
2. To highway agencies:
   a. Cost of utility line relocations in states where reimbursement of utilities is allowed or practiced—to extent not further reimbursed by federal-aid funds.

Decision-Making Factors

1. Total costs of utility relocations due to highway improvement and incidence of costs:
   a. Utility companies.
   b. Highway agency construction budget.
   c. General Fund of State.
   d. Federal-aid highway funds.
2. Net result of benefit/cost comparison between utility benefits from rights-of-way locations and cost to utilities of line relocations due to highway improvements.

CATEGORY: 11. Public Utilities
VARIABLE: C. Utility Patterns and Costs

Area:	Urban
Type of Consequence:	Economic
Location of Impact:	Community or System
Timing of Impact:	After Construction—Short Term After Construction—Long Term

Consequences

Insofar as highways influence the pattern, density, and type of land development, there will be a correlated differentiation in the cost of utilities designed to serve such development. Length and capacity of lines, scale economies, volume of customers relative to capacity, and number of connections all influence the capital, operating, and maintenance cost of utilities. Ultimately, these costs will be reflected in the size of the customer's utility or tax bill.

Research has revealed that lower population densities are associated with cities that have developed during the period of automobile technology. Wynn and Levinson (*11-6*, p. 38) state these findings from investigations into population density and its correlates:

> Traditionally, density has been closely related to transportation systems, even today, the impacts and intereffects are apparent.
>
> . . . .
>
> Cities that reached 350,000 between 1830 and 1890 (before the advent of the electric street railway) generally had the highest densities, whereas cities that reached 350,000 between 1930 and 1960 (the automobile era) generally had the lowest densities. Thus, central city density also depends on the mode of intraurban transportation prevailing at the time the central city was built, with cities built around pedestrian travel often being the most dense.

The reasons for the low density of automobile-oriented cities are basically (1) the large supply of land—relative to demand—that the speed and range of the automobile and the ubiquity of the highway and street system open to development, and (2) the low capacity-volume limitations of the mode whose proneness to congestion discourages high densities.

The lower densities made possible (and desirable) by highway improvements imply increasing residential lot size, including longer front footages. The length of streets and utility lines (and public service routes) required to service a given number of households increases as settlement occurs at lower and lower densities. Offsetting these costs somewhat is the fact that lower capacities and standards are possible and acceptable (e.g., smaller pipe, streets without curbs or storm sewers installed). Also, a full line of services and utilities may not be required or can be obtained at private expense (e.g., large lots can use septic tanks, may draw water from wells).

Nevertheless, where two areas require a similar set of utilities the one having the lower-density development has been found to incur the greater per-unit cost. This conclusion is supported by the findings of a study of the cost of services in residential areas conducted for the U.S. Housing and Home Finance Agency (HHFA) by Wheaton and Schussheim (*11-5*). A relevant sample of their findings is as follows:

1. Effects of density on costs.—Density and type of housing development affect municipal service costs in residential districts in two principal ways: First, by influencing the level and standards of municipal services; secondly, by determining the average length of frontage facilities required by each home. Higher density of housing development is ordinarily associated with the provision of full urban services, while a narrower or less elaborate complement of municipal services may be adequate and more economical in low-density settlements. Shorter average house fronts mean shorter average lengths of service streets and primary water and sewer lines, and, hence, lower capital investments per dwelling. "Thus, unit investments

are considerably lower in multiple-family developments than in single-family areas in completely serviced municipalities . . . ." (*11-5*, p. 91).

2. Effects of scattered development on costs.—

> To the extent that decentralization of residential areas is now taking place in a widely scattered pattern, municipal costs face unnecessary increases.
>
> . . . .
>
> Substantial economies can be realized if the development of partially developed areas is completed before construction is encouraged or permitted in undeveloped areas. Premature installation of municipal services is costly . . . . (*11-5*, p. 5).

3. Effects of population growth in achieving economies of scale.—

> Average fixed unit costs decline when the total fixed costs are spread over more and more users.
>
> So far as neighborhood facilities are concerned, the number of homes in the service area is a crucial consideration, because economies of scale hinge on the degree to which the full capacity of various municipal facilities is utilized (*11-5*, p. 92).

Other factors found to influence municipal service costs included betterment practices, service levels and standards, and stage of community development.

From these findings it is possible to infer that a portion of the heavy demands for capital expenditures, the high taxes, and local financial problems of suburban communities in the postwar years has, in part, been due to the low population density development encouraged by automobility and highway improvements into and through suburban areas.

Part of the "crisis" of the central cities may be a reciprocal effect of the cost of providing new utilities plant in the suburbs to accommodate the outward shift of commerce, industry, and residents: the increased cost of capital plant with excess capacity as the number of firms and households using the plant shrinks. The ongoing costs of central-city utility plant is divided among fewer users, forcing up the average cost to each.

To the extent that alternative development patterns and population densities are influenced by transportation improvements, each alternative will incur a different set of utilities costs. Transportation improvements that lower time-distance to work centers will increase the supply of residential land relative to demand and encourage settlement at lower densities on larger residential lots. The longer front footage per connection will tend to drive up utilities cost per household. Some of the higher costs will get passed along to occupants of new housing through installation or connection charges and front foot benefit assessments. Others will be spread over the total population or consumer group in the form of taxes and utility charges.

Lower-density residential areas typical of auto-oriented cities tend to have higher utilities costs than higher-density areas for a similar set of services.

Gains and Utilities

1. To utilities users:
   a. Lower utility costs where low population density settlement permitted by automobility allows private, less costly alternatives to public utilities (e.g., septic tanks, wells) or lower standards or capacities of equipment (e.g., smaller pipe, lack of sidewalks, storm drains).

Costs and Losses

1. To utilities users:
   a. Higher utility costs or taxes where low population density settlement permitted by automobility requires longer front footages of utility line per connection, realization of fewer scale economies, and a higher average share of costs due to the low ratio of users to total capital and operating expense. Costs are also increased by longer mains required to serve "leapfrog" development and excess capacity in older systems created by decentralization based on highway improvements.

Decision-Making Factors

1. Differential costs of utilities installation, operation, and maintenance at alternative population densities influenced by alternative transportation modal capacities and system characteristics, time-distance relationships between home and work places, and the resultant supply-demand relationship for residential land.

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CATEGORY: 12. Residential Neighborhoods
VARIABLE: A. Rents, Costs, and Prices of Replacement Housing

Area:	Urban
Type of Consequence:	Economic
Location of Impact:	Corridor
	Community or System
Timing of Impact:	Before Construction
	During Construction
	After Construction—Short Term

Consequences

Replacement housing for dislocated households from inner-city urban neighborhoods usually costs more in rents or price than the unit from which the household was displaced.

> The phenomenon of increased housing costs following relocation is characteristic of virtually all the rehousing efforts reviewed. With only one exception, every relocation study, from the early 1930's until the present, reports increased rents, in some cases relatively small, but in most cases quite substantial (*12-6*, p. 273).

This effect stems mainly from (1) improvement in housing quality, and (2) change in the supply-demand relationships in the housing market.

> A review of the findings from other studies indicates that in most cases housing quality, measured in terms of structural condition and facilities, improved considerably after relocation.
>
> . . . .
>
> The sudden and large-scale increase in demand for low-rent housing caused by major removal projects clearly is a key factor in causing higher rents, particularly in areas of housing shortage (*12-6*, p. 271-73)

Low-cost housing is in constant shortage. Little added supply comes from new construction in the form of public housing. Most is from the "filter down" of older units as they deteriorate and becomes obsolete. When construction or interest costs or increased demand up the line hinders the "filter down" process, the alternative is overcrowding of the existing supply by doubling up or subdivision of larger dwelling units into smaller.

The demand for relocation housing is usually localized in the same area from which dislocated households were moved. "Most . . . studies of the redistribution of relocated families . . . indicate that most families clustered in the immediate vicinity of the area from which they were dislocated" (*12-6*, p. 268). This means that the full impact of the housing demand of relocating households is usually felt in the same vicinity that just suffered a large-scale reduction in housing supply due to the right-of-way takings. Because of the higher densities typical of inner-city neighborhoods, a mile of freeway there will displace more households than a similar mile in outlying low-density areas. Relocation impacts in terms of numbers affected and rent levels will be relatively greater toward the urban center and will fall off with distance from that location.

Theoretically, and apparently in practice, the following change in relationships occurs. In Figure B-1, the supply curve, S_1, indicates the supply of available vacancies in the period before right-of-way taking. The demand curve, D_1, reflects the normal turnover demand in the same period. The average equilibrium rent falls at R_1.

After right-of-way taking, the supply of available vacancies has been reduced by the taking from S_1 to S_2. Simultaneously, the relocatees, added to normal demand, have shifted the demand curve to D_2. The new equilibrium average rent, R_2, reflects the supply-demand conditions after taking. The shift from R_1 to R_2 is in the direction of higher rents.

Local market conditions will determine the extent of any increase in rent rates. Influential factors will be the "tightness" of the market as determined by the supply of available vacancies. Supply is determined by the amount of new residential building. The velocity of the "filter down" process may be retarded by higher interest rates or construction costs that slow the pace of new construction. Supply also is affected by the availability and use of federal and local aids (e.g., rent supplements, public housing, and low-interest or nonprofit housing loans).

Other factors inhibiting participation in the larger market may include lack of knowledge, desire to keep contacts in the former neighborhood, and the need to remain in dense areas to economize transportation costs. Vacancy rates and prices in the over-all market may be irrelevant to the desires of and housing available to a particular set of relocatees.

Less desirable means of increasing the supply of low-income housing include the conversion of large to smaller units, overcrowding, and "block busting."

The rise in rents due to increasing the number of households seeking shelter while reducing the number of housing units is felt most heavily by (1) low-income families, (2) elderly persons, and (3) large families (*12-12*). For these groups higher rents represent added hardship.

Because the poorest housing, usually nearer the central business district, has the lowest acquisition cost, the low-rent housing of low-income families is often depleted by public programs, (e.g., highways, urban renewal, code enforcement, school buildings, and other public improvements). Private renewal activities also take a share. The result is not only to increase the price or rents, but also, for the lowest incomes, to cause housing to take an inordinate share of limited incomes.

> The increased burden of these higher rents is revealed in the several studies which report rent/income ratios. For example, the San Francisco study (Smith, Wallace, "Relocation in San Francisco," *Bay Area Real Estate Report*, 4th Quarter 1960), indicated that the median rent/income ratio rose from 17 percent to 23 percent following relocation. The 1957-1958 Chicago study of families

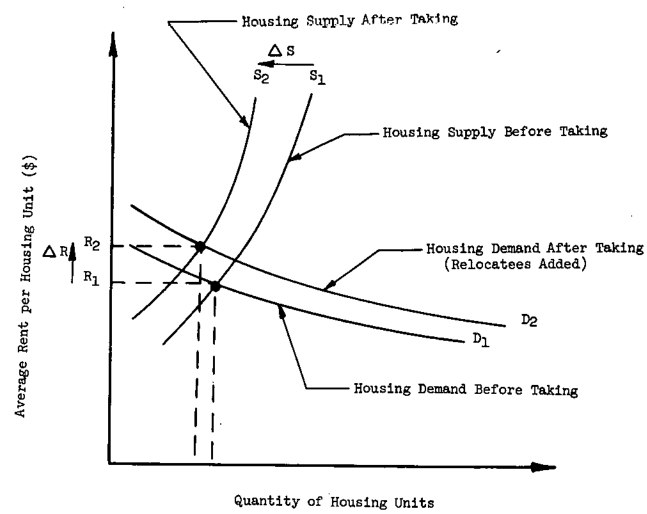


Figure B-1. Hypothetical relationship of housing demand, supply, and rents in relocation areas before (D_1) *and after* (D_2) *right-of-way takings in central-city areas.*

displaced from public housing sites (Chicago Housing Authority, *Rehousing Residents Displaced from Public Housing Clearance Site in Chicago, 1957-1958.* Chicago: Chicago Housing Authority, 1960) reported an increase in the median rent/income ratio following relocation from 16.6 percent to 26.3 percent. Breaking down changes by income level, this same study indicates the degree to which poorer families suffer most from these increases: among those earning less than $3,000 per year (35 percent of all households) median rent/income ratio rose from 35.3 percent before relocation to 45.9 percent after relocation; among those in the $3,000 to $3,999 bracket, the median ratio increased from 18.3 percent to 25.4 percent; and among those earning over $5,000, the median ratio increased from 9.1 percent to 17.4 percent (*12-6*, p. 273).

Public housing, rent supplements, and increased welfare payments may be necessary to offset the deeper bite increased rents make in low incomes. Although improvement of housing condition may (or may not) accompany rent increases, there may be a decline in general household welfare as the added rent costs are made up from the amounts formerly budgeted for other necessities (e.g., food, clothing, medicine, transportation, and savings for children's education). Also, the relocation cost and ensuing rent increase are involuntary and distort preferences. Some households choose inferior housing in order to have more to spend on more preferred wants. This is true of the lowest income groups who already spend up to 50 percent of income on housing. Destitution may result from being forced to spend more.

Land clearance often occurs in the neighborhoods having the worst housing in terms of its condition, design, layout, and amenities. Therefore, any alternative housing probably will be in better condition and in more desirable neighborhoods, costing more and being worth more. However, there is no guarantee that relocation assures housing improvement. "While most studies report considerable improvement, significant numbers—in some cases, the majority of families—still live in substandard housing following relocation" (*12-6*, p. 271).

The rehousing problem of the elderly is exacerbated by (1) their relatively fixed incomes without prospect of increase to cover added rents, and (2) the difficulty of elderly owner/occupants getting a new mortgage for replacement due to lack of credit eligibility. Many elderly owners occupy fully paid-for dwellings and have no rent or mortgage expense prior to dislocation. This creates the problem of beginning payments on a house or apartment. A change occurs in preferred life style where it is necessary to move from a house to an apartment or into a lower-quality neighborhood due to rent or price differential. This change occurs where the government payment does not cover the cost of replacement housing equivalent to that given up. Nonwhites, whose housing market in most cities is already extremely restricted by segregation, probably fare worst.

Every study of racially mixed relocation areas in which effects of relocation are analyzed separately for white and non-white households indicates that the effects of discrimination make decent relocation housing more difficult and expensive to obtain for non-whites and force them to pay high rents, even for poor housing (*12-6*, pp. 273-74).

In addition to higher rents, additional financial burdens are placed on relocatees. Improvement of housing quality frequently calls for increases in joint costs: operation, maintenance, taxes, heating, transportation, and furnishings. These are a function of the degree of home improvement, the size of house and yard, the status of the neighborhood, and the new location in relation to work and shopping. Government, to the extent it does not compensate such added burdens, may pass the true cost of relocation onto low-income displacees, injuring most those least able to bear it.

All or part of the expense of replacement housing may be offset by provisions of the *Federal-Aid Highway Act of 1968* (*12-15*) which authorizes:

§ 506. Replacement Housing

(a) In addition to amounts otherwise authorized by this title, the State agency shall make a payment to the owner of real property acquired for a project which is improved by a single-, two-, or three-family dwelling actually owned and occupied by the owner for not less than one year prior to the initiation of negotiations for the acquisition of such property. Such payment, not to exceed $5,000, shall be in the amount, if any, which, when added to the acquisition payment, equals the average price required for a comparable dwelling determined, in accordance with standards established by the Secretary, to be a decent, safe, and sanitary dwelling adequate to accommodate the displaced owner, reasonably accessible to public services and places of employment and available on the private market. Such payment shall be made only to a displaced owner who purchases and occupies a dwelling within one year subsequent to the date on which he is required to move from the dwelling acquired for the project. No such payment shall be required or included as a project cost under section 504 of this title if the owner-occupant receives a payment required by the State law of eminent domain which is determined by the Secretary to have substantially the same purpose and effect as this section and to be part of the cost of the project for which Federal financial assistance is available.

