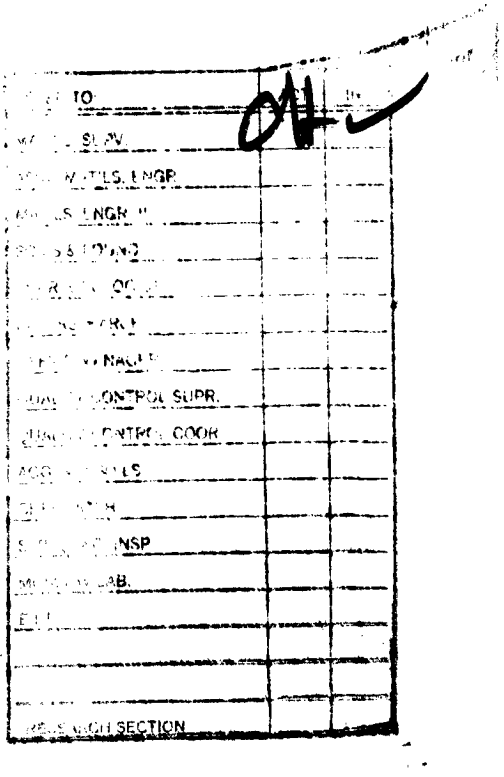
NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM
REPORT 193

BENEFICIAL EFFECTS ASSOCIATED WITH FREEWAY CONSTRUCTION

ENVIRONMENTAL, SOCIAL, AND ECONOMIC



TRANSPORTATION RESEARCH BOARD
NATIONAL RESEARCH COUNCIL

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM
REPORT 193

BENEFICIAL EFFECTS ASSOCIATED WITH FREEWAY CONSTRUCTION

ENVIRONMENTAL, SOCIAL, AND ECONOMIC

HAYS B. GAMBLE AND THOMAS B. DAVINROY
THE PENNSYLVANIA STATE UNIVERSITY
UNIVERSITY PARK, PENNSYLVANIA

RESEARCH SPONSORED BY THE AMERICAN ASSOCIATION OF STATE HIGHWAY AND TRANSPORTATION OFFICIALS IN COOPERATION WITH THE FEDERAL HIGHWAY ADMINISTRATION

AREAS OF INTEREST:

- TRANSPORTATION ECONOMICS
- HIGHWAY DESIGN
- ROADSIDE DEVELOPMENT
- CONSTRUCTION
- ROAD USER CHARACTERISTICS
- URBAN COMMUNITY VALUES

TRANSPORTATION RESEARCH BOARD
NATIONAL RESEARCH COUNCIL
WASHINGTON, D.C. 1978

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 and Transportation 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 Transportation Research Board of the 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 and transportation departments and by committees of AASHTO. 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 and Transportation 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 Transportation 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.

NCHRP Report 193

Project 20-13 FY '75
ISSN 0077-5614
ISBN 0-309-02852-3
L. C. Catalog Card No. 78-57990

Price: $7.80

Notice

Published reports of the

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

are available from:

Transportation Research Board
National Academy of Sciences
2101 Constitution Avenue, N.W.
Washington, D.C. 20418

Printed in the United States of America.

FOREWORD

By Staff
Transportation
Research Board

This report will be of special interest to engineers, economists, sociologists, and environmentalists engaged in highway planning activities. As a reference document, the report will assist individuals at all levels of government to identify the positive impact of new highway facilities and will be especially useful in the preparation of environmental impact statements. Administrators and planners will also find the report helpful in preparing presentations to civic and business groups. The results of an exhaustive literature search are presented, identifying a wide range of positive benefits related to freeway construction. Negative impacts that occur in conjunction with the more significant identified benefits are also addressed to provide a more balanced perspective. More than 600 significant reference publications are cited.

Transportation administrators and public officials face increasingly difficult decisions related to highway construction, especially freeways. The responsibility of providing adequate transportation facilities to meet current and future travel demands, while giving appropriate consideration to the anticipated benefits and negative impacts, creates a decision-making framework that is broad in scope and extremely complex. Negative impacts have received major emphasis in urban freeway planning in an attempt to evaluate the sometimes severe effects on the community in conjunction with the primary benefit; i.e., improved mobility.

This report focuses on the less obvious positive benefits associated with social, environmental, and economic impacts in both rural and urban areas. The primary objective of this study was to provide a comprehensive summary of benefits from which the planner can select those specific benefits that are applicable to his evaluation of a new freeway facility. The relative significance of individual benefits varies widely among projects and could not be addressed in depth in this study.