(b) In addition to amounts otherwise authorized by this title, the State agency shall make a payment to any individual or family displaced from any dwelling not eligible to receive a payment under subsection (a) of this section which dwelling was actually and lawfully occupied by such individual or family for not less than 90 days prior to the initiation of negotiations for acquisition of such property. Such payment, not to exceed $1,500, shall be the amount which is necessary to enable such person to lease or rent for a period not to exceed 2 years, or to make the down payment on the purchase of a decent, safe, and sanitary dwelling of standards adequate to accommodate such individual or family in areas not generally less desirable in regard to public utilities and public and commercial facilities.

Gains and Utilities

1. To landlords:
   a. Rent increases.

Costs and Losses

1. To owners and tenants:
   a. Higher rents and prices for housing. May be partially or wholly offset by compensation practices, relocation assistance.

Decision-Making Factors

1. Dwelling unit demolition that seriously harms the relocating population economically and for the long term due to higher rents; especially important when rent increases do not offer the prospect of reflecting house betterment.

2. Compensation for hardships caused the dislocatees whose housing market and budgets have been adversely affected by one or combination of:
   a. Excess relocation payments and effective relocation assistance.
   b. Joint development that includes an extensive housing element suited to the needs of the displaced population and preferably completed *before* right-of-way taking.

3. Extent that dislocatees are left economically whole—substantially no worse off after dislocation than before.

CATEGORY: 12. Residential Neighborhoods
VARIABLE: B. Residential Relocation Costs

Area:	Urban
Type of Consequence:	Economic
Location of Impact:	Right-of-Way
Timing of Impact:	Before Construction

Consequences

Those forced to move due to right-of-way taking pay other costs in addition to possible higher rents in their relocation housing. The relocatee incurs monetary costs for travel and time off from work while seeking housing in which to relocate. At the time of relocation, the displaced household or person incurs moving costs.

To offset costs of seeking alternative housing and moving to it, the *Federal-Aid Highway Act of 1968* authorizes the following relocation assistance (*12-15*):

> § 505. Relocation payments
> (a) *Payments for Actual Expenses.*—Upon application approved by the State agency, a person displaced by any highway project approved under section 106 or section 117 of this title may elect to receive actual reasonable expenses in moving himself, his family, his business, or his farm operation, including personal property.
> (b) *Optional Payments—Dwellings.*—Any displaced person who moves from a dwelling who elects to accept the payments authorized by this subsection in lieu of the payments authorized by subsection (a) of this section may receive—
> (1) a moving expense allowance, determined according to a schedule established by the Secretary, not to exceed $200; and
> (2) a dislocation allowance of $100.

Owners or tenants who move in anticipation of dislocation but prior to the time compensation is legally authorized suffer uncompensated loss of moving costs and other dislocation expense.

Owners or tenants who incur expense in excess of allowable compensation suffer a net loss to the extent of the excess.

Gains and Utilities

1. To residents:
   a. Payments for "actual reasonable expense in moving," or:
      "(1) a moving expense allowance, determined according to a schedule established by the Secretary, not to exceed $200; and
      "(2) a dislocation allowance of $100" (*12-15*).

Costs and Losses

1. To residents:
   a. Travel and time-off cost while seeking new housing, to the extent uncompensated by dislocation allowance and relocation assistance.
   b. Moving costs, to extent uncompensated by moving expense payments or allowances.
2. To highway agency:
   a. Compensation of moving costs and dislocation allowances; cost of operating relocation assistance agency.

Decision-Making Factors

1. Total cost of relocating dislocatees, regardless of compensation or who suffers the cost in the end.

CATEGORY: 12. Residential Neighborhoods
VARIABLE: C. Social and Economic Relationships of Dislocatees

Area:	Urban
Type of Consequence:	Economic or Social
Location of Impact:	Right-of-Way Corridor
Timing of Impact:	Before Construction During Construction

Consequences

Displacement of people and business may disrupt or destroy established relationships with: (1) persons: family ties and friendships with neighbors; (2) firms: credit and special service relationships; and (3) places: familiar surroundings with affective significance. Such relationships represent the investment of time and energy over long periods of time. Their disruption or destruction creates a psychological cost and would sometimes occur anyway due to urban mobility. Displacement speeds up the process and makes a move involuntary, however.

The greatest hardship probably falls on the elderly who lack the energy or financial resources to invest in building up similar relationships elsewhere or retain former ones. Similar hardship accrues to working-class populations that are prone to develop strong webs of neighborhood relationships and often generally lack the degree of psychological resources to make the transitions implied by dislocation "with meaning and satisfaction" (*12-3*, p. 101). One researcher has likened their reaction to uprooting to an emotion resembling grief (*12-4*). Even the improvement of housing quality and status, according to one researcher, did not ameliorate the psychological trauma of relocation. The writer states: "[O]ur findings from the West End, supported by similar studies from other cities, suggest that the deleterious effects of the uprooting experience, loss of familiar places and persons, and the difficulties of adjusting to and accepting new living environments may be far more serious issues than are changes in housing status" (*12-6*).

Research reveals those most able to accomplish a satisfactory readjustment were:

1. Those with negative feelings about their neighborhood or neighbors prior to relocation (*12-3,* p. 95).
2. Those with greatest familiarity with and orientation toward the world outside the neighborhood (*12-3,* p. 95).
3. Those with higher occupational skill and educational levels (*12-3,* p. 94).

Neighborhoods in which persons with these characteristics are a minority, as determined by attitude surveys and census data on occupation and education, are likely to produce the most negative reactions to dislocation.

Gains and Utilities

1. None known.

Costs and Losses

1. To displacees:
   a. Psychological cost: grief over loss of home, personal ties, and familiar haunts; lack of satisfactory readjustment may extend over long periods.
   b. Social and economic cost: time, energy, and financial cost to develop new relationships or to retain old ones, now scattered.

Decision-Making Factors

1. Low-mobility neighborhoods, especially those with a high proportion of elderly and/or working-class households —population segments severely psychologically and socially traumatized by relocation—avoided where possible.

CATEGORY: 12. Residential Neighborhoods
VARIABLE: D. Quality of Neighborhood Life

Area:	Urban
Type of Consequence:	Social
Location of Impact:	Right-of-Way Corridor
Timing of Impact:	Before Construction

Consequences

Between time of route designation, or even discussion of alternative locations, and actual taking of right-of-way: (1) owners in a proposed right-of-way become reluctant to improve or maintain property due to impending forced sale; (2) owners and tenants, residential and commercial, move out, creating vacancies; (3) new tenants and owners hesitate to rent or buy except at depressed rents or prices due to shortness of occupancy period. The quality of neighborhood life deteriorates: (1) aesthetic quality declines due to deterioration of structures; (2) social and economic life, including quantity and quality of commercial and other services available, plus convenience, are reduced by departures; (3) crime, vandalism, and rubbish accumulation grow due to vacancies and the lower-income residents attracted by the reduced rents necessary to fill vacancies. Effects may be visible in all potential route locations during discussion period, becoming localized in the proposed right-of-way after route decision and announcement. Condition increases with length of time covered before actual takings.

Nearby neighborhoods outside the proposed right-of-way may be negatively affected by the proximity of a blighted area.

Gains and Utilities

1. None known.

Costs and Losses

1. To tenants or owner/occupants:
   a. Psychological costs in comfort, convenience, and aesthetic enjoyment from living in a neighborhood with a deteriorating quality of life.
   b. Tangible costs: deterioration in safety, health, and welfare; decline in property values.

Decision-Making Factors

1. Period of uncertainty and delay in discussion phase and period between route designation and taking of right-of-way.
2. Number of dwelling units in right-of-way taking.

CATEGORY: 12. Residential Neighborhoods
VARIABLE: E. Property Values in Right-of-Way Before Taking

Area:	Urban
Type of Consequence:	Economic
Location of Impact:	Right-of-Way
Timing of Impact:	Before Construction

Consequences

Property values in right-of-way decline due to: (1) deterioration of property condition and neighborhood quality during period between beginning of route discussion and the date the government acts to condemn right-of-way, fair market value being set as of that date; (2) reduction of demand for property in area depresses prices, forces owners to sell at a loss if they desire to move prior to government taking.

Owners hesitate to incur costs for property improvement or maintenance due to the likelihood of the property's condemnation in the near future. Would-be owners hesitate to buy into the area for the same reason—the short period of prospective ownership. Tenants and owners of both residential and commercial property, faced with the prospect of forced relocation, begin to move out voluntarily. The vacancies created go largely unfilled. The high vacancy rate depresses the rental income of owners and encourages deterioration and vandalism to the property. The departure of neighbors and shops and the rising incidence of crime accelerates the departure of still more tenants.

The deterioration of neighborhood quality combined with the lowering of demand causes property values to decline. Actual dollar losses begin to occur as those forced to move prior to right-of-way acquisition due to employment transfers or other causes must sell at a price lower than the fair market value price and other compensations that would be paid by right-of-way agents.

Those waiting to sell to the right-of-way agent will find that neighborhood and property deterioration will have caused the fair market value to drop from its level prior to right-of-way or corridor designation. Appraiser's evaluations may be based on deteriorated conditions and depressed prices that do not reflect original worth of properties before right-of-way discussion or decision. The longer the period between discussion and/or designation of the right-of-way, the greater the decline in market value is likely to be. So, those selling to the right-of-way agent are likely to be no better off than those forced to sell prematurely, both receiving a depressed price.

Gains and Utilities

1. To highway agency:
   a. Savings in right-of-way costs due to purchase of property at depressed "fair market prices."
2. To speculators:
   a. Purchase property in desperation sales or prior to route designation at prices lower than eventual appraised price.
3. To housing and building code violators:
   a. Taking price is greater than cost of correcting violations of housing and building codes. (Usually of more benefit to absentee landlords than resident owners who perform better maintenance.)
4. To property owners:
   a. Foregone expenditure on maintenance and improvements in anticipation of property condemnation.
   b. Avoidance of transfer charges and mortgage penalties in sale to government.
   c. Eligibility for up to $5,000 added assistance for new residences [*cf. Federal-Aid Highway Act of 1968* (*12-15*)].
   d. Highway may give any usable remainder parcel increased value. Benefits may be offset against potential losses, reducing or eliminating them, providing benefits and losses accrue to the same person.

Costs and Losses

1. To property owners:
   a. Loss as difference in fair market value of property before route location discussion and amount received in sale to private party (before) or government (after) condemnation. Loss may be increased by expenditures for necessary maintenance and improvements occurring after condemnation and are not reflected in appraised value. Loss may be partially offset by (1) government's absorption of all title transfer costs and penalties, (2) owner's foregone maintenance and improvements, (3) increased relocation assistance payments (up to $5,000 authorized by *Federal-Aid Highway Act of 1968*), (4) increased value of any remainder parcel.

Decision-Making Factors

1. Property owner's loss or gain: fair market value of properties before route discussion *less* price actually paid owner by buyer (private or government) *equals* loss or gain in property values. Loss is increased by the cost of any maintenance or improvements the owner is impelled to make between the time property is appraised and taken.

CATEGORY: 12. Residential Neighborhoods
VARIABLE: F. Neighborhood and Community Stability

Area:	Urban
Type of Consequence:	Economic or Social
Location of Impact:	Right-of-Way Corridor
Timing of Impact:	After Construction—Short Term After Construction—Long Term

Consequences

Neighborhood and community stability and viability may be disrupted or destroyed by (1) right-of-way taking removing population and essential establishments and institutions altogether or reducing them to a level that inhibits stability or viability, (2) bisecting and isolating portions of an integrated neighborhood from each other, (3) having a blighting effect on the remaining neighborhood through nuisance and barrier effects, and an unaesthetic appearance. When urban revenues, population, environmental quality, and social cohesion are generally declining, cities have a stake in preserving their stable neighborhoods in order to slow, if not reverse, those declines.

Gains and Utilities

1. To neighborhoods not disrupted:
   a. Preserves the tax base for local government.
   b. Preserves residential satisfaction and population levels.
   c. Preserves environmental quality and convenience.

Costs and Losses

1. To stable neighborhoods disrupted:
   a. Diminishes the tax base; increases expenditure for public services.
   b. Increases blight and creates the future necessity for publicly assisted urban renewal.
   c. Encourages out-migration, lowers population levels.
   d. Exacerbates the dissatisfaction and alienation of the residents and diminishes the sense of urban community.

Decision-Making Factors

1. Disruption of stable urban neighborhoods, avoided where possible.

2. Evidences of stability include housing vacancy and turnover rates, crime and delinquency statistics, age and income of residents, length of residency, tax assessment trends, degree of home-ownership, property maintenance,

and social organizations (number of voluntary organizations and institutions, and participation rates).

CATEGORY: 12. Residential Neighborhoods
VARIABLE: G. Neighborhood and Community Linkage Patterns

Area:	Urban
Type of Consequence:	Economic or Social
Location of Impact:	Corridor
Timing of Impact:	After Construction—Short Term

Consequences

The highway, if controlled-access, acts as a barrier dividing neighborhoods and communities. It may disrupt linkage patterns of the neighborhood through bisection or isolation. Neighborhood, service, and trade-area boundaries become altered. Distances may be increased to churches, schools, shops, and other neighborhood facilities. Some establishments or institutions may have their tributary population so depleted that they no longer form viable units and reap losses or undergo dissolution. Others, acquiring added tributary populations due to the shift, may become overloaded and cease to function efficiently due to congestion.

Gains and Utilities

1. To establishments or institutions:
   a. Gains of tributary populations and patronage due to the rearrangement of service and trade areas.

Costs and Losses

1. To establishments or institutions:
   a. Losses of tributary populations and patronage due to the rearrangement of service and trade areas; or gains to the extent that overloading causes inefficiency.
2. To residents:
   a. Inconvenience of longer linkage distance to acquire goods and services, and pursue institutional activities.
   b. Loss of or inconvenience to retain social contacts, friends, and common-interest groups; destruction of cohesiveness, identification, organization of social groups, based on propinquity and ease of interaction, due to barrier.

Decision-Making Factors

1. Major trade and service area boundaries, of enterprises, their tributary populations, and linkages between them.

CATEGORY: 12. Residential Neighborhoods
VARIABLE: H. Residential Land Development

Area:	Urban
Type of Consequence:	Economic
Location of Impact:	Corridor
	Community or System
Timing of Impact:	After Construction—Short Term
	After Construction—Long Term

Consequences

Highway improvements have the following consequences on residential land development:

1. Increases demand due to dislocation.—Residential dislocation increases demand for more residential land use to the extent that demand exceeds space available in vacancies. The demand for low-rent space is likely to be greatest in that such space is usually found at higher densities; is in shortest supply in that no new housing is built for this market (outside of a limited amount of subsidized housing); and involves more dislocatees who have least choice in the market due to limited incomes.

2. Increases demand for and the supply of land potentially developable in residential use by:
   a. Increasing the commuting range from major workplaces to previously undeveloped areas. The extension of the 30- to 40-min driving range of the average work trip into rural areas makes them ripe for urban residential use, leading to residential decentralization and suburbanization. See Figure B-2.
   b. Influencing workplace decentralization. When workplaces are decentralized, attracted to beltway or radial expressway locations, for example, a new set of commuter driving ranges is established around each new workplace. This leads to a further outward extension of the area potentially developable in urban residential use. See Figure B-3.

3. Increase in traffic carrying capacity of transportation system or segment thereof allowing intensification of residential land use.—Raising feasible trip generation levels allows the equilibrium or balance between system carrying capacity and land-use intensity to reach a higher level. Apartment or townhouse building may be made feasible where, before, the congestion already present discouraged adding trip generation in a particular location or corridor, or the demand for space was not sufficiently high. Density increases are made possible: raising the number of people using a given supply of land through new development or intensifying the use of presently developed land.

4. Sets an upper limit on the density of residential development and determines its form.—The flexibility and mobility of the automobile and the ubiquity of roads and streets makes more space available for residential development. At the same time, the tendency for trip generation to balance with transportation system carrying and storage capacity makes low-density development desirable to balance the relatively low capacity of the automobile-highway mode with matching low trip generation levels. Automobility thus tends to both create low densities and operate most efficiently at them. Hence, what has become known as "urban sprawl" is the characteristic form of residential development induced by automobility.

By contrast, mass transit has higher capacities and a narrower right-of-way. It has no requirement for parking facilities (except at outlying stations unserved by feeder buses). It has limited flexibility and mobility due to passengers becoming pedestrians at destinations and being limited by walking time and distance tolerances. These considerations tend to produce a smaller supply of land for development within a narrow corridor. See Figure B-4. Given a population with a desire to locate residences in a transportation corridor, they will locate at a lower density in a freeway corridor than in a mass-transit corridor. Because transit operates most efficiently at high volumes, the system carrying capacity and high population density (high trip-generating residential uses and forms) are mutually reinforcing. In other words, both modes operate most efficiently in the context of the residential density and form they tend naturally to produce in view of their technological and economic characteristics.

5. Has an effect on the timing of residential development in various portions of urban areas according to the staging of highway improvements and their location.—A study of population density changes over time related to the freeway network in Los Angeles undertaken as part of NCHRP Project 2-2 led to the following conclusions (*12-5*):

> Freeway construction has had a differential impact, the nature of its effect upon population density and land use depending on time or phase of the freeway construction under particular consideration. The findings identified three phases of regional growth linked to freeway development: (1) the substitution phase, wherein freeways serve existing demands from the present population created by auto-for-transit substitution; (2) the transition phase, wherein freeways follow induced demands caused by population spread into newly developed areas; and (3) the developmental or deterministic phase, wherein freeways traverse previously undeveloped areas and begin to determine the location and timing of land use change, thus creating demands. Also apparent was the tendency of the freeway network to decentralize work and residence, lower central residential densities, disperse population, and encourage industrial location and relocation near freeways.
>
> The Los Angeles Urban Region experience suggests that when the pace of achievement of the freeway program has arrived at the third stage, its impact with respect to population density and land use will be greatest.

Gains and Utilities

1. To landowners:
   a. Gains in value from rural land made developable in residential uses by change in accessibility to work places due to highway improvement.
   b. Gains in value from increased capacity of highways followed by increased demand from added market made accessible.
2. To housing developers:
   a. Profits from development of land in residential uses made possible by highway improvements' geographic expansion of demand.
3. To residents:
   a. Lower price of land for housing due to expansion of the supply of developable land relative to demand brought about by the new accessibilities created by a highway improvement.
   b. A low-density residential pattern productive of more private open space in the form of large yards.

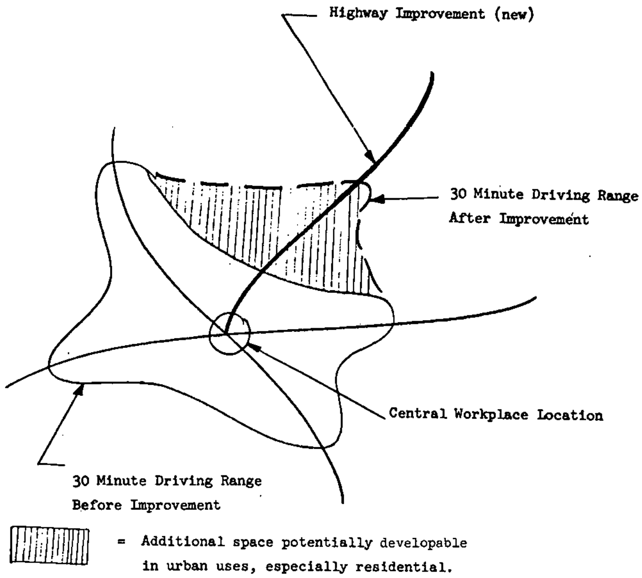


Figure B-2. Change in residential land-use supply due to extension of commuter range by highway improvement.

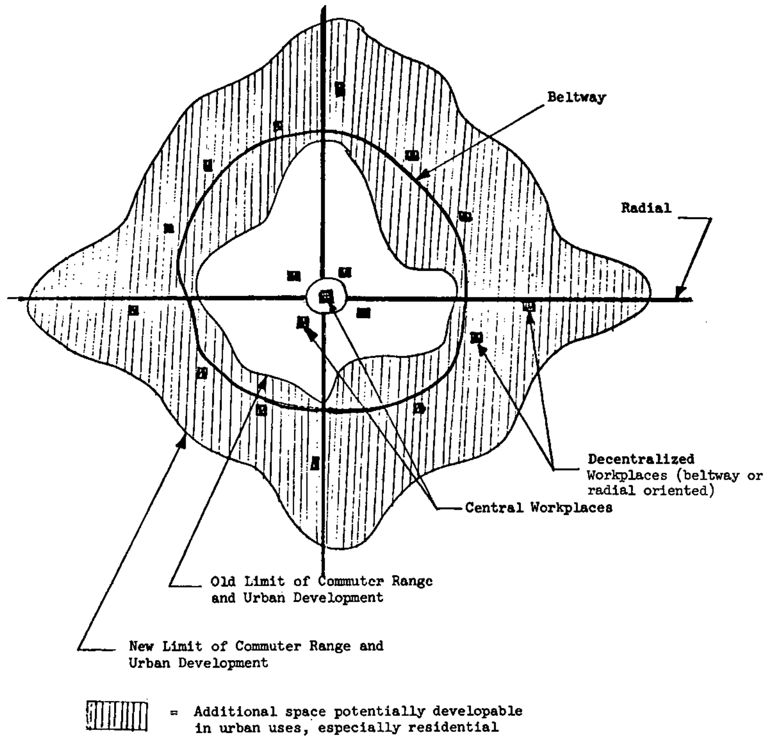
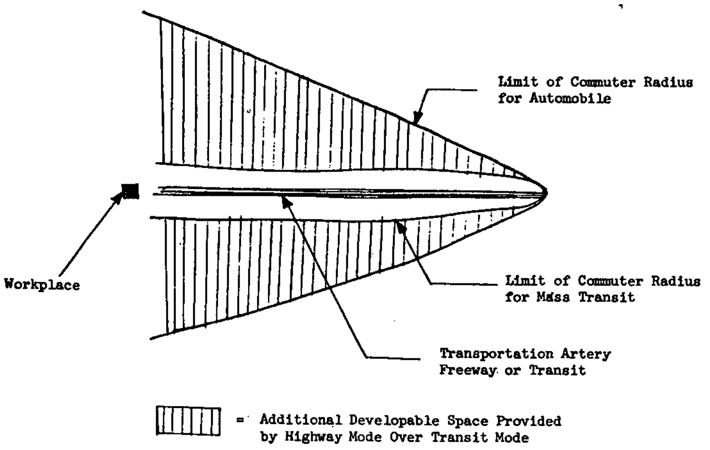


Figure B-3. Change in residential land-use demand and supply due to extension of commuter range by highway improvement-related workplace decentralization.

Costs and Losses

1. To landowners:
   a. Lower relative land values due to increase in supply of land due to changed accessibility created by



Hypothetical example:

Freeway rush hour work trip capacity: 10,000 AHT

Transit rush hour work trip capacity: 20,000 AHT

Developable residential land made accessible by automobile: 2,500 ACRES

Developable residential land made accessible by transit: 500 ACRES

Density per net residential acre under automobile assumption: 4 DWELLING UNITS/ACRE
Form: Single-family houses on $\frac{1}{4}$-acre lots.

Density per net residential acre under transit assumption: 40 DWELLING UNITS/ACRE
Form: 6 story apartment houses.

Figure B-4. Contrast in space availability within commuting range of a workplace by mass transit (without feeders) and automobile mode.

highway improvement where the land supply so created grossly exceeds demand.

2. To residents:
   a. Higher price of housing due to increase in demand relative to supply from right-of-way dislocatees, decentralizing industrial and commercial workers, and escapees of urban blight; effects, in whole or in part, of highway improvement.
   b. Higher cost of transportation as (1) residential settlement occurs at lower densities, creating longer origin to destination distances; and (2) continued residential development begins to cause trip generation to exceed the capacity of existing highway facilities in peak hours.
   c. Distance increases between origins and destinations due to lower-density residential development hinders the frequency of social interaction and participation in neighborhood, community, and metropolis.
   d. Residential density levels produce differing sets of aesthetic consequences from the close-knit pattern of buildings at high density with more public open space to the dispersed pattern of low density with more copious quantities of private open space; each is a "cost" or a "benefit" according to individual aesthetic tastes and preferences.

Decision-Making Factors

1. Desired residential development pattern according to urban and metropolitan goals, planning, and policies leading to a modal and system pattern choice that tends to produce the residential land-use pattern desired.

2. Relative aggregate costs and benefits of various residential development patterns in terms of cost of housing, public utilities and facilities, taxes, transportation costs, aesthetics, social and communal life, and open space preservation.

CATEGORY: 12. Residential Neighborhoods
VARIABLE: I. Residential Property Values

Area:	Urban
Type of Consequence:	Economic
Location of Impact:	Corridor
	Community or System
Timing of Impact:	After Construction—Short Term
	After Construction—Long Term

Consequences

Residential property values have generally increased in corridors served by improved highways.

Improved accessibility is only one of a variety of factors influencing residential property values. Others include: (1) house and lot characteristics—space, design, age, view and other amenities; (2) neighborhood—appearance, status, social composition; (3) location—shopping, schools, parks; (4) costs—construction, taxes, financing; and (5) local housing market supply-demand conditions (*12-11*). Under these conditions all the value increase occurring in the vicinity of the improved highways is probably not ascribable to the highway. However, the consistent findings of increases, especially in excess of control areas with similar housing but no highway improvement, indicate that the highway accounts for some portion of the change in value.

Residential property value increases occur due to one or a combination of the following causes:

1. Dislocation.—A highway improvement that involves taking residential property for right-of-way depletes the local housing supply while releasing the added demand of the dislocatees into the market. The impact of the higher demand on the reduced supply forces prices and rents higher.

2. Accessibility.—Reduction in the cost of trips, particularly work trips, which are usually the most frequent, numerous, longest daily trips and consume almost one-half the average household's transportation budget, increases values. Value increase accrues to:

   a. Present and prospective owners up to the capitalized net present worth of their cost and time savings.
   b. Present owners to the extent of the premium added to the value due to added demand induced by broadening the market to include those for whom the property appeared undesirable under previous conditions of accessibility but which becomes desirable due to accessibility improvement.

3. Land supply-demand.—Increasing the amount of developable land having desirable accessibility characteristics increases its value because of the potential for a higher use or productivity. At the same time, the price is deflated for land with similar accessibility characteristics that had a higher value previously when the supply was smaller. Two cases exist.

In the first case, extending the urban commuter radius into rural areas makes low-cost farmland potentially developable in urban residential use. The value of the land rises because of its higher order use potential but falls short of the value of the land previously available with similar accessibility characteristics due to increased abundance. The relatively low cost of land allows the developer to market dwelling units built thereon at a competitively lower price and thus attract a larger number of demanders.

A second case exists where residential land is scarce relative to demand. A highway improvement raises the traffic-carrying capacity of the transportation system, thus allowing higher levels of trip generation and, thus, intensification of land use. High-rise apartment buildings become feasible and residential property values rise in response to the greater potential earning power of the higher-order residential use.

These two cases explain residential land value increases in (1) suburban areas developed in single-family tract houses, and (2) inner-city areas where apartment building has been the result of highway improvement (although suburban apartment building is also a growing phenomenon).

Evidence of residential property value increase due to highway improvement is found in a Bureau of Public Roads analysis of 84 highway-influence urban study segments in 8 states. Of the total, 82 segments showed average annual percentage increase in value ranging from 1.1 percent to 68.9 percent. Value declines were found in only two segments (*12-14,* pp. 33-36). Table B-13 gives the number of occurrences of each annual percentage change in value from the samples.

Detailed examination of the data revealed the following generalizations:

a. Value increases were greatest: (1) nearest the improved facility, falling off with distance therefrom, (2) for vacant land, (3) for new housing areas, and (4) for multi-family residences.
b. Land value increases at a faster rate than value of improvements in areas ripe for development in other uses leading to eventual demolition of older housing and its replacement by commercial, industrial, and multi-family residential structures.
c. Bridges that overcome water barriers to residential expansion increase residential property values in a manner similar to highway improvements that likewise increase home-workplace accessibility.

4. Proximity to parkway amenity.—A fourth aspect of highway improvement having the effect of influencing land values, usually in a positive direction, is the presence of a parkway in proximity to urban residences. The amenity of landscaping or park space that is visible to, usable by, or enjoyed on the approaches to residences has been found to add a premium to residential property value.

TABLE B-13

ANNUAL PERCENTAGE CHANGES OF RESIDENTIAL PROPERTY VALUES ALONG SELECTED HIGHWAY IMPROVEMENTS, IN CONSTANT DOLLARS ($N=84$)[a]

ANNUAL CHANGE IN VALUE (%)	NUMBER OF OCCURRENCES
0—5	2
0–+5	26
6–10	21
11–15	12
15–20	13
21–25	6
26–30	2
45–50	2
60–65	2

[a] Source: (*12-14,* pp. 28-33).

Studies of residential values along two parkways in the New York City area revealed: an increase, over time, of 102 percent compared with a 23 percent decline in nonparkway-oriented properties for one parkway. The same figures were +73 percent and +19 percent for the second parkway (*12-14,* p. 39).

A study conducted in the Washington, D.C., area covering the period from 1950 to 1961 found that parkways generally exceeded nonparkways both in land value increases and in the share of Washington's development locating nearby (*12-1*). In citing the study, Theil and Yasnowsky quoted this example from its findings (*12-13,* p. 8):

> [T]he corridor along the George Washington Memorial Parkway experienced a 300 percent gain in average land value between 1950 and 1961. Whereas the average increase in land value along Shirley Highway (a nonparkway) during the same period was about 80 percent.

Residential property value declines, to the extent they are affected by highway improvements, appear to stem from two sources:

1. The nuisance aspect of the facility.—The noise, fumes, vibrations, dust, and light it emits and its aesthetic form and scale make it an undesirable residential environment. Sample findings:

a. Louisville-Watterson Expressway.—"There is some evidence that the location of the expressway and subsequent heavy traffic created a pattern of residential use such that the land closer to the expressway was less desirable, and a less expensive type of development occurred in these areas. In addition, it is probable that the facility had a depreciating effect on some expensive residences nearby. At the same time, many residential owners half a mile to a mile away probably enjoyed land value increments as better access was provided and the nuisance of a heavily traveled highway was largely avoided" (*12-14,* p. 38).

b. Edsel B. Ford Expressway, Detroit.—The degree of expressway-induced change varied considerably between land uses (along a depressed expressway). Residential property values decreased significantly. The extent of change resulting from the expressway was found to be limited to 1,000 ft north and south of the route (*12-2*, p. 506).

c. California Freeways.—"Resales averaged from 1 to 2 percent loss for residences adjoining freeways, as compared to similar houses one block or more away. This indicates there is a nominal depression in market value caused by proximity to a freeway" (*12-7*, pp. 26-27).

2. The spatial redistribution of demand.—New housing areas with superior accessibility created by the highway improvement probably will draw demand away from the older areas with relatively inferior accessibility, thereby lowering the values in the latter locations. This systems effect has been little researched, but one study's findings tend to support the likelihood that the theoretical effect does occur in fact:

a. Lexington Northern Belt Line.—"Along the uncontrolled-access Lexington bypass, the old residential area showed a decrease in value on a constant dollar basis; however, the value of residences in the study area did not decrease as much as the control area. On the other hand, new residences showed very substantial increases, especially in the control area" (*12-14*, p. 38).