A multidisciplinary research team from the Institute for Research on Land and Water Resources, The Pennsylvania Transportation Institute, and the Institute for State and Regional Affairs, all of the Pennsylvania State University, conducted an exhaustive literature search to identify positive benefits resulting from freeway construction. Team members were selected from all related disciplines in the social, environmental, and economic fields, as well as transportation planners, to provide the comprehensive approach required by this study.

In addition to identifying and documenting related reports and past studies, the researchers catalogued each benefit in terms of (1) urban vs rural, (2) short-term vs long-term, and (3) direct vs indirect. A matrix was developed to present a summary of individual benefits in relation to these categories.

Although this research effort identified numerous reports and studies related to social, environmental, and economic benefits, a wide range of additional research needs was recommended. Improvements to quantification techniques used to measure and evaluate specific benefits are needed, as well as refinements to planning methodologies, to permit full consideration of all impacts, both positive and negative. Because the major thrust of new freeway development is likely to be concentrated in rural and outlying suburban areas, most of the recommended future research efforts address the specific issues, impacts, and benefits encountered in these areas.

CONTENTS

ACKNOWLEDGMENTS

The research reported herein was performed under NCHRP Project 20-13 by the Pennsylvania State University, with Hays B. Gamble, Professor of Agricultural Economics, Institute for Research on Land and Water Resources, and Thomas B. Davinroy, Associate Professor of Civil Engineering, Pennsylvania Transportation Institute, as co-principal investigators. Assistance in the literature search and analysis, as well as in the preparation of the report, was provided by a team of eight researchers representing as many fields of interest, and affiliated with various components of the University, as follows:

John L. George, Professor of Wildlife Management.

Irving Hand, Associate Professor of Urban and Regional Planning, Institute for State and Regional Affairs.

Craig Humphrey, Assistant Professor of Sociology.

Donald V. Joyce, Instructor of Recreation and Parks.

Donald W. Leslie, Assistant Professor of Landscape Architecture.

Owen S. Sauerlender, Professor of Economics, Institute for Research on Land and Water Resources.

Roger Hornberger, Research Assistant, Institute for Research on Land and Water Resources.

David Bradshaw, Graduate Research Assistant in Sociology.

The tedious task of reviewing the extensive highway literature of interest to the project was made considerably easier by the valuable assistance rendered by Ali El-Aroud, Helen McGinnis, Merrill Katz, and Ronald Perry.

BENEFICIAL EFFECTS ASSOCIATED WITH FREEWAY CONSTRUCTION
ENVIRONMENTAL, SOCIAL, AND ECONOMIC

SUMMARY

The beneficial effects from freeways, as disclosed in the literature and as identified by the researchers, are classified in this report into three main groups: environmental, social, and economic.

Environmental benefits include (1) effects on the physical components, such as improvement of air quality through a reduction of emissions; (2) effects on the biotic components of the environment, such as preservation and diversity of plants as well as food, cover, and range extension of animals; and (3) improvements to the aesthetic quality of the environment. Benefits within the third category occur for both highway users and nonusers, and comprise such effects as improvement of visual access and landscape quality, reduction of glare, provision of open space, modification of land forms, and perceptions of spatial relationships.

Social benefits accruing to individuals, both as users and nonusers, consist of such effects as improved accessibility and freedom of choice, better health and safety, and reduced congestion leading to less irritability and stress. Also included within this group are the beneficial effects of highways on population distribution and change, as reflected by age, race, and socioeconomic status. Highways have a noticeable impact on public and private community services and strongly affect settlement patterns. Other social benefits are reflected in improved interaction and communication, which serve to strengthen community values, to increase social contacts, to foster better public participation in highway planning, and to improve the effectiveness of comprehensive land use planning.

Economic benefits realized from highway improvements are reflected most strongly in economic growth and development, which are stimulated through improved accessibility (reduced travel time and operating costs), more employment and income, and agglomeration economies and economies of scale. Many of these direct benefits are transferred to highway nonusers in the form of increased land values. Other direct economic benefits include reduction of accidents, injuries, and fatalities and their associated costs. Operational effects of highways are exhibited in the form of bypass and relocation benefits, reduced congestion, and energy savings. Finally, there are the benefits derived from improved efficiency in all kinds of public services and the use of waste materials as substitutes for more valuable resources in highway construction and maintenance.