On the other hand, a rise in value is possible if older residential areas are ripe for a change in use to commercial or industrial. A Bureau of Public Roads study concludes: "The most spectacular increases in land value seem to occur when the improved facility has been responsible for a conversion in the use of a piece of property" (*12-14*, p. 47).

The new accessibility levels in outlying locations match those that formerly existed closer to the urban center. This often means that newer, more spacious housing can be procured at no sacrifice in travel time or cost.

Gains and Utilities

1. To property owners:
   a. Increased property value due to highway improvement's effect on (1) dislocation, (2) accessibility, (3) land supply and demand, and (4) amenity.
2. To property users, buyers:
   a. Cost reductions and consumer satisfactions in property occupancy due to highway-induced gains in accessibility, land supply, and amenity.

Costs and Losses

1. To property users, buyers:
   a. Increased property rents and prices due to value increases based on highway improvement effects on dislocation and supply-demand relationship.
   b. Decreased satisfaction in property use caused by nuisance aspects of highway.
2. To property owners:
   a. Reduced property values due to highway improvement effects of displacing demand geographically and creating nuisance effects.

Decision-Making Factors

1. Potential residential property value changes based on highway improvement effects on:
   a. Dislocation for right-of-way.
   b. Accessibility and capacity.
   c. Land supply-demand relationship.
   d. Amenity provided by parkway treatment.
   e. Nuisance spillovers.
   f. Geographic shifts in demand in land for residential and other uses.

CATEGORY: 12. Residential Neighborhoods
VARIABLE: J. Neighborhood and Community Patterns

Area:	Urban
Type of Consequence:	Social
Location of Impact:	Corridor Community or System
Timing of Impact:	After Construction—Short Term After Construction—Long Term

Consequences

A community, geographically defined, may be considered as a subarea of a city usually having a distinguishing function and character, and a community of interest that causes its residents to identify with it. Its characteristics are usually:

1. Identification by name.
2. A focus or center where residents enjoy joint use of common facilities, public and private.
3. A generally definable boundary set where identification with one community ceases and most residents begin to identify with or gravitate to an alternative center of activity.
4. Often, a high degree of socio-economic and/or ethnic homogeneity.
5. A high degree of interaction and common interest in support of local organizations and causes based on propinquity and mutual self-interest; a "sense of community."
6. A high degree of self-sufficiency in the provision of basic daily needs such as shopping, elementary schools, parks, and other community facilities appropriate to the scale and threshold levels of the community (a function of population and income) that permit support of such facilities.

A neighborhood, geographically defined, may be considered as a subarea of a community. It is usually comprised of the immediate residential environ with which the resident identifies. Within the neighborhood the resident carries on his leisure at-home activity and establishes those social contacts based on propinquity. Its boundaries are set by the realm of interaction within which occur such evidences of "neighboring" as: children's playmates and "gangs"; a housewife visiting over coffee, doing favors, borrowing, hiring baby sitters; bridge groups, parties; expressing advice, concern, gossip. With these characteristics, the neighborhood is essentially a social unit, whereas the community usually has economic and sometimes political functions as well.

These definitions of "community" and "neighborhood" aid in the understanding and analysis of the potential beneficial and adverse effects of highway improvements on such entities:

1. Beneficial:
   a. Highway installed on community's natural boundaries serves to better define it geographically.
   b. Improved access extends the boundaries of the community, permitting added support for existing facilities and creating thresholds for additional ones, thereby strengthening community self-sufficiency and adding convenience.
   c. Better access may encourage in-migration of socio-economic groups, who, by reason of income, education, and tendency to participate, lend greater support to community facilities and organizations.
   d. Controversy over highway improvements may itself be a source of community strengthening and identification by providing an issue around which disparate community groups can unite in a common cause. Once united and with leaders identified, they may identify and find the ability to attack other community problems.
2. Adverse:
   a. Highway improvements, especially limited-access, tend to divide the community geographically if they bisect rather than bound it, thereby hindering or destroying its functioning.
   b. Right-of-way taking may remove the community's focus or center(s) of activities.
   c. Neighborhoods may be totally removed, divided, or dispersed by the same process.
   d. The nuisance effects or "negative externalities" of the highway may encourage out-migration of the existing population and their succession by other groups who do not share the community values of the departing group and may thereby alter the character of the community, its functioning, and stability (*12-8*).
   e. Attracted by the improved access provided by the highway improvement, industrial, commercial, and institutional uses may supplant the residential ones and thereby also alter the community's character, stability, and functions.
   f. The service areas of various enterprises, community associations, public services, and institutions serving community and neighborhood may be altered in negative ways, leading to loss of patronage, the necessity and cost of restructuring service areas, and, possibly, to their dissolution.

Gains and Utilities

1. To community and neighborhood residents:
   a. Better community definition as to boundaries.
   b. Expanded service area due to improved access leading to thresholds for more community enterprises and institutions.
   c. Greater neighborhood attraction for potential residents due to improved access, with potential for additional community participants of a similar socio-economic status.
   d. Propensity for highway controversy to unify communities and create associations that may carry over to action on other community problems.

Costs and Losses

1. To community and neighborhood residents:
   a. A community or neighborhood divided by a highway, especially if limited-access.
   b. Removal of community center by right-of-way taking.
   c. Loss of community cohesiveness by bisection, removal, or dispersion due to right-of-way taking.
   d. Out-migration of residents due to nuisance effects of highway resulting in community character change.
   e. Infusion of nonresidential uses due to improved access reducing residential character of neighborhood.
   f. Shift in service area boundaries of community enterprises, associations, services, and institutions due to highway's "barrier" effect leading to patronage changes, service area restructuring costs, and, possibly, dissolution where post-highway patronage levels are insufficient to support activity.
   g. In-migration of new residents that differ in socio-economic status from present residents, thereby changing the character and stability of the neighborhood.

Decision-Making Factors

1. Community and neighborhood identification: name, center(s), boundaries, and socio-economic character.

2. Patterns of community social, economic, and political organization potentially disruptable by highway improvements. Maps of the service areas of (1) institutions, (2) public facilities and services, (3) political wards and precincts, (4) voluntary associations, and (5) commercial outlets are useful in determining impacts of right-of-way taking, barrier effects, and accessibility improvements.

3. Benefits from reaffirming pre-set and "natural" boundaries and access improvement versus costs of patronage changes, changes in community participation, and service area restructuring as a result of highway improvement.

CATEGORY: 12. Residential Neighborhoods
VARIABLE: K. Social Life and Social Patterns

Area:	Urban
Type of Consequence:	Social
Location of Impact:	Corridor
	Community or System
Timing of Impact:	After Construction—Short Term
	After Construction—Long Term

Consequences

The improvement of highways and the increase in automobility that usually ensues have implications for social life and social patterns of a community. Because a variety of factors influence social change, the contribution of automobility as a force for change is, and may remain, imperfectly known. Some generalizations are possible, however, on the basis of research and logic.

The following consequences stem largely from the characteristics of automobility (e.g., privacy, insulation from environment, range, speed, and system ubiquity). They relate to highway improvements to the extent that (1) autos and highways together comprise the transportation "system," and (2) improved highways encourage increasing reliance on automobiles for most transportation purposes.

1. Time budgets.—In economics, money budgets are an index of relative values, costs and prices, supply and demand, indicating the way money is allocated within the limitations of an income of finite size. In social life, time budgets perform a similar function: an index of the value placed on various activities, by necessity (sleep, work) or choice (leisure), according to the time allocated to them within each 24-hr period.

Automobility has been influential in some reallocations of time: the speed of automobiles, especially after a highway improvement, shortens commuting time, with an addition to leisure time. Conversely, traffic congestion lengthens commuting time and a deduction from leisure is added to congestion's other frustrations. In the low-density residential pattern made possible and desirable by automobility, more time is spent by the drivers in the family chauffeuring the nondrivers to various destinations. Car care (washing, waxing, maintenance) takes up additional time. The instant availability of the automobile, its mobility, and its speed probably mean more time is being spent in away-from-home social and leisure activity than heretofore, although television may have counteracted this tendency somewhat.

2. Manners, mores, and customs.—The advent of the motor car has worked a change in manners, mores, and customs. There is probably an increased tendency to "dine out" rather than have family dinners at home. Coming of age, once symbolized by the transition from short to long pants, is now largely signaled by a driver's license and access to a car. Teen-age hangouts are now drive-ins and their parking lots, rather than soda shops. Courting has long since left the parlor and porch swing for the car parked on "lovers' lane."

Casualness in clothing and manners may, in part, stem from the fact that much of the time one is hidden from the view of others inside an automobile, often bound for a destination where one is a comparative stranger.

Automobiles, by their style, color, and luxury, or lack of same, appear to have replaced dress and manners as a symbolic expression of one's status, prestige, income, and self-image. Further, with so much of life coming under the control of machinery, bureaucracies, corporations, and such, the operation of an automobile may be providing many of the psychological satisfactions that once came from a variety of other sources: freedom, independence, control, power, risk, display of skill, and physical exercise.

3. Neighborhood and community life.—The low-density settlement patterns encouraged by automobility have reduced the number of persons within "neighboring distance," dispersed community facilities and reduced "centrality" (i.e., a common center for most communal functions). The accompanying mobility has encouraged greater access to and selectivity in activities, destinations, and friends and associates.

A study (*12-10*) in Los Angeles showed that the geographic awareness and social environments of persons vary according to their socio-economic status, usually a function of income, and the concomitant availability of an automobile. Those lowest in income and socio-economic status were restricted in social interaction and environmental awareness to their immediate neighborhood. Advancing up the income and status scale the social environment of respondents in the survey progressively widened to the point that the highest group's field of interaction and awareness extended over the entire metropolitan area.

Automobility is enlarging the realm of interaction, the "community," for some (i.e., those with access to the system—car owners and drivers). Meanwhile, those lacking such access (those too old, too young, too poor, or too handicapped to own or drive a car) have had their mobility increasingly restricted by the spillover effects of automobility's ascendency. These include rising fares and deterioration of service in public transportation; increasing hazards of barriers to and lack of facilities for pedestrianism; and low-density decentralized development whose distances discourage both walking and transit riding.

Automobility probably is thus contributing to the phenomenon of the increasing substitution of specialized common-interest communities for diverse living-place communities. Mobility allows persons to pursue interaction with those with common vocational or avocational interests throughout a metropolitan area rather than being restricted to those within physical proximity (i.e., those in the neighborhood or local community). Because of this mobility, people may change to spend less time on local community affairs and with neighbors in the immediate vicinity and more time with persons and groups dispersed throughout the metropolitan area, and in some cases throughout the state.

4. Social environments.—The environments in which social interaction takes place have changed with the increasing use of and accommodation to the automobile. Consider the following activities that can now be engaged in at drive-in facilities without leaving the automobile: banking, dining, movies, church-going (in California), automatic car washing, mailing letters, delivering laundry, returning library books, and even "viewing the remains" (at a Southern mortuary).

Changing the environment of these activities from dining room, bank lobby, mortuary chapel, church, cinema house, etc., to auto interior has doubtless affected the degree of socializing that occurs in their execution.

Environments conducive to chance meetings and the mixing of people of different social groups have grown fewer under the impact of the privacy of the automobile and the isolationism of the "sprawl" pattern of one-class neighborhoods, from ghetto to enclave. Variegated communities, public transportation, and pedestrian-oriented "downtowns" where meeting and mixing once occurred are things of the past in many locales. This trend raises the question of whether the ensuing lack of social consciousness bears a price tag in unawareness, unconcern, misunderstanding, lack of empathy, noninvolvement, alienation, and the social conflicts these produce.

5. Crime.—Low population densities, the "efficiencies" of mechanization, and the demands of traffic control have often replaced policemen on a walking beat with those in a patrol car. Has the crime rate been affected by the patrol-car policeman's insulation from the sights and sounds of his environment, his inability to separate stranger from resident, and his increasing traffic law enforcement responsibilities? The swiftness of the criminal's get-away by car and the temptation toward noninvolvement by car drivers may also be affecting crime rates. At the same time, the swiftness of response to a crime report via patrol car and the ability to chase escaping criminals is doubtless a "plus" (although the death of innocent bystanders struck down in high-speed chases detracts from its merits). Time spent investigating auto accidents and car thefts is another cost of automobility falling on the police force, distracting it from time spent preventing or investigating illegal activity not involving autos.

The foregoing discussion indicates the tendency for social life and social patterns to change in accordance with environmental change and the characteristics of the mode of transportation used by a majority of the population. It is apparent that automobility has furnished a high degree of mobility to those who could afford it, giving them innumerable choices relative to activities, jobs, friends, and housing locations. It is also apparent that there have been certain costs to communal participation and social awareness stemming from the automobile's privacy and the low-density housing pattern and decentralization it encourages. How much the social "crisis of the cities," race and class division, segregation, crime, the flight of trade, industry, and the middle and upper class is a product of automobility is a question for further research. That done to date indicates the influence of the automobile and improved highways has not been insignificant (*12-9*).

Gains and Utilities

1. To community residents:
   a. Expanded mobility and more selective choice of social interactions and environments for those having automobiles.
   b. Psychological rewards: status, power, prestige, privacy, independence, freedom of mobility, and enjoyment of driving for those with automobiles.
   c. Speed and mobility of mobile police patrols in responding to crime calls.
   d. Positive effects on life styles, manners and mores according to the tastes and preferences of some of the population (e.g., those preferring low population density or semi-rural residential environments; private activity; the privacy and mobility of the automobile; casualness in manners and mores; and auto-oriented communities, environments, and life styles).

Costs and Losses

1. To community residents:
   a. Restrictions on mobility for those without access to automobiles.
   b. Increased time involved in auto-oriented activity (e.g., chauffeuring, commuting, car care as a reduction to leisure time and activities).
   c. Erosion of community life due to decentralization, lower-density development, and decline of public transportation and pedestrianism.
   d. Loosened social control and increase in crime to extent influenced by anonymity, mobility, and irresponsibility fostered by automobiles.
   e. Problems of crime control due to: insulation of police-car patrols from environment; preoccupation with traffic control responsibilities; and high-speed get-aways by criminals using automobiles.
   f. Negative effects on life styles, manners, and mores according to the tastes and preferences of some of the population (e.g., those preferring high-density urban residential environments; a high degree of community participation; the crowds, public contact, and street-life inherent in public transportation and pedestrianism; the refinement of dress, manners, and mores more typical of urban areas; and pedestrian-oriented communities, environments, and life styles).

Decision-Making Factors

1. Personal life-style preferences evidenced by the types of activities and environments chosen and the mode of transportation demanded or used by a majority of the local population.

2. Community goals as evidenced by observation of local environments and life styles, objectives articulated in various city planning documents, types of transportation improvements supported by local government policies, bond issues, or capital budgets and responses to transportation proposals at public hearings.

3. Philosophical issues as to what constitutes the "good life" can be partially resolved by public policy. Policies can affect the degree of social interaction, community consciousness, and the level of public safety, health, morals, and welfare achievable through the choice of transportation mode and system design where correlations between transportation and social factors are found to exist.

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CATEGORY: 13. Road User
VARIABLE: A. Accident and Safety

Area:	Urban and Rural
Type of Consequence:	Economic and Social
Location of Impact:	Right-of-Way Corridor Community or System Region or Nation
Timing of Impact:	After Construction—Short Term After Construction—Long Term

Consequences

Provision of superior accessibility and transportation service through highway improvements frequently has the effect, in regions of population and economic growth, of attracting land development. As development occurs, it, in turn, has feedback effects on the transportation system and improved highways. Frequently the feedbacks are at cross purposes to the intent of the highway improvement that was to reduce congestion, time, and operating, accident, and driver strain costs. Development that increases the amount of traffic over the improved facility, requires numerous curb-cuts and turning movements, and offers visual distractions to the driver will serve to increase congestion and operating, accident, and driver strain costs.

Because transportation facilities are built to serve development, rather than vice versa, these benefit erosions are perhaps inevitable. However, recognition of the interrelationships between land use and transportation safety and efficiency perhaps can make possible a reduction in the scale and rate of obsolescence of improved highways.

Concomitants of land development that are productive of increasing highway accidents are as follows:

1. Increased traffic volume.—"The combined weight of evidence seems to indicate that average daily traffic is related to accident rates" (*13-1,* p. 4).

2. Increased mix of truck and auto traffic.—"[P]ercentage of trucks appears to be strongly correlated with the accident rate" (*13-1,* p. 6).

3. Increased congestion.—"[F]indings . . . suggest a strong relationship between accidents and congestion" (*13-1,* pp. 6-7).

4. Increased number of curb-cuts for driveways.—"Kipp found that commercial driveways had a measurable relation to accidents . . . ." (*13-1,* p. 65).

5. Increases in parking demand.—"There is considerable evidence that vehicles which are parked or maneuvering into or out of a parking space figure in a high percentage of accidents" (*13-1,* p. 75).

6. Intersections increase in number with more cross streets in developed areas.—"About 25 percent of all reported accidents, nearly half of all fatal accidents in urban areas and about 10 to 15 percent of rural fatal accidents occur at intersections" (*13-1,* p. 47).

Features of highways that have been used to reduce development-induced traffic frictions that cause accidents have included: access control, grade separation of intersections, separate service roads for commercial frontages, one-way street designation, pedestrian sidewalks, crosswalks, and signals, elimination of truck traffic on certain routes, fewer intersections, additional routes or lanes to reduce congestion, restriction of on-street parking and few curb-cuts (*13-1*).

Planning and zoning could doubtless aid in the effort to cut down accident-producing aspects of development by such means as: reducing the number of intersections (longer blocks); limiting the scale and number of traffic-generating land users to the approximate capacity of roadways serving them; limiting traffic-generating uses at interchanges; reducing the incidence of roadside commercial strip development; eliminating pedestrian traffic across main thoroughfares by using superblocks; pedestrian over- and underpasses in pedestrian-oriented areas; and subdivision design that uses "T" rather than four-way intersections, employs cul-de-sacs, and routes through traffic around rather than through residential neighborhoods. Finally, arrangement of land uses so as to reduce trip lengths or encourage making them by alternative modes would decrease the exposure to highway accident potentials. The concepts of self-contained "new towns" and satellite cities are examples of this type of development, especially insofar as they encourage densities that make pedestrian and transit-travel feasible.

Gains and Utilities

1. To road user:
   a. Reduced cost or likelihood of accident where highway improvements via planning or traffic engineering reduce the number of hazardous conditions.
2. To accident remediers:
   a. Where unsafe conditions develop, accidents generate income to accident remediers such as doctors, hospitals, mortuaries, insurors, tow services, and auto body shops.

Costs and Losses

1. To road user:
   a. Accident cost and likelihood increase where land development has produced conditions inimical to user safety.
2. To highway agency:
   a. Incremental cost of reducing or controlling hazards increased by land development.

Decision-Making Factors

1. Control or reduction of the highway hazards to user safety generated by land development:
   a. Traffic volumes.
   b. Mix of truck and auto traffic.
   c. Congestion.
   d. Curb cuts.
   e. Parking movements.
   f. Turning movements.
   g. Intersections.
2. Control of land development to reduce user hazards induced by development:
   a. Roadside development.
   b. Traffic generation of land uses.
   c. Provision for pedestrian ways and crossings.
   d. Street design in subdivisions to eliminate through traffic.
   e. Number and type of intersections.
   f. Trip length reduction by planned land-use arrangements.

CATEGORY: 13. Road User
VARIABLE: B. Running Costs—Distance Related

Area:	Urban
Type of Consequence:	Economic
Location of Impact:	Right-of-Way Corridor Community or System
Timing of Impact:	During Construction After Construction—Short Term After Construction—Long Term

Consequences

Motor vehicle running costs respond to distance. Distance is, in turn, affected by the geographic extent of development as determined by the vehicle's range, capacity, and speed, the system pattern and time- and cost-distance tolerances for various trip purposes.

Research has shown that people tend to respond to the increase in travel speed afforded by highway improvements by increasing the distance between home and work, rather than by decreasing the time spent in travel. Bone reported in a study of the Massachusetts Route 128 circumferential around Boston (*13-2*, p. 193):

> The average Route 128 employee work trip is 11.7 miles in 24 minutes at an average speed of 29 m.p.h. Employees using Route 128 for part of this trip travel farther (15 miles) but at a higher average speed (32 m.p.h.). Non-users travel a shorter distance (8.5 miles) at a lower average speed (24 m.p.h.).
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> . . . .
>
> As the percentage use of Route 128 increases, the distance to work increases, but the average speed increases at an even greater rate so that the time to work is nearly the same (27 to 29 minutes) for all percentage uses.

Journey-to-work trips have thus been increased in distance as a function of urban residential dispersal and decentralization encouraged by lowered travel times. The decentralization of industry and commercial centers has further increased the area falling within commuter range of employment opportunities and thus further increased extent of the developable area. The availability of such a large supply of developable land relative to the number of households and firms seeking sites has meant each land user could obtain and afford more land for its use.

Residents desired large tracts for their amenity values; industry and commerce required them for spacious low-rise structures, parking, future expansion, and landscaping. The lowering of population density led to shops and shopping centers spread at more distant intervals due to lack of an operating threshold. Shopping-trip distances were increased thereby. Trips for all other purposes—visiting, recreation, church, civic activity, personal business—were likewise increased by the dispersal of the population and the institutions serving it.

The net effect is for highway improvement gains to be eroded by the restructuring of land uses that involve increasing trip lengths for all purposes. The temporary economies of a highway improvement encourage a form of urban development that results in higher money cost of transportation due to increased trip distances while trip times tend to remain stable.

Further impacts that ensue from the lowering of density is the declining feasibility of operating lower-cost public transportation and transit's eventual elimination in some instances. The increase in distances likewise eliminates no-cost pedestrian travel. This promotes the further substitution of automobiles and school buses for what are often walking trips at higher densities. The "monopoly effect" in auto travel tends to further increase the aggregate highway transportation bill. Further rounds of investment in highway improvement based on this induced "demand" appear mandatory and capital as well as operating expense increase.

Gains and Utilities

1. To automotive suppliers:
   a. Added income from increased car running costs due to the greater trip distances resulting from the dispersed urban pattern induced by highway improvement.

Costs and Losses

1. To road users:
   a. Added cost of auto operation over greater distances made necessary by the dispersed urban pattern induced by highway improvement.

Decision-Making Factors

1. Possibilities for coordination between highway and land-use planning to reduce travel distances for most purposes and so reduce automobile running costs by such means as:
   a. Relating residential areas to employment centers and shopping.
   b. Higher capacity roadways to encourage higher densities of settlement.
   c. Creation of "new towns" or satellite communities with a high degree of self-sufficiency.

CATEGORY: 13. Road User
VARIABLE: C. Running Costs—Land-Use Intensity and Population Density Related

Area:	Urban
Type of Consequence:	Economic
Location of Impact:	Right-of-Way
	Corridor
	Community or System
Timing of Impact:	After Construction—Short Term
	After Construction—Long Term

Consequences

Development and redevelopment responding to highway improvement set the location and intensity of activities (traffic generators). Origins and destinations and desire-line patterns shift to match these changes. Motor vehicle running costs respond to conditions of traffic flow and access through their effect on stopping and starting frequency, speeds attainable, and degree of congestion which produce various running cost rates per mile.

Bone's Route 128 study (*13-2*) of the Boston Circumferential contains circular feedback effect. Highway improvement and lowered running costs lead to land development. Development causes traffic generation, congestion, and higher running costs. These promote demand for further highway improvement leading back to further land development, etc.

> The desire line patterns illustrate vividly the lateral type of movement made possible by Route 128. Prior to the building of Route 128 a road net did not exist that could accommodate these desires. Thus, traffic has been "generated" by the highway and its adjacent land use changes, an event that was not anticipated when original traffic estimates were made. . . . New plants completed or on which construction has been started since September 1957 will bring employee trips to an estimated 33 percent of the peak hour traffic (*13-2*, p. 194).

Further evidence of the interaction of highway improvement and land use is contained in an address by Pitkin. It reports findings of an investigation of development in the area of a highway interchange at the intersection of the Schuylkill Expressway and the Pennsylvania Turnpike. Pitkin reports (*13-4*):

> In the three year period since the interchange was opened the population of the town of King of Prussia has doubled and land values have risen from $500-$700 an acre to $9,000 to $12,000 an acre. In addition to the increase in economic activity, the problem of maintaining an efficient traffic flow is created. The commercial and industrial development in the area of the interchange has resulted in a significant increase in traffic generation. Adequate planning is required if the capacity of the interchange is to be adequate after a period of economic growth in the area.

The type and size of the company generating employment, Bone found, has an effect on the traffic generation potential per employee: "The number of people per car tends to increase with increasing employment size of company. It is also higher than average for service industries and lower for distribution types" (*13-2*, p. 195).

Distribution of employees by residential areas also influences the traffic relief to be gained from car pooling:

> Car pools are most used by employees coming from areas where there is the highest concentration of residences of Route 128 workers . . . . least used by workers . . . who live in many towns of low employee home density (*13-2*, p. 195).

Bone found parking-space-to-employee ratios to be 1.43 for companies with under 50 employees; 0.54 for companies with more than 1,000 employees. It may be concluded that traffic generation per employee varies inversely with the size of the company due to car-pooling potentials. This will tend to increase the employment "holding capacity" of a highway corridor and keep commuting costs and congestion from rising as rapidly as they would if the employee-vehicle ratio were constant.

Eventually, congestion does occur as development continues to take place and addition of further traffic generators will be discouraged. Larson and Schenker (*13-3*) mention this effect in a Michigan study of effects of a major highway that concluded: "Ensuing industrial and commercial development, with attendant traffic congestion, inhibited residential development in the rest of the area."

Hence, highway-induced development occurs up to the point where congestion and user running costs increase to levels discouraging further trip generation. Development will then stabilize at this point of traffic generation-highway capacity equilibrium until further improvements are made.

Development follows superior access and in turn erodes that superiority. In growth areas and large metropolitan areas of more than a million, experience has indicated that development potentials are so great that excess capacity is absorbed soon after its creation. Congestion and user costs rise to previous levels as an inevitable result of highway improvement.

Gains and Utilities

1. To automotive suppliers:
   a. Added income from increased running costs due to congestion based on land development responding to highway improvement.

Costs and Losses

1. To road users:
   a. Added cost of automobile operation due to congestion induced by land development whose traffic generation exceeds roadway capacity.
2. To landowners and users:
   a. Limitations on land development and value due to highway congestion.

Decision-Making Factors

1. Possibilities of coordination between land use and highway planning to reduce congestion and achieve a better balance between trip generation and highway capacity by such means as:
   a. Density zoning.
   b. Dispersion of high trip generating land uses.

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CATEGORY: 14. Spatial and Geographical Changes
VARIABLE: A. Local

Area:	Urban and Rural
Type of Consequence:	Economic and Social
Location of Impact:	Right-of-Way
	Corridor
	Community or System
Timing of Impact:	Before Construction
	During Construction
	After Construction—Short Term
	After Construction—Long Term

Consequences

Transportation is a means of overcoming space. It links activities separated in space such as resources and factory, home and work, wholesaler and retailer, farm and market. Transportation changes in general, and highway, road, and street improvements in particular, have their consequences revealed within a spatial or geographic framework.

Under the impact of a transportation or highway improvement, activities will develop and redevelop, locate and relocate, to take advantage of the superior service, the enlarged capacity or the economies, efficiencies, and accessibilities afforded by the improvement.

Having jurisdiction over the routing and design capacity of the routes and ways in most modes of transportation places the government in a strategic position. By manipulating route locations and designs it is able to shape development and the location of activities of various sorts to suit policy and goals or fulfill the needs and demands of the government or the population.

By transportation planning with an eye to consequences, local jurisdictions can influence the timing, extent, intensity, and direction of their land development.

The types of choices offered planners have been characterized by Morrill (*14-2*) as follows:

1. By speeding up highway improvement, jurisdictions can hasten residential and industrial dispersion. By slowing it down they can encourage residential concentration and limit spatial expansion. Ceasing improvements altogether without offsetting investments in other modes, however, may create levels of congestion that will discourage industry and hamper business.

2. By directing highway improvements in certain directions, development will be encouraged in those directions. The form of development will be characteristic of the mode: highways producing low-population-density sprawl with the possibility of discontinuous leapfrog development; transit systems producing higher-density corridors and satellite centers growing by accretion around stations and stops.

3. Highways traversing undeveloped land will give it development potential. This may occur at the expense of established centers with invested social capital, however, and its desirability must be carefully evaluated.

4. Limited-access highways can be used to create barriers and boundaries. This characteristic may be used in a positive manner to set area boundaries and separate incompatible uses or in a negative way when neighborhoods are divided or certain groups in the population are contained.

5. Highway improvements can be used to maintain the vitality of the business structure. Business districts whose accessibility to their trade areas are strengthened by a highway improvement will remain viable. Those made less accessible due to bypassing, barrier effects, interchange location, or the growth of competition along relocated routes will tend to suffer.

Morrill's listing of the highway planning alternative according to desired geographic effects indicates that the local spatial consequences of highway improvement are mainly ones of land-use reorganization to accommodate the new conditions of accessibility and traffic flow created.

Following are some of the conclusions reached by research into the geographic effects of highway improvement on various types of land uses and land users:

1. Retail business.—Two types of retail districts exist: (1) nucleated centers significantly related to population distribution and (2) arterial "strips" significantly related to traffic volumes (*14-2*, pp. 98-99). Of the two, the arterial types are affected more by bypass type of improvements than lower traffic volumes. Nucleated centers are less affected by such improvements and may be benefitted by the removal of through traffic in that their main traffic-related problem is usually congestion (*14-4, 14-2*, p. 109).

Larger centers gain competitive advantage when made as accessible as smaller centers, due to their greater variety of goods and prices. This leads to increased concentration and specialization in the larger centers and the waning of smaller centers (*14-4, 14-2*).

To survive, highway-oriented tradesmen re-orient their methods or lives to the available local clientele or change their location to a frontage road or interchange to recapture their market (*14-4, 14-2*).

Limited-access highways make interchange locations and frontage roads, where provided, the points of optimum visibility and access for commercial purposes. These locations, therefore, are used intensively for retail purposes, both nucleated (shopping centers) and arterial (highway-oriented uses) (*14-2*).

In cities of more than a million, shopping trips to the CBD are discouraged by congestion and parking costs. Suburban shopping centers compete to advantage. Radial highway improvements exacerbate this condition. Only mass transportation possesses sufficient capacity to handle the number of potential shopping trips (*14-4*).

2. Residential land use.—People with similar socio-economic conditions tend to cluster in cities due to similar locational requirements, income constraints on ability to pay rent, and propensity of clustering to provide thresholds for various amenities, goods, and services desired in common (*14-2*).

Decentralization of residence occurs in reaction to the opportunity created by highway improvements to enjoy more choice or acquire more residential space at no sacrifice in travel time or costs. Growth is thus accommodated without increasing congestion or time in transit (*14-4*).

Drawbacks to residential decentralization are the lack of efficient use of space by leapfrog development, depression of the central housing market, and revenue loss to the central jurisdiction where decentralizing residents move beyond city boundaries (*14-4*).

Residential land is preferred for urban right-of-way for highway improvements due to its lower value relative to commercial and industrial and its usually high turnover (*14-4*).

Gains and Utilities

1. To local communities:
   a. Development of residences, commercial centers, and industry attracted by highway improvement.

Decision-Making Factors

1. Local development potentials and possible adversities stemming from highway improvements that influence:
   a. Activity relocation and migrations.
   b. Neighborhood cohesiveness.
   c. Community organization for land-use efficiency.