Literature dealing with all these effects is reviewed, analyzed, and evaluated in this report. Adverse effects, often accompanying beneficial effects, are briefly mentioned for some of the more significant benefits. A matrix of beneficial effects is provided that further categorizes the effects as being found primarily in urban or rural areas, of short-run or long-run duration, and of a direct or indirect nature. Extensive bibliographies are included for each of the three principal groups of benefits—environmental, social, and economic.

CHAPTER ONE

INTRODUCTION AND RESEARCH APPROACH

STATEMENT OF THE PROBLEM

Most people would agree that few technological developments in the last 100 years have had more influence on contemporary society than the automobile. For example, it is the primary mode of travel for most individuals; it is a major determinant of income (directly or indirectly) in the economy; it has been a prime factor in shaping the settlement patterns of cities; it plays a major role in how leisure time is spent; and it has influenced the social structure and institutions in both urban and rural areas. Highways, in turn, apart from the automobiles that they serve, have effects of their own on society and the environment.

In recent years, there has been a growing awareness that the economic growth and affluence achieved in the United States has been costly. This realization has been expressed in concern over the quality of air and water resources, the depletion of some natural resources, the abuse of scenic amenities, and the threat to human health.

The environmental, social, and economic effects from highways and motor vehicles can be both beneficial and harmful. To many, well-meaning citizens, the motor vehicle and the highway have become symbolic of the technological development that has resulted in environmental degradation. Much of the opposition of organized environmental groups, as well as individual citizens has been directed toward proposed new highway construction. The requirement as set forth in the National Environmental Protection Act of 1969 for environmental impact statements for all new federally funded projects has provided a means by which such opposition can be legitimized.

Although the purpose of such statements is to provide as realistic an analysis as possible of all effects from highways, positive as well as negative, to cope better with the breadth and intensity of opposition to new highway construction, state highway department officials have concentrated much time and effort on identifying the adverse effects when preparing environmental impact statements, at the sacrifice of giving adequate attention to the beneficial effects. (Among citizens there is little organized clamor for a review of highway benefits as compared, for example, to the demand for the elaboration of highway costs.) As a result of overemphasizing the adverse effects, a balanced perspective on the present and future role of highways has not been provided.

Opposition to highway improvements by environmentally concerned citizens and by proponents of the no-growth philosophy has led to the cancellation or delay of many highway projects in the last few years. There is no doubt that some of these projects were rightfully rejected, either because of unusual or severe environmental abuse or because of lack of clear economic or social justification. But other highway projects, where the need for improvement was great, have been thwarted, resulting in high costs to society in terms of congestion, safety, air quality, and inflated delayed construction costs. If, at the time when corridor selection, highway design alternatives, and environmental impact statements were presented to the public for approval, a more balanced perspective on beneficial as well as adverse effects could have been portrayed, some of the delayed and/or cancellation costs might have been avoided.

This report presents the findings of a study, sponsored by the National Cooperative Highway Research Program, which identifies all known beneficial effects associated with freeway construction. The term "freeway construction" is interpreted broadly in this report, and is taken to mean all the beneficial effects from freeways, both when under construction as well as when in use.

RESEARCH OBJECTIVES AND SCOPE

The principal objectives of this study were as follows:

1. To identify, by means of a thorough literature search, all the known beneficial effects associated with freeway construction.
2. To identify the beneficiaries of the various benefits where appropriate and possible.
3. To analyze the research methodology and point out the strengths and shortcomings of the significant research reported in the literature.
4. To "brainstorm" the entire topic of beneficial effects with the goal of identifying possible effects not previously recognized or presented in the literature.
5. To present the results of the literature review and "brainstorming" in a manner useful to highway planners, designers, engineers, and administrators.

Accomplishment of these objectives involved grouping the beneficial effects, thus identified, according to whether they were principally environmental, social, or economic in nature. These effects were further delineated as being of long-run or short-run duration, direct or indirect in origin, and applicable primarily in urban or rural areas. Additionally, a matrix, which could be easily understood by workers from diverse professional backgrounds, was developed and used to classify all the beneficial effects.

RESEARCH APPROACH

A team of researchers representing a wide variety of disciplines and interests (wildlife biologist, regional planner, transportation engineer, sociologist, recreation specialist, landscape architect, economist, and land economist) cooperated in this project. They undertook a wide search of the literature, and carefully examined the principal studies dealing with highway beneficial effects. They peri-

odically assembled to discuss and evaluate their findings and "brainstorm" new effects that were not presented in the formal literature.