CATEGORY: 14. Spatial and Geographical Changes
VARIABLE: B. Metropolitan

Area:	Urban and Rural
Type of Consequence:	Economic and Social
Location of Impact:	Community or System
Timing of Impact:	After Construction—Short Term After Construction—Long Term

Consequences

At the metropolitan level, highway improvements can aid in providing coherence and a degree of coördination between disparate parts of the urban region. They can also create problems of metropolitan scale and efficiency.

A case study of the Los Angeles metropolitan area was undertaken as part of NCHRP Project 2-2 (*14-3*) to investigate the impacts of freeway system development on metropolitan spatial organization from 1940 to 1960, the period of freeway development, and population growth.

1. Industry.—Industry in 1940 was oriented to port and rail facilities and natural resource areas (i.e., oil fields). By 1960 industrial areas had developed throughout the metropolitan area along nearly all the freeways.

The study concluded: "[I]ndustry is highly responsive to the opportunities to minimize space friction by means of situating in close proximity to the freeways."

2. Residential.—In 1940, development was relatively dense and centralized in Los Angeles and discrete outlying communities separated from the central city by open space or agricultural areas. By 1960 residential development had filled up the entire Los Angeles basin "at a fairly uniform density, although there still existed the nodes of somewhat higher density in the older population centers." Densities in the older centers had either declined or had not grown beyond their 1940 levels, however.

3. Commercial.—No *new* large commercial nuclei appear to have grown up in the 20-year period. "Rather, smaller nodes are scattered widely throughout the populated areas." Shifts have occurred from existing commercial districts or "downtown" "to a nearby area of open land, usually closer to a freeway interchange where an integrated shopping center will situate, reflecting the realignment which high automobile usage and improved facilities (freeways) dictate under circumstances of greatly increased population" (*14-3*).

Morrill (*14-4*, pp. 5.29-5.30) has described what he calls the "opportunity costs" of a highway-oriented metropolitan area such as Los Angeles:

> For large metropolitan areas (over 750,000, particularly over 1,500,000) the freeway approach alone will not work in the long run. Freeways simply do not have the capacity to bring the number of workers to central locations that would be efficient for a city of that size;

> the CBD in turn is strangled by the attempt to park so many cars; hence the downtown declines, business disperses to regional markets, and economic efficiency of the metropolis declines. Only one point of maximum accessibility, a single CBD, can realize the threshold economies of the entire urban market, thus for its over 7 millions Los Angeles has unusually small stores with surprisingly limited selection or specialization—a restraint on economic potential. Even if the freeway enthusiast can technically find ways to handle the traffic within a "dispersed metropolis," this can only be done at the great opportunity cost of abandoning the tremendous efficiency and value of agglomeration and centralization of many kinds of trade and service. . . .

In the NCHRP 2-2 study of Los Angeles three stages of metropolitan development were identified in the course of freeway system development:

1. The substitution phase.—The earliest freeways were justified by demands generated by increased use of automobiles in the process of their being substituted for transit use.
2. The transition phase.—Population growth sets up continuing demand with freeway development attempting to remedy deficiencies in the former system which makes it incapable of handling the increased traffic.
3. The developmental phase.—Freeways cease to lag and begin to lead population growth in this phase. New freeways are built into relatively undeveloped areas, thereby attracting population and urban activities to them. In this phase freeways influence the direction and timing of urban development and have begun to determine the metropolitan pattern and geographic structure (*14-3*).

Again, Morrill in his study of highway network effects points out the economic costs of a metropolitan pattern dispersed by freeway development (*14-4*, p. 5.27):

> Encouragement of substitution of space for intensity . . . also means dependence on the private car with a fairly early risk of diseconomies of congestion. To use the example of Los Angeles, dispersion required dependence on an arterial and freeway system, but the sheer volume of traffic generated, the excessive trip length and complicated cross-over, is already exceeding the economic capability of the system . . . .
>
> . . . .
>
> Another danger is excessive land consumption, involving potentially necessary recreation sites . . . .

Morrill warns that total dependence on highway systems for metropolitan transportation may be creating a spatial organization that is inefficient due to loss of centralization and agglomeration economies. Centralization and agglomeration, under highway transportation, produce congestion which hinders accessibility. In reaction, industry decentralizes. Bone (*14-1*) notes in his Route 128 study that the predominant factor motivating industry to move adjacent to Route 128 was "accessibility." This emphasizes the reorganization aspects of highway improvement in a metropolitan area. It also raises the question of the fate of land values at the moving industry's former site and in other portions of the region that have become relatively "inaccessible" due to congestion.

Bone also notes that the movement of industry to a circumferential highway extends the geographical limits of the labor market (*14-1*). In so doing it also extends the geographic dimensions of the metropolitan area. Philbrick (*14-5*) in a Michigan study of this effect concluded:

> The result of these processes is the creation of "dispersed cities." Under the influence of such processes, all of southern Michigan may become one dispersed city, with state and Interstate highways serving as its streets.

Various types of metropolitan spatial organization (spread, satellites, corridors, etc.) are being tested by computer models at some metropolitan transportation studies. The results should begin to provide answers to the questions of what are the relative efficiencies of various possible metropolitan geographic patterns and what modes and system configurations are likely to produce them.

Gains and Utilities

1. To metropolitan areas:
   a. Coordination and connectivity of various parts of the metropolitan area.
   b. Efficient transportation system to serve the desired patterns of land uses.
   c. Device for directing the direction, timing, and scale of development.

Costs and Losses

1. To metropolitan areas:
   a. Inefficiency of transportation and land use due to scale of the metropolitan area and its trip generation potential compared with its transportation capacity.

Decision-Making Factors

1. Relative efficiency and desirability of alternative metropolitan geographic patterns made possible by choice of timing, system configuration, and modes and their effects on:
   a. Patterns of industrial location.
   b. Residential patterns and densities.
   c. Commercial activity location, scale, and diversity of goods and services offered.

CATEGORY: 14. Spatial and Geographical Changes
VARIABLE: C. Regional

Area:	Urban and Rural
Type of Consequence:	Economic and Social
Location of Impact:	Region or Nation
Timing of Impact:	After Construction—Short Term After Construction—Long Term

Consequences

Regionally, highway improvements tend to have a variety of impacts, benefits and costs being differentially distributed among locations. Knowledge of the way in which highway improvements act on a region and its parts allows regional authorities to influence the region's economic health. The economic health of depressed areas, the direction of growth patterns, and exploitation of the region's resources can be promoted. The goal is optimization from the standpoint of efficient use of productive capacity and conservation of scarce resources.

Research into the regional geographic and spatial effects of highway improvement has produced the following findings:

1. Trade.—Transportation efficiency encourages trade by broadening markets. Goods can more easily move from areas of surplus to ones of deficit. More products can compete in more markets. The higher demand so produced encourages the scale economies of mass production and productive efficiency is raised thereby. Relieved of the necessity of self-sufficiency in many lines, communities can specialize in those products that they can produce to competitive advantage, another spur to efficiency in the use of resources (*14-4*).

2. Urbanization.—Problems of congestion and scale of demand usually mean that the links between major nodes are the ones having priority in highway improvement programs. Strengthening these linkages increases the advantages of major cities for industry: markets, a mix of skilled labor, specialized services, complementary industries, social overhead resources, and urban amenities desired by employees. Urban concentration results. Smaller centers decline or have problems competing. Depressed areas may emerge (*14-4*).

Some empirical evidence of this tendency for larger centers linked by highway improvements to prosper at the expense of smaller centers also served by the improvement was provided by NCHRP Project 2-2 (*14-6*). A study of the impact of the New York Thruway on the Mohawk Valley revealed that population in the major nodes showed a higher percentage growth than the minor nodes in the corridor. Cities of more than 100,000 averaged + 14.39 percent change in population from 1950 to 1960. Cities of less than 100,000 showed − 3.48 percent change in the same period (*14-6*).

3. Area redevelopment.—Proposals have been advanced to use highway improvement as a means of relieving economically depressed areas or regions (e.g., Appalachia). This strategy might be successful if lack of good transportation was a factor retarding regional growth. In theory, better highways would attract new industry, create demand for new services, increase export levels and internal trade, provide access to under-utilized resources, and provide better linkages to markets. There would be further side benefits in the employment generated by highway construction and the relief from isolation which could encourage education and innovation.

Against these arguments in favor are these considerations: depressed areas are often poor in resources and lack the proper mix of skilled labor for many industries. Depressed areas might be no more attractive in industries after highway improvement. In fact, the improved access might encourage increased out-migration. Although there are indications that highway improvements may have been instrumental in creating some depressed areas by favoring already successful ones with new linkages, there is some uncertainty that the process can be reversed by belated highway investment in the depressed areas (*14-4*).

4. Resources.—Highways have long been used as a means of tapping resources. Forest recreational and agricultural areas have become developed as a result of the access provided by highway improvements. Although few areas of the United States have yet to have their resources developed, a potential still exists for more efficient resource utilization as a result of highway improvement. Larger markets encourage greater productivity through consolidation of operations into large-scale units and the more efficient use of equipment (*14-4*).

Conversely, avoidance of highway improvement into or through resource-rich areas can be an effective strategy for conservation of scarce resources where that is desirable.

5. Interregional effects.—Lowering transportation costs as a portion of the total cost of production and distribution has freed many industries from dependence on proximity to resources or markets. This has made them more "footloose" and allowed them to relocate where other now more significant factor inputs were less costly or living conditions were more favorable. Northern industries have gone South to reduce their labor costs; Eastern industries have moved to the Southwest for a more pleasant climate and surroundings. Areas left behind by migrating industry have, in some cases, become pockets of depression—New England and portions of the Middle Atlantic States, for example.

Gains and Utilities

1. To regions:
   a. Increase in trade, specialization, industry, and productive efficiencies.
   b. Increased urbanization.
   c. Area redevelopment potentials of highway improvements.
   d. Resource development due to increased accessibility to resource-rich areas; or conservation of resources through access limitations.

Costs and Losses

1. To regions:
   a. Depressed areas and under-utilization of resources from competitive disadvantage due to highway improvements going into other areas and regions.

Decision-Making Factors

1. Effects on the development potential of a region according to:
   a. Resources unused or under-utilized.
   b. Trade potentials.
   c. Urbanization potentials.
   d. Industrial efficiency increases.
   e. Attraction for new industry.

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CATEGORY: 15. Urban Form and Development
VARIABLE: A. Land-Use Inventory

Area:	Urban
Type of Consequence:	Economic
Location of Impact:	Community or System
Timing of Impact:	During Construction
	After Construction—Short Term
	After Construction—Long Term

Consequences

A highway improvement changes the land-use inventory of an urban area or subarea (traffic zone, census tract, community, district) in the following ways:

1. Land-use substitution.—The right-of-way taking substitutes "highway and street" use for the land uses existing in the path of the alignment prior to taking (e.g., residential, commercial, public open space). The inventory of these latter uses is depleted and that of "highway and street" use is increased.

2. System effect of dislocation.—The dislocated households and activities create demands for alternative space that may require shifts in land use to create a supply capable of accommodating the demand released by the right-of-way taking where existing space or vacancies are insufficient.

3. System effect of expansion of transportation systems due to increased travel demand.—The highway improvement induces a demand for additional highway transportation-related land uses needed to complete the "system," such as:

a. Parking.
b. Connector and collector streets.
c. Auto graveyards.
d. Gas-food-lodging commercial uses serving highway users.
e. New- and used-auto dealers.
f. Car washes.
g. Enforcement and maintenance facilities.
h. Bus transit storage and maintenance facilities.
i. Truck loading, storage, and maintenance areas.
j. Repair garages, parts and accessory dealers.

In addition to highway improvements that lower the motor vehicle running cost and thus increase the demand for highway travel, other factors operate simultaneously to produce this effect; e.g., (1) additional trip generation through the creation of new activity centers (origins and destinations), (2) additional automobile registration and trip generation due to population and income growth, and (3) the substitution of automotive for other modes of transportation.

4. System effect of accessibility change.—The change in the relative accessibility between various sites, locations, and areas and the supply of such sites relative to demand causes land-use change. The change is due to (1) land users taking advantage of the new efficiencies of production, distribution, or consumption or the increase in market potential created, and (2) land users reaping the economy of lower-priced land resulting from the creation of a new developable supply with attractive accessibility characteristics which is large relative to demand. The result is a shift to higher-order uses or more intensive use of the land affected. Growth of floor space makes possible intensification of use without growth of ground space, making the former a better index of change.

The initial changes induced by a change in accessibility or the supply of accessible land is frequently followed by a second round of changes reacting to the opportunities for advantageous location and relocation afforded by the first. For example, an industrial park attracts surrounding residential settlement by employees; residential settlement attracts commercial development, usually in the form of shopping centers. Highway improvement thus sets in motion a force for change that continues over a long term until holding capacities are reached, all development opportunities are exploited, and benefits bestowed by the improvement are cancelled out by congestion as land-use traffic generation reaches system capacity.

5. Case example.—Table B-14, reproduced from the *Chicago Area Transportation Study* (*15-3*), reveals changes in land-use inventory from 1940 to 1956, a period of growth of the highway system and automobility.

The previously described substitution and system effects are visible in the data:

a. Streets and alleys.—Space allocation grew in three of the four inner rings. Reductions may have been due to the tendency to close some streets and alleys in order to make larger "islands" of development and longer blocks more conducive to automotive efficiency.
b. Commercial and parking.—Space allocation grew considerably in all rings reflecting economic growth, decentralization, transport system demands, and the accommodation of the consumer shift to automotive transportation with its parking requirements.
c. Public buildings.—Grew in all rings except the outermost, reflecting the growing demand for gov-

TABLE B-14

COMPARISONS OF 1940 AND 1956 GENERALIZED LAND USE IN THE CITY OF CHICAGO [a]

MILES TO LOOP	GENERALIZED LAND USE (SQ MI) RESIDENTIAL		MANUFACTURING AND PARKING		COMMERCIAL AND PARKING		PUBLIC BUILDINGS		PUBLIC OPEN SPACE		STREETS AND ALLEYS		VACANT		WATER AND UNUSABLE		TOTAL	
	1940	1956	1940	1956	1940	1956	1940	1956	1940	1956	1940	1956	1940	1956	1940	1956	1940	1956
0–1.9	0.82	0.31	2.26	2.17	1.13	1.50	0.28	0.38	0.95	0.55	2.43	2.60	0.63	0.37	0.23	0.20	8.73	8.58
2.0–3.9	5.32	5.20	4.45	4.64	2.11	2.40	0.66	0.99	1.57	1.47	6.13	5.99	1.83	1.07	0.39	0.36	22.46	22.12
4.0–5.9	9.85	10.16	5.93	5.73	2.65	2.91	1.03	1.21	2.38	1.86	8.60	8.67	2.56	1.64	0.23	0.17	33.23	32.35
6.0–7.9	14.40	15.71	5.11	5.33	2.54	3.00	1.19	1.43	3.57	3.50	11.83	11.86	5.74	2.82	0.15	0.13	44.53	43.78
8.0–9.9	10.75	15.15	3.71	3.89	1.50	2.02	1.01	1.18	2.09	3.05	10.75	10.33	10.55	4.21	0.04	0.05	40.40	39.88
10.0–11.9	4.67	9.59	4.54	4.05	0.55	0.95	0.33	0.42	0.75	1.27	6.90	6.73	10.35	5.07	0.05	0.08	28.14	28.16
12.0 and more	4.78	8.38	5.12	6.03	0.52	0.86	0.60	0.54	1.36	2.15	6.25	5.67	13.98	10.01	4.53	3.63	37.14	37.27
Total	50.59	65.00	31.12	31.84	11.00	13.64	5.10	6.15	12.67	13.85	52.89	51.85	45.64	25.19	5.62	4.62	214.63	212.14

[a] Source: (15-3, Table 5, p. 22).

ernment services and the decentralization of the population requiring such services.

d. Residential.—Declined slightly in the two innermost rings, grew considerably in the noncentral ones, reflecting both population growth and its outward expansion. The effect of automotive transportation is to increase the range at which development can occur and the space available for it.