One of the principal efforts of the research team was to develop a classification system for the beneficial effects of freeways. The classification system presented in this report is the result of a desire by the research team to provide an exhaustive, yet nonoverlapping system. It represents the work of members from eight disciplines. The terminology and order of each of the categories in the system were required to be relevant to workers from the appropriate discipline as well as easily understood by others from different professional backgrounds who were involved with the project. The intent of this approach was to provide a classification system which would be understandable and useful for all potential readers.

Within the classification system, benefits were grouped into three main categories: environmental, social, and economic. The environmental effects were those associated predominantly with the physical, biotic, and aesthetic attributes of the highway corridor. The beneficial effects on air, water, soils, rocks, plants, animals, and aesthetic qualities affecting both users and nonusers were considered. The wildlife biologist, transportation engineer, and landscape architect assumed responsibility for evaluating the literature dealing with these effects.

The social effects included (1) the beneficial societal ways in which highway improvements might influence individuals (both as highway users and nonusers); (2) the beneficial effects on population distribution and change; (3) the various community effects such as public and private services, settlement patterns, social interactions, and interrelationships between comprehensive planning, land use planning, and transportation planning; and (4) the different regional and national social effects. The sociologist, regional planner, and recreation specialist reviewed these effects.

Economic effects were those associated with (1) economic growth and development arising from improved accessibility, reduction in travel time, and vehicle operating costs; (2) land values; (3) improved health and safety; (4) various operational aspects such as congestion, bypasses, relocation, and energy; (5) efficiency in public and private service delivery; and (6) resources substitution. The two economists developed this section.

The literature review process included information retrieval from TRIS-NET and a combined NTIS-SSIE search, which yielded citations for about 450 pieces of literature. In addition, requests for studies were sent to all state highway departments. Researchers combed the journals, periodicals, and books relevant to their fields of interest. The literature search concentrated primarily on writings published after 1950, although some important works before that date were reviewed. Each team member was responsible for reviewing the literature in his field and for analyzing and evaluating the articles and other writings found to contain relevant information. The review not only identified known benefits, but also critically examined the validity and reliability of the studies.

CHAPTER TWO

FINDINGS

ENVIRONMENTAL BENEFITS

Environmental effects of freeways vary with the placement, degree of interdisciplinary planning, care in building, and type of management of the finished highway. These effects are sometimes easier to demonstrate than they are to evaluate because they will also vary with the nature of the effect; with what is affected; and with the goals, priorities, and value system of the evaluator. This section concentrates on the beneficial environmental effects that have been shown to occur, or that are possible with enlightened management; others have amply pointed out the detrimental effects. The benefits are presented under three major categories: the physical, the biotic, and the aesthetic quality of the environment. A detailed discussion on the classification of environmental benefits is included in Appendix A.

It is anticipated that this discussion will help increase benefits and reduce damages from freeways. Hopefully, freeway planners will consider possible ways of applying the practices discussed to specific highway projects, so that their maximum potential for multiple use can be realized. As an example, freeways that are planned, constructed, and managed with no consideration of wildlife can aid a few species, but most benefits will not result accidentally. Rather, benefits are often the product of voluntary cooperation between state highway departments and specialists (such as archaeologists, botanists, wildlife managers, and geologists).

Physical

Physical environmental effects of freeways are discussed under the following headings air, water, and soils and rocks. In general, air environmental effects of freeways are aspects of air pollution and urban climate. Water effects pertain to aspects of water quality, changes in runoff, and retention of ground and surface water. Environmental effects of freeways on soils and rocks are concerned with infiltration, erosion, and salvage of materials of interest to earth scientists and archeologists.

Air

The quality of air is partially determined by the amount of pollutants: (1) carbon monoxide (CO), (2) hydrocarbons (HC), (3) oxides of nitrogen (NO_x), (4) lead, and (5) particulate matter from motor vehicles discharged into the atmosphere. The amount of pollutants varies with respect to, among others, vehicle speed, gear changes, number of stops, and speed from which stops are made. Freeways reduce most of these pollutants because the number of stops and gear changes made are fewer, and the vehicle speed is generally more uniform and higher than on roads without access control. Although air quality benefits to be derived from improvements in traffic flow are comparatively small, the greatest improvement in air quality will be obtained where vehicle speeds are low; that is, increasing average vehicle speeds from 10 mph to 30 mph will result in greater improvements than a similar increase at higher speeds. This would indicate that, although the reduction of stop and start operations on local streets will be of considerable benefit, greater benefits will result if much of this traffic were transferred to a limited-access freeway where speed changes are minimized.