Net residential density (the ratio of population to land in residential use) rose in central areas as population demand rose while residential land supply declined. For areas from 4 to 7 miles from the Loop, population declined while space in residential land increased, causing densities to fall. In the peripheral areas beyond 7 miles from the Loop, densities also declined while population was rising in that developable land made available by highway improvements became relatively abundant. The substitution effect of auto for public transit is also visible in that, in 1940, higher densities existed in suburban areas in spite of a lower population level.

e. Manufacturing and transportation.—Declined as an inner-city land use, grew in outlying areas reflecting a decentralizing trend due to space needs and highway improvement effects on accessibility. Transportation declines may reflect some abandonment of railroad properties as auto and trucks absorbed more of rail's former traffic.

f. Open space.—Apparently contributed much of the land reallocated to other public uses (public buildings, streets, and alleys) in central areas. It declined in the four inner rings; grew only in the three outer ones.

g. Vacant land.—Apparently fulfilled the same function in the private sector: that of providing the bulk of the land required for development of higher-order uses, especially in outlying areas. Conversions from previously developed uses apparently also took place through public and private renewal efforts.

h. Water and unusable.—Quantities declined in almost all rings, reflecting demand sufficient to make reclamation of water and slope areas economically feasible.

Gains and Utilities

1. To inner-city area:
   a. Gains in space for commerce, parking, streets and alleys, and public buildings.
2. To outer-city area:
   a. Gains in space for residential, manufacturing, transportation, commerce, parking, and open space.

Costs and Losses

1. To inner-city area:
   a. Losses of space for manufacturing, transportation,

residential, open space, vacant, water, and unusable.

2. To outer-city area:
   a. Losses of space for vacant, water, streets, alleys and unusable.

Decision-Making Factors

1. Land-use inventory before and after highway improvement in relation to metropolitan and community goals and objectives.

CATEGORY: 15. Urban Form and Development
VARIABLE: B. Land Values; General

Area:	Urban
Type of Consequence:	Economic
Location of Impact:	Corridor
	Community or System
Timing of Impact:	After Construction—Short Term
	After Construction—Long Term

Consequences

Land values, in general, tend to rise in response to highway improvement in areas where demand exists. Lowering the time and dollar cost of transportation for affected sites allows firms, retail outlets, and residents to arrive at more efficient solutions to their respective production, distribution, and consumption activities. They are therefore willing to bid more for land that allows them the advantages of superior accessibility.

From research results, contained in *NCHRP Report 18* (*15-4*) and other sources, the following generalizations appear valid concerning the geographic location and magnitude of land value increases due to highway improvement:

1. "Unimproved or vacant land receives greatest benefit from highway improvements, ranging from two to three times the value increase received by improved property" (*15-4*, p. 19). Buyers of vacant land avoid the cost of demolition or remodeling of existing structures to make the site suitable for their intended use.

2. "Land value computed with improvement value deducted also emerged with increases in value that were double to triple those of land inclusive of improvements" (*15-4*, pp. 19-20).

3. "Value of land abutting the highway facility exceeded that of land further removed, as well as land in control areas, in the majority of instances" (*15-4*, p. 20). According to Table B-15 (from *NCHRP Report 18*):

> [T]he value of land in the B tier, not abutting but proximate to the freeway, also exceeded the average value increase in control areas. Property in the C tier, still further removed from the facility, shows least benefit; its percentage increase in the B tier is usually one-third to one-half that of the A tier, indicating that the area of impact falls off rapidly. The C tier percentage increase is far below that of the A and B tiers, indicating that the impact is largely diffused at this distance (usually more than four blocks away). The fall-off of impact appears least rapid for vacant or unimproved land, reaffirming that this type of property receives greatest benefit both near and far from the facility (*15-4*, p. 20).

4. Table B-16 was developed by the Bureau of Public Roads based on data from 183 "study segments" from a number of research reports relating land value and highway improvement. On the basis of these findings, value change is greater for higher-order uses that can profit more from the gains in efficiency and productivity offered by the improved accessibility. In order of magnitude of "median annual percentage change" in land value the most benefitted properties were industrial, unimproved, commercial, and residential (*15-6*, pp. 22-24).

5. Value increases peak at interchange locations where accessibility advantages are at a maximum. A Michigan study found incremental percentage change of "after" over "before" land values at interchanges to average 505 percent for land purchased for service stations; 201 percent for land purchased for other purposes. Table B-17 based on the study's data reveals greater percentage increases in value in rural and small-town areas for service station sites. Sites for other uses appear to show greater value gains in urban areas (*15-2*, p. 51). Accounting for these value increases, the most frequently found land uses at interchanges were, in order, service stations, restaurants, motels, shopping centers, and industrial plants.

6. Land values increase when land, previously outside the commuter range of urban employment centers, is brought within a 20- to 40-min peak-hour driving time of the centers. The previous use of such land is usually for agriculture or forestry. Its potential for higher order urban uses raises its value. At the same time, due to increased supply, it appears temporarily less expensive than closer-in vacant land whose value has been previously increased by urban development and dwindling supply relative to demand.

7. Value declines may be experienced in areas left at a disadvantage by the highway improvement for one or more of the following reasons:
   a. Increasing the supply of land with superior accessibility may cause it to become so abundant relative to demand that the value of such land may not be as high as land with similar accessibility formerly sold for. The value of the latter land probably will be deflated by the added competition.
   b. Drawing demand to locations advantaged by the improvement diverts it from other areas. Lowering demand in areas left with relatively inferior degrees of accessibility will tend to deflate values there.
   c. The new facility, because of its superior user benefits, causes modal and route, as well as locational, substitutions to occur. A reduction in the use of the modes and routes substituted for may deflate the value of land at locations geared to serve or be served by traffic moving by those former means.

Gains and Utilities

1. To landowners:
   a. Higher land values induced by highway improvements attracting higher order or higher-bidding

TABLE B-15

CHANGES IN LAND VALUES BY LOCATIONAL RELATIONSHIP TO FREEWAY (EXPRESSWAY) [a]

LOCATION [b]	AVERAGE INCREASE OVER BASE YEAR (%) [c]											
	LAND WITH IMPROVEMENTS [d]				LAND WITHOUT IMPROVEMENTS				UNIMPROVED (VACANT) LAND			
	BAND A	BAND B	BAND C	BAND D	BAND A	BAND B	BAND C	BAND D	BAND A	BAND B	BAND C	BAND D
Dallas:												
1941 Annexation	431	100	139	106	623	123	185	130	518	383	291	166
1946 Annexation	127	26	(22)	31	1,027	538	—	104	1,179	766	—	136
Houston:												
Unadjusted	250	130	50	90	282	150	38	76	—	—	—	—
Adjusted	245	125	(15)	44	190	96	(70)	(12)	—	—	—	—
Atlanta:												
West	99	4	11	102	—	—	—	—	197	12	53	148
East	40	18	(35)	102	—	—	—	—	247	35	(58)	148
San Antonio	251	181	71	(2)	377	264	127	30	—	—	—	—
Over-all average	206	83	28	68	500	234	70	66	535	299	95	149
Over-all range	40–251	4–181	−35–139	−2–106	100–1,027	96–538	−70–185	−12–130	197–1,179	12–766	−58–291	136–166

[a] Source: (*15-4*, p. 19).

[b] Delineation of study and control areas. The study areas for the four reports (*15-4*, p. 18) were delineated as follows:

1. Houston—A band, adjacent; B band, removed; C band, affected (nearby on good thoroughfares); and D area, distributed control areas.
2. Atlanta—A, B, and C bands were variable-width segments of homogeneous uses roughly parallel to this facility; and D area, one control area supposedly similar to expressway vicinity.
3. Dallas—A band, abutting; B band, next two blocks; C band, next two blocks; and D area, dispersed control areas.
4. San Antonio—A band, expressway fronting; B band, expressway not fronting; C band, main thoroughfare not at expressway; and D area, dispersed control areas not on main thoroughfare or not on expressway.

[c] Adjustment for inflation and local cost factors:

1. Houston—Adjusted for construction costs, inflation, and assessment factor.
2. Atlanta—Adjusted for inflation only.
3. Dallas—Variety of adjustment methods, including inflation and construction costs.
4. San Antonio—No adjustments.

[d] Definitions of value:

1. Houston—Land values with and without improvements, adjusted and unadjusted (four methods).
2. Atlanta—Improved land values, vacant land values, and both combined (three methods).
3. Dallas—Land less improvements, land and improvements, unimproved land, and tax valuation of land in the 1941 and 1946 annexations (four methods).
4. San Antonio—Land and improvements, land less improvements, and non-residentially zoned land (three methods).

land users desiring to take advantage of the superior accessibility it offers.

2. To land users:
   a. Lower rents or prices due to displaced demand.

Costs and Losses

1. To landowners:
   a. Lower land values resulting from highway improvements drawing demand away from land with relatively inferior accessibiilty to other locations or to consumers traveling over modes or routes substituted for.
2. To land users:
   a. Higher rents or prices due to value increases based on improvement.

Decision-Making Factors

1. Net increase in land values commensurate with and reflecting community needs and goals concerning the amount, timing, and location of land development compatible with highway function and efficiency.

CATEGORY: 15. Urban Form and Development
VARIABLE: C. Central Business District

Area:	Urban
Type of Consequence:	Economic
Location of Impact:	Community or System
Timing of Impact:	After Construction—Short Term After Construction—Long Term

Consequences

Highway improvements that serve the CBD of an urban area have the following consequences.

Land supply in an urban system, being analogous to space in a polar coordinate system, is scarcest toward the center and increases toward to periphery. Because the center of such a system is the point of maximum accessibility to the balance of locations within it, a great many activities desire such access and attempt to locate near that point. The resulting high demand for space relative to the limited supply is what gives "downtown" its intensity of land use, variety of activity, and density of daytime population. This high demand is expressed architecturally in the height and bulk of the buildings which multiplies the ratio of floor to ground space, satisfying more demand. Such a high traffic generating area, if it is to be adequately served by highways, requires that highways be of high capacity, meaning increasing number of lanes and width of right-of-way. Likewise, the system, to be complete, must include high terminal storage (parking) capacity. Large quantities of space for highway transportation are thus required in the portion of the city where the supply of space is scarcest.

Because traffic generation and transportation capacity must eventually approach approximate equilibrium, the capacity of the mode sets a limitation on the number and size of trip generators that can be accommodated in a given area. This relationship limits the density of daytime population, and the intensity and variety of centralized activity to that which can be handled by the system. Automobility arrives at this balance in three ways:

TABLE B-16

FREQUENCY DISTRIBUTION OF ANNUAL URBAN PROPERTY VALUE PERCENTAGE, CHANGES IN STUDY SEGMENTS ALONG MAJOR HIGHWAY IMPROVEMENTS, BY TYPE OF LAND USE (CHANGES BASED ON CONSTANT DOLLARS) [a]

	NUMBER OF CHANGES IN STUDY SEGMENTS BY TYPE OF LAND USE [b]					
CHANGE (%)	INDUSTRIAL	COMMERCIAL	RESIDENTIAL	UNIMPROVED	TOTAL CLASSIFIED USES	NOT SPECIFIED
(−10) to (−5)	—	—	—	—	—	1
(−5) to (−1)	2	4	2	1	9	1
0 to 5	—	7	26	6	39	13
5.1 to 10	3	5	21	3	32	6
10.1 to 15	—	9	12	2	23	4
15.1 to 20	1	2	13	3	19	1
20.1 to 25	1	1	6	1	9	2
25.1 to 30	—	2	2	2	6	1
30.1 to 35	—	1	—	—	1	1
35.1 to 40	—	—	—	—	1	—
40.1 to 45	—	—	—	—	—	—
45.1 to 50	1	1	1	1	4	1
50.1 to 55	—	—	—	—	—	—
55.1 to 60	—	—	—	—	—	—
60.1 to 65	—	1	1	—	2	—
Over 65	3	—	1	2	6	1
Total	11	33	85	22	151	32
Median percentage change	17.5	10.3	8.5	12.5	9.3	5.8

[a] Source: *Final Report of the Highway Cost Allocation Study,* H. Doc. 72 (87th Cong., 1st Sess.), 1961, p. 7. Reproduced by Bureau of Public Roads (*15-6,* p. 23).

[b] A study segment is a designated portion of land-value study that has been analyzed. For instance, in the table on industrial land-value changes, in the *Highway Cost Allocation Study,* there were 2 observations for Alameda County, 3 for Los Angeles, Calif., 1 for Atlanta, Ga., 2 for Stemmons Freeway, in Dallas, 2 for Houston, and 1 for San Antonio, Tex., making a total of 11 observations. All study segments were taken that were amenable to systematic treatment in order to derive constant "dollar data and annual average change."

Where the breakdown between "Land," "Improvements," and "Total" appears in the tables showing annual percentage changes in land values, only the percentages for "Total" were counted for bands, zones, and groups. Thus, one study may provide several items in this tabulation so that the more intensive studies would weigh heavier than the smaller studies.

1. *Space* required for right-of-way and parking removes some traffic generators by preempting their space and changing the land use.

2. *Congestion* (saturation of street, highway, and parking capacity) together with tolls and parking fees raise the time and money cost of tripmaking to the CBD, so discouraging many trips with a low utility value (e.g., shopping trips). With trip attraction reduced, enterprises that attracted lower utility trips lose their trade and either quit business or relocate in another location, if one can be found with sufficient access to a threshold market. In any case, their departure further lowers the level of trip generation toward an equilibrium with transportation capacity. Employment, that has a high utility (income production) relative to trip cost, will continue to justify CBD trips even as trip cost increases; hence, the increase in office space that has accompanied the decline in department store sales in most metropolitan CBD's.

3. *Distance* from trip origins, usually homes, to CBD destinations grows longer with the relatively large peripheral geographic expansion of settlement possible in urban areas due to the speed, range, and mobility of the automobile over improved highways. More and more of the population thus locate outside the "trade area" of the CBD, usually set at about 6 miles from the center. Decentralized shopping centers with ample free parking form convenient "intervening opportunities." They acquire a competitive advantage over CBD outlets induced by lower distances, travel times, and trip costs (less congestion, no parking

TABLE B-17

LAND AT INTERCHANGE LOCATIONS, VALUE INCREMENT AS PERCENTAGE OF "BEFORE" VALUE [a]

INTERCHANGE CLASSIFICATION	SERVICE STATIONS ONLY (%)	ALL OTHER SALES (%)
Major city	441	227
Secondary city	338	215
Small town	641	205
Rural	627	161
Average [b]	505	201

[a] Source: (*15-2,* pp. 46-58).

[b] Service station sales, 15; other sales, 52.

fees). This effects a further decline in CBD attraction and number of traffic generators.

In summary, the effect on land use is to increase the amount of space used for streets, highways, and parking and reduce that available for other uses. Diminishing the supply causes intensification of use of the remainder (i.e., increasing height and bulk). The price of space, the cost of tripmaking, and the distance between origins and destinations cause a shifting from retail and commercial to office uses and functions. Over-all daytime population density of the CBD goes down while the density of particular buildings rises. This winnowing process continues until equilibrium between traffic generation and transportation capacity is reached. To continue, it means further preemption of present uses by streets and highways and further increases in building height and bulk. (In Los Angeles, 75 percent of CBD ground space is given over to vehicular movement and storage; the CBD's functions, mainly office, are carried on in high-rise buildings set on the remaining 25 percent.) Uses have been sorted out with office functions remaining while shopping and lower order functions have been dispersed. Even many new offices are shunning the CBD in favor of remote office-building developments (e.g., Century City in Los Angeles; Rosslyn near Washington, D.C.).