The sustained higher speeds of freeways, as compared to nonaccess-controlled roadways, also create air movements that mix pollutants and disperse them over a larger area where their effect is reduced.

Water

The effects of freeways on water quality, which result from both the construction and the operation phases, are primarily negative. However, the intersection of an aquifer by a highway cut may interrupt the natural flow of groundwater and thus draw down an aquifer, improving the characteristics of the land immediately adjacent to the highway. Groundwater supplies can be recharged as a result of changes in permeability and rate of runoff from soil disturbance during construction. Where a perched water table exists because of an impervious hard pan layer, breeching this layer during highway construction will permit infiltration into the lower layers.

Soils and Rock

Both soil and rock will be disturbed in areas through which highways pass—particularly freeways with their greater widths, flatter grades, and longer radius curves than roads built to less demanding standards—generally with damaging results. Again, there are some situations, however, in which the construction of a highway has beneficial results. Low strength soils can be strengthened in situ, the effects of which often extend well beyond the limits of the highway. Soil characteristics in wet areas might be improved by opening up hard pan layers during construction, thus permitting better drainage.

The exposure of subsurface rock formations can have a number of benefits. Freeways may aid scientific research by exposing geologic structure, unearthing fossil deposits, and enabling archeological salvage. Road cuts can be of great benefit to geologists, soil scientists, paleontologists, and archeologists. Geologists often rely on road cuts in demonstrating local geologic features, especially in the humid, well-vegetated eastern United States; the importance of road cuts is also reflected in guidebooks for tours that are often a part of geological conferences. Soil scientists may have the opportunity to see clean-cut soil profiles; and fresh, unweathered fossils and new fossiliferous pockets are exposed. For example, Interstate 70 west of Denver cuts through the Hogback of the Morrison Formation, famous as a source of dinosaur bones. Sixty million years of earth history are exposed in the cut, which has been officially designated as "Colorado's Sixty Million Year Nature Center." Paleontologists at the Cleveland Museum of Natural History were delighted that excavation for the freeway would reexpose the fossiliferous shale covered by urban development.

Paleontologists and archeologists also realize benefits through the use of Federal highway funds, authorized by the U.S. Department of the Interior, for paleontological and archeological salvage, up to 1 percent of the funds appropriated for construction. The federal highway salvage program is also important to archeologists studying the remains of past human activities—from Indian villages and burial mounds to early white settlements. Some states have set up cooperative salvage programs between archeological and historical institutions and their highway departments.

Biotic

Biotic environmental effects due to the building of freeways vary with: the width and length of the freeway, which determines the area involved; the soils and soil configurations of the area; the degree of environmental understanding and planning in construction; and the maintenance of the right-of-way.

Thought and policy have changed in regard to the management of the highway right-of-way. In 1971 Interstate highway rights-of-way occupied approximately one million acres. The very large increase in right-of-way acreage in recent years, together with current trends to manage the right-of-way with wildlife and multiple use, has had a positive influence on the biotic environment. In the past, neatness was stressed, and this led to endless miles of rights-of-way planted with a limited number of nonnative grasses kept short and "weed" free by frequent close mowings or liberal applications of herbicides. The results were monocultures of benefit to relatively few species rather than a diverse environment of general ecological benefit. The escalating costs of trying to make rights-of-way look like lawns, coupled with increasing interest in multiple use of these areas, have brought dramatic changes in management in many states.

Highway departments may finance ecological studies as a means of finding out about the impacts of existing or proposed freeways on certain animals or entire ecosystems. The studies may go beyond consideration of the freeway itself and produce a great deal of additional useful biological data. Effects of freeways on plants and animals are discussed under the following headings: with respect to plants, under diversity, preservation, and firebreaks; with respect to animals, under wildlife, terrestrial, and aquatic and amphibious.

Diversity

It is considered sound ecological management to encourage a diversity of plant species, which, in turn, may produce a diversity of wild animals that depend on them.

Freeway rights-of-way are sometimes the largest pieces of land suitable for plants in heavily built-up urban regions, particularly interchanges. A different kind of diversity may be realized on rights-of-way in rural areas. On forested, highly cultivated, or open land, and in arid regions, species may be planted that grow sparsely or not at all in the surrounding area. Such plantings may provide cover and food for wildlife and scenic diversity for motorists. A word of caution is necessary, however: although these exotic species may be beneficial to the environment, often they are not; in general, it is preferable to use native species on rights-of-way.

Preservation

Freeways affect rare, endangered, and uncommon species of native plants and the natural assemblages of vegetation that ecologists call plant communities. Roadside rights-of-way can be among the last places where native plants can grow in intensively developed regions where almost all the land is cultivated or preempted for other uses. In some instances transportation corridors (railroads) have helped preserve native flora.

The wide rights-of-way associated with modern freeways might have served as a protective reservoir for prairie grass communities. Unfortunately, by the time the Interstate Highway System was approved, there was little tall grass prairie left to save; but there is a growing interest in prairie restoration. Prairie grasses and broad-leafed herbs provide forage for livestock, habitat for wild animals, and control of erosion, and are aesthetically pleasing.

As the United States becomes more densely populated, use of freeway rights-of-way as a special habitat will gain in importance.. As a current example, the Baltimore-Washington Parkway right-of-way shields the suburbs through which it passes with a wide strip of native trees and shrubs. This right-of-way is now one of the only remnants of the original vegetation in the more built-up suburbs.

Marshes and brushland can also be preserved in freeway rights-of-way. Many areas bordering the Susquehanna and Chenango rivers in New York are swamps and brush-covered sites that provide wildlife habitat. Over-all, however, new freeways have destroyed far more wetlands than they have preserved.

Firebreaks

Freeways and their rights-of-way are effective firebreaks in fire-prone regions. This has proved to be so evident that roads are often used as boundaries in managed burns. They also make possible the speedy transport of men and equipment to the scene of a forest or bush fire.

Wildlife

Benefits to wildlife accruing from freeway construction depend on the width, topography, and soil configuration of the right-of-way. Proper planning, design, care in construction, and subsequent right-of-way management will also influence the benefits to wildlife. All animals must have food, shelter, and a place to breed. If a freeway right-of-way supplies one or more of these needs to animal species, it has the potential of benefiting them.

Terrestrial Animals

Freeday rights-of-way may be beneficial to wildlife in both rural and urban environments, but they are likely to be most significant in urban and highly cultivated regions where living space for animals is scarce.

Animals may feed on plants growing on the freeway right-of-way and along the margins of artificial ponds created during freeway construction. The plants growing on freeway lands are considered to be a naturally occurring food source regardless of whether they were established as a consequence of natural seeding or were planted by man. Deer and meadow mice are examples of animals who use this food source. Hawks and other animals who prey on mice may benefit indirectly. Animal feeding may also be enhanced by food introduced to the animal's environment through operational aspects of the freeways.

Freeways and associated structures, as well as the physical and biotic features of the right-of-way, can enhance the habitat of terrestrial animals by providing cover for animals through: (1) structures for nesting and roosting sites, (2) soils (especially embankments) for burrows and nesting sites, and (3) vegetation in the right-of-way for cover and for nesting and escape.

Highway bridges and overpasses provide shelter to several species of birds and certain mammals and reptiles. For example, several insect-eating birds attach their nests to the undersides of bridges. Animals that use structures for nesting and roosting sites include bats, cliff swallows, barn swallows, phoebes, red-shafted flickers, water ouzels, pigeons, starlings, and house sparrows. Nest sites of many species are limiting factors in population growth; this situation could be improved by incorporating nesting needs in design and management.

For some burrowing mammals, birds, and reptiles, highway embankments and road cuts are excellent digging and lookout sites. Animals that benefit from these burrowing and nesting sites are pocket gophers, woodchucks, bank swallows, and possibly lizards. Properly managed rights-of-way are beneficial to nesting ducks, pheasants, and other ground-nesting birds. These benefits are chiefly attributable to a change in maintenance practice from the regular mowing of the right-of-way to allowing unmowed rights-of-way in many areas. Many midwestern states—including Minnesota, Illinois, North Dakota, South Dakota, Nebraska, and Ohio—have adopted an arrested mowing program to improve game-bird habitat. The program also sharply reduces mowing costs for highway departments.

Freeways can have noticeable effects on the movements of individual animals and on entire populations. Rights-of-way corridors in suburban areas that are planted with shrubs, tall grass, or other cover may make possible the survival of certain medium-sized mammals, including skunks and raccoons.

Certain birds and mammals, for example cave swallows and pocket gophers, have extended their range via highway rights-of-way. Some animal species, such as kangaroo rats and the California ground squirrel, may have invaded new territories via highway bridges.