The CBD is and probably will remain a setting for a variety of activities that need its centrality and accessibility to the entire metropolitan area and/or the advantages of fast communication and external economies (complementary enterprises) it offers. For the rest, dispersal and decentralization from the CBD will be the answer as it has been for numerous activities, including wholesaling, retailing, manufacturing, and residence—all of which have declined in most U.S. metropolitan centers (*15-7*).

This analysis helps explain the trends evident in CBD areas:

1. Expansion of the office function (communications efficiency, prime accessibility to labor pool, clients, and supporting business services, the conservative movement propensities of financial houses) (*15-7*).
2. Specialized goods and service outlets and cultural facilities requiring access to the entire metropolitan population to find an operating threshold (*15-1*).
3. Retail outlets geared to the population and incomes of those living close-in (usually the very rich in expensive new housing, and the very poor, in low-cost obsolete housing).
4. Outmigration of industry (seeking to escape congestion, improve access, and modernize facilities) (*15-1*).
5. Outmigration of residents (following employment, substituting modern for obsolete housing, shunning negative environmental impacts of auto transportation, racial mixing, crime, and other inner-city problems) (*15-5, 15-7*).
6. Outmigration of retail establishments (following residential decentralization, and declines in trade due to central area population and employment losses, transit deterioration, congestion, and rising parking costs) occurring with growing use of automobiles for shopping trips (*15-5, 15-7*).

Gains and Utilities

1. To CBD land users and owners:
   a. More space available to low-rent retail and industrial land users due to decentralization of many high-rent users based on CBD's relative inaccessibility via highways (congestion, parking fees).
   b. Higher incomes to parking-lot owners and operators due to competition for scarce parking space.
   c. Higher values and rents to owners for certain CBD land used for office buildings based on relative supply (scarce)-demand (large) relationship created by subtraction of CBD space for highways and parking.
   d. Higher CBD values and employment levels where highways permit express bus operation and thereby increase the potential work population and activity potential of the CBD.

Costs and Losses

1. To CBD department stores:
   a. Loss of trade due to population decentralization, deterioration of transit service and suburban shopping center competition related to highway influence.
2. To CBD landowners:
   a. Loss in value and rent revenues due to limitation on intensity of CBD use set by limitation on auto accommodation due to its space consumption propensities.
3. To local government jurisdiction:
   a. Lower tax revenue income and job availability where CBD declines in value and employment.

Decision-Making Factors

1. Intended role and importance of the CBD in the city and the region according to current policies and plans will indicate the degree to which its economic health and/or survival should be accommodated in highway plans.
2. Advantages of a strong CBD:
   a. Business efficiency.
   b. Incubator of infant enterprises.
   c. Specialized goods and services outlets.
   d. Cultural facilities requiring metropolitan patronage.
   e. Convenience of shopping for central-city residents.
   f. Revenue production for central city.
   g. Agglomeration and concentration economies.
3. Degree to which proposed highway improvements are compatible with a strong CBD according to the traffic congestion and parking requirements generated there; the effect on public transportation serving the CBD, the encouragement that will be given CBD enterprises to decentralize and the competitive advantage given off-center shopping centers over the CBD.

CATEGORY: 15. Urban Form and Development
VARIABLE: D. Urban Form and Development Patterns

Area: Urban
Type of Consequence: Economic and Social

Location of Impact:	Corridor Community or System Region or Nation
Timing of Impact:	After Construction—Short Term After Construction—Long Term

Consequences

Urban form and development patterns respond significantly to the transportation system route patterns, speeds, ranges, and capacities, and costs or prices.

Route patterns of the system determine where development is feasible; to what locations access exists and how much land, in acres or square miles, is thereby opened to development. The network nodes or centroids, usually intersections and interchanges, are points of maximum accessibility to most other points and thus become the foci of intensive development.

Speeds of the vehicles using the system determine the feasible limits of development by determining time-distance between locations. Development is limited to the area having tolerable travel times to activity centers such as employment and shopping.

Ranges of the vehicles may also enter in. Range is the maximum distance that can be covered before the energy source for locomotion is depleted or only enough energy is left to complete a round trip.

Capacities of the system and/or its vehicles help determine the intensity or density of development—that is, how much activity, how many employees, patrons, shoppers, or residents can be accommodated with trips to a given location during a certain time period before peak system capacity is reached.

Costs or prices of transportation are another spur to or limitation on development. They determine the travel distances that can be regularly undertaken and reasonably paid for at various income or profit levels. Both money and time costs are involved in that both are scarce resources with alternative uses.

To demonstrate how these transportation parameters set urban form and development patterns and to identify the unique features of the pattern produced by highway transportation the following comparative analyses are made (*15-1, 15-4, 15-6*).

Pedestrian-Oriented Development

1. Route pattern.—Pedestrian systems are often meandering and irregular, conforming to the topographical "path of least resistance," avoiding steep climbs and barriers and preferring gradual grade changes as a means of conservation of energy. The system may be formalized in a geometric pattern and grades altered for aesthetic, efficiency, or land-use reasons. Access is usually continuous along all routes except where prohibited by barriers. System coverage is usually ubiquitous out to the range of time and human energy limitations.

2. Speed.—Speeds of 3 to 6 mph yield developed areas of small diameter but intensive use (tightly clustered buildings and, abetted by elevator technology, very tall ones). The "walking city" of early Boston was an area with a radius of two miles. Ancient Greek cities were said to have a diameter that could be walked in an hour. Most "downtown" cores have a radius of a mile or less.

3. Range.—Human energy and willingness to walk for many purposes appears expended at about ¼ mile. Beyond that range, for instance, studies have shown bus stop patronage falls off rapidly.

4. Capacity.—In that a man occupies only 2 to 3 sq ft of space, pedestrian ways can accommodate extremely high volumes. Capacity of a 12-ft lane is about 30,000 persons per hour.

5. Cost or price.—The cost of pedestrianism is the human energy and time expended. There are no identifiable out-of-pocket costs except for the negligible costs of extra food to replace expended energy, shoe leather, and the alternative uses of time. There are compensating benefits—better health from the exercise of walking, opportunity for meeting and greeting people, and observing shop displays, nature, architecture, and other details of the environment in intimate detail.

6. Typical urban form and development patterns.—The urban form tends to be compact and extremely dense, with little open space and many tall buildings clustered in central areas of intensive activity. Rights-of-way for pedestrians tend to be narrow for greater convenience and protection from the elements. The developed area is usually circular, continuous, and spatially limited. Typical examples include the tightly clustered buildings and narrow, often winding streets, punctuated with squares and plazas found in the "walking city" portions of central Boston (Beacon Hill), New York (Greenwich Village), and New Orleans (the Vieux Carré).

Trolley-Transit-Oriented Development

1. Route pattern.—Trolley transit systems form a radial or grid system usually conforming to street patterns used as right-of-way. Capability for tight turning radii at street intersections and ability to manage extreme grades (traction trollies and cable cars) make comprehensive coverage possible. Frequent stops provide continuous access along routes. In that passengers become pedestrians after leaving the system, development is intensive within walking distance of transit stops. A continuous corridor of dense development centered on the trolley route results, with lower density development in the interstices between routes. The resulting urban pattern is frequently star-shaped under a radial route system or forms a more uniform circular street where lines follow a grid system or combine radials with "cross-town" lines in annular rings about the urban center.

2. Speed.—Speeds of 8 to 15 mph produce developed areas of moderate diameter and intensive use, especially along system routes. The diameter of the resulting urban area usually has a radius of 6 to 8 miles.

3. Range.—Range is the extent of the system of tracks and power source, usually electric lines.

4. Capacity.—Capacity one-way ranges from 7,000 to 13,500 persons per hour per track.

5. Cost or price.—Transit fares vary from $0.04 to

$0.08 per mile. The mode is low in accident hazards. It has the added advantage of permitting leisure activity while in transit (reading, conversing, relaxation).

6. Typical urban form and development pattern.—Trolley-transit-oriented development results in intensive corridor developments where accessibility is continuous along routes. Typical streetcar corridors include Commonwealth Avenue, Boston; Delmar Boulevard, St. Louis; and Connecticut Avenue, Washington, D.C.

Rail-Transit-Oriented Development

1. Route pattern.—The usual rail transit system is radial, focussing on a common central terminal. High speeds lead to a system configuration that includes large turning radii, long straight tangents, and grade-separated rights-of-way (subway or elevated). Efficient operation and attaining of economical speeds require discontinuous access at discrete intervals at which are located the system's depots and stations. Again, passengers become pedestrians at the system's interchange points leading to intense development of nodes surrounding stations out to pedestrian range. The range may be extended by "feeder" operations by public or private mechanized transportation modes (e.g., bus, trolley, auto, bicycle).

The pattern of development is one of linear corridors radiating from a common centroid in a star-shaped pattern with bead-like nodes of dense population and intense activity around station stops.

2. Speed.—Speeds of 20 to 40 mph produce an urbanized area of large diameter, usually with a radius of 20 miles.

3. Range.—Range is fixed by the extent of the system and the time and cost tolerances of commuters, whichever comes first.

4. Capacity.—Capacity is up to 40,000 persons per hour per track.

5. Cost or price.—Fare prices range from $0.03 to $0.08 per mile. Again, accident experience is relatively low. Time spent in transit has alternative uses. This fact and the higher speeds produced by grade separation and station spacing make feasible commuter trips that are quite lengthy in terms of miles.

6. Typical urban form and development pattern.—Rail transit leads to dense clustered development around rapid transit stations due to its speed, range, and high capacity. Extremely dense centers of residences and work places are made possible by rail transit. Examples of rail transit and railroad oriented development include: Harvard Square, Cambridge; Chicago's Loop and North Shore communities; Manhattan and the commuter towns along New York's Long Island Railroad; and Philadelphia's Center City and "Main Line" communities.

Highway-Oriented Development

1. Route pattern.—The ideal system route pattern for highway transportation is the grid. Speed, distance economy and safety of operation dictate straight rights-of-way, gradual curves, and flat grades to the extent possible. Radial systems are discouraged by the propensity for congestion and lack of parking space to occur at the focus of a radial system. A grid creates multiple foci at intersection points in the net and so spreads development and the traffic it generates, thereby relieving congestion and parking difficulties.

Highway systems generally provide continuous ubiquitous coverage over wide geographic areas in that graded rights-of-way are the only public investment requirement, vehicles being privately owned, operated, and maintained. The flexibility and mobility of the vehicle over the system makes access and therefore development possible at uniform densities over wide areas in street or sprawl fashion. Although higher densities of population and intensity of activity occur at intersections, interchanges, and in corridors of high-speed, high-capacity highway facilities, development levels off as peak-hour roadway and parking space capacities are reached at the intersection or in the corridor.

2. Speed.—Speeds of 20 to 60 mph give urbanized areas a potential radius of 30 miles or more. This potential is increased by the presence of high-capacity, high-speed, limited-access, grade-separated highways that provide for the achievement of the higher speed potentials by large numbers of vehicles. The large amount of developable land made accessible via street and highway systems and auto speeds makes low-density development possible even as low system capacities make it desirable (to avoid congestion).

3. Range.—Frequency of refueling sites (service stations) makes the fuel tank capacity of no relevance to range. Of greater importance are economic and time cost tolerances of commuters.

4. Capacity.—Capacity is lowest of all the modes—1,000 to 1,700 vehicles per lane per hour depending on total highway width. This translates to from 1,000 to 4,000 persons per lane per hour, depending on the number of persons per vehicle. Capacity limitations stem from the size of the vehicle, its carrying capacity, the spacing required for safety at various speeds, attainable speeds according to traffic density, and parking capacity at destinations.

5. Cost or price.—Cost runs about $0.08 to $0.15 per vehicle-mile, including cost of vehicle, insurance, etc. Cost may be higher due to parking fees. Accident experience and costs are relatively higher than for other modes. An added cost is that of operating time in that the traveler is also vehicle operator and cannot put in-transit time to any optional uses. Passengers, however, may read or otherwise occupy themselves.

6. Typical urban form and development patterns.—The typical form and pattern of highway-oriented cities includes low-density residential development (sprawl) intermittently punctuated with low-intensity shopping centers and industrial parks that are geographically extensive due to parking requirements. Ribbon commercial development along unlimited access thoroughfares is another typical feature in the pattern. Architecturally, urban forms tend to be spread out and isolated, to account for parking space and low system capacity; also massive and abstract to relate to the speed and scale of the vehicles. Los Angeles, Oklahoma

City, Denver, and other cities of the West that have had most of their development occur in the period of the automobile's predominance are examples of highway-oriented urban development.

Gains and Utilities

1. To communities:
   a. Social and economic benefits and satisfactions emanating from congruence of desired pattern of urban form and development and transportation mode and system capable of producing the desired pattern.

Costs and Losses

1. To communities:
   a. Social and economic costs and dissatisfactions stemming from incongruence between pattern of urban form and development desired and the one produced by the transportation mode and system invested in.

Decision-Making Factors

1. Goals and policies of affected jurisdictions concerning their form and development patterns.

2. Transportation modes and system patterns that will tend to produce the form and development patterns set as goals.

CATEGORY: 15. Urban Form and Development
VARIABLE: E. Real Property and Land Taken for Right-of-Way; Use and Value

Area:	Urban
Type of Consequence:	Economic
Location of Impact:	Community or System
Timing of Impact:	During Construction After Construction—Short Term

Consequences

Taking of rights-of-way for highway improvements involves a substitution of land uses and a reduction in the supply of land, floor space, and structures in their former uses and quantity. Although there is compensation at "fair market value," which includes the capitalized returns from land and structures in their present use over their economic lifetimes, there is, nevertheless, a drop in the supply of structures, floor space, and nonhighway land uses in the community.

Loss may be particularly heavy for owners of residential properties buying on a "contract" rather than a mortgage basis. Financing under this plan is often found in low-income neighborhoods. The selling price of property is inflated by this means to compensate for lack of a down payment and the buyer's being a poor credit risk. Under the contract plan, the seller keeps title until the buyer has made numerous payments. When the government condemns the property the buyer may not only lose his equity but also, where the fair market value paid is less than the purchase price, remain liable for paying the difference. He therefore ends up continuing to pay for property whose use and equity have been lost to him. Although unjust, this is legal in many states. Even when the buyer has title, the government's compensation may not equal what is owed on the property and the buyer must still make up the difference under the contract. Added to economic loss is the psychological one of discovering that home investment does not necessarily mean security.

Fair market value compensation may also fail to equal purchase price due to property deterioration or a depressed market occurring in the waiting period.

Gains and Utilities

1. To landowners:
   a. Compensation in the form of fair market value and transfer costs to the extent it equals or exceeds buying price or capitalized value based on net expected revenues from property.
   b. Landowners who are able to command higher rents as a result of the change in the supply-demand relationship due to right-of-way taking depleting the supply of land and floor space in various uses.

Costs and Losses

1. To landowners:
   a. Loss of land and structures, their use and income. Loss of investment to the extent buying price or capitalized value of property income is not equalled or exceeded by fair market value compensation and transfer costs.
2. To tenants:
   a. Lose use of land or floor space. May pay higher rents elsewhere as a result of the change in supply-demand relationship—reduction in supply relative to demand. Loss likely to be heavy if structures housed a population or establishments for which alternative housing or floor space is in short supply.
3. To community:
   a. Loss of structures or sites of architectural, scenic, or historic merit are a loss to the aesthetic, cultural, and social life and values of the community. Tangible losses accrue if these assets attracted visitors who paid admission or patronized local establishments in large numbers. These losses are generally irremediable. Such sites and structures are usually unique. They cannot be replaced by alternatives and substitutes as can other land uses through rezoning, new building, and conversion of uses and structures.

Decision-Making Factors

1. Criteria for decision making include:
   a. Landowners displaced, amount of land needed to accomplish the highway objective, land strategic to the economic and social health of the community, aggregate value of land taken, net loss, if any, to landowners, number of structures and aggregate amount of floor space taken, structures of architectural, scenic, or historic merit, and pressure on space-user rent levels, especially for low-income groups.

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