Aquatic and Amphibious Animals

State fish and game and highway departments can cooperate in the planning of new highways to reduce losses of aquatic life or even use highways to benefit wildlife. In Montana, substantial alterations were made to original highway plans. Road alignments were moved to avoid encroaching on rivers, and new artificial meanders were built to replace those destroyed during construction. In other instances, extra bridges were constructed to preserve existing meanders. Bushy, floodplain vegetation destroyed by construction was replaced and channel excavation was limited to times when fish were not spawning. The Highway Department can purchase land parcels cut off by new highways and turn them over to the Fish and Game Department for management.

Aquatic and amphibious animals may receive habitat benefits from stream shading by structures, borrow pits, and situations where highway embankments function as dams and dikes. During periods when fish are quiet and not feeding, they often retreat to deeper pools and shelter where light intensities are lower. These spots frequently are under bridges, especially if large rocks and stumps are lodged there. Predatory fish may use such places to conceal themselves, and many cold water fish seek shade in these pools during hot weather.

Abandoned borrow pits that fill with water are often capable of supporting fish, waterfowl, and other aquatic and marsh-dwelling animals. With the increasing destruction of natural wetlands by intensified agriculture and spreading urbanization, these man-made ponds could be important for breeding and migrating ducks and for amphibians.

The Nebraska Chain-of-Lakes is an outstanding example of cooperation between the State Game and Parks Commission, the Department of Roads, contractors, private land owners, and communities along the freeway. Provisions were made to purchase land immediately alongside the highway, dig borrow pits there, and give the Game Commission title to the land and pits, so that a 200-mi-long chain of artificial lakes could be created along the new freeway. The lakes have been stocked with fish and are used by fishermen; they have been stocked as well with many waterfowl and other aquatic birds. Artificial ponds support many other kinds of wildlife—including mink, muskrat, cottontail rabbit, bobwhite quail, raccoon, mourning dove, and many nongame species.

Highways can do double duty as dams and dikes for impoundments for aquatic and marsh animals. Reservoirs as large as 1,000 acres have been created in this way. An outstanding example is the Thousand Acre Marsh in Delaware, which is diked by a state road. Up to 50,000 ducks have fed and rested on this impoundment at one time. Dikes commonly serve as low standard roads in waterfowl refuges. However, high-speed highways can be used as dams if the planners of the highway incorporate the necessary design modifications.

Aesthetic Quality of the Environment

Benefits may accrue to highway users and nonusers by enhancing the individual's perception of the aesthetic quality of the environment, which has as its central focus the interactions of the highway with the landscape. The artistic elements of visual quality, although not a separate topic of discussion in this report, are essential to the presentation of highway beneficial effects. The urban freeway may generate visual and functional coherency in the lines and forms constituting the urban pattern. Additionally, the human sensory response to the highway environment is related to man's comfort, health, and safety, and is manifested in the feelings of pleasure or stress. Freeway improvements that ameliorate the effects of sound and glare are considered here to be a contribution to the aesthetic quality of the environment.

Traditionally, it has been difficult to place a value on the importance of aesthetics in highway design, and to use preservation or enhancement of aesthetic quality of the environment as a justifying determinant in highway location and design decisions. It is necessary, however, to consider aesthetic impacts in the same planning context as the more commonly recognized design determinants. For example, aesthetic design criteria may assume a prominent place in highway route selection and highway design process, even though problems may be encountered in incorporating aesthetic quality considerations in the highway design process because of the difficulty in uniformly quantifying aesthetic factors in the environment. Other problems dealing with the validity of beneficial effects are found in literature references to scenic highways, design characteristics of freeways, and landscape development. The reader is referred to Appendix A where further discussions of these topics and a complete bibliography are presented.

Highway Functions Benefits for Users (Actions Influencing Aesthetic Quality)

The process of planning and constructing a freeway can cause changes in the landscape that enhance the aesthetic quality of the environment or facilitate the highway users' perception of aesthetic quality. The freeway can provide visual access and a pleasing visual experience, reduce or replace displeasing land uses, enhance visual quality through design standards and controls, and reduce headlight glare.

Visual access benefits include the improvement of existing views, the development of new views, and the control of views in both the urban and rural landscapes. Freeway development has had a positive impact on view development due to location studies, the use of elevated structures, and the development of rest stops and overlooks. For example, a freeway may provide a series of evolving views of the outstanding physical features of a city. This is especially true of an elevated freeway that provides a new vantage point.

The freeway may provide a pleasing visual experience by revealing the natural and man-made character of a region. The appropriate design and location of the freeway have been credited with deepening the travelers' grasp of meaning of the environment, especially in rural areas, and developing a dramatic urban experience with views of the colors, forms, and shapes of the city, particularly relevant to the silhouetted structures and city lights at dusk. In both urban and rural areas, the aesthetic experience may be enhanced by providing access to historic and cultural features or by reducing stress so that the driver has a clearer sense of orientation.

Most of the literature dealing with the benefits derived from elimination of or reduction in the extent of displeasing land uses refers to strip commercial, industrial, and deteriorated or blighted areas of the urban environment. Some authors see the presence of a freeway as a stimulus to industrial or blighted areas to clean up their surroundings and improve their image. The replacement of commercial strip development by a more dynamic grouping of facilities is cited as an aid in promoting a pleasant driving experience. The construction of a freeway may eliminate blighted housing in the right of way; in some cases, new housing is developed jointly with the highway.

The geometrics of the freeway may provide visual benefits that include controlling views and vistas. Elements of the freeway cross section, such as the median, may benefit the driver by reducing the strain of facing opposing traffic and headlight glare at night. The reduction of visual clutter along a highway by controlling billboards, structures, guardrails, and signs can reduce stress on the motorist. The positive visual influence of the freeway may extend beyond the actual legal right-of-way to include the scenic corridor, which may insure the conservation and protection of environmental, historical, cultural, and otherwise valuable scenic elements of the landscape by preventing encroachment of undesirable uses. The expanded controlled right-of-way may create a benefit of improvement of the driver's view from the road.

The freeway may be designed to reduce headlight glare through the use of wide medians and independent roadways and the use of plant materials in the median.

Users Perception of Landscape Form (Dynamic Viewing)

The freeway influences the form of the natural and man-made landscape by additions to the elements of visual quality and by modifications of the shape, structure, and patterns of the landscape. Additions and modifications to the landscape include: the spatial relationships created by the freeway (especially relative to the urban pattern), the highway and highway structures, modified land forms, and landscape development.

The freeway can provide orientation to the urban area, make the scale of the city comprehensible to the highway users, and help to define existing or potential city districts. Expressways in New York City have articulated the urban mass into visually distinctive chunks.

Regarding the visual quality of the highway and highway structures, freeways may create a sculptural form of art in their own right. Some authors note that the undulating ribbons of pavement possessing both internal and external harmony are a basic tool of spatial expression. This is an important aspect of freeway design in realizing optimum visual quality. The internal harmony is derived from lines, forms, scale, and shape achieved through a control of the horizontal and vertical alignment, medians, and proportions of cross-sectional elements. The external harmony is derived from the way the paved ribbon fits in the total sculpture of the landscape and the visual relationship to the landscape.

Modified land forms that expose geologic structure may be a point of unique scenic interest, not only capturing visual attention but also expanding the highway users' awareness of environmental features.

Beneficial effects dealing with the importance of landscape development may be described in three categories: the use of plants as an element of highway beautification, the relationship of landscape development to the safety of freeways, and the visual and functional relationships created by the use of plant material. Landscape development provides for harmony with nature and acts to conserve the natural environment. The buffering provided by the use of plant material and other landscape techniques provides transitions between the freeway and its surroundings.

Highway Functions Benefits for Nonusers (Actions Influencing Aesthetic Quality)

The freeway can enhance the aesthetic quality of the environment also for nonusers. Long duration effects of freeways are particularly important for nonusers living near the freeway. It can provide open space, reduce or replace displeasing land uses, enhance visual quality through design standards and controls, reduce headlight glare, and reduce noise.

One of the most often cited nonuser benefits of the freeway is the creation of open space. This provides visual attractiveness, buffering capabilities, and opportunities for related auxiliary uses. The benefits of open space are most relevant in the urban and suburban environments. The green spaces may also facilitate the movement of air that helps to provide cooling breezes for otherwise hot and humid residential neighborhoods.

Regarding the reduction of displeasing land uses, the visual benefits associated with freeway construction also apply to the nonuser. Blighted or substandard housing, junkyards, dumps, and other sources of ugliness may be eliminated through condemnation, eminent domain, outright purchase, and other procedures. The effect is a reduction in visual discontinuity to the highway viewer and a possible improvement in the entire visual quality of the affected area and the community. The relationship of the freeway cross section to the surrounding environment and the legal controls that reduce visual clutter and conserve spaces adjacent to the freeway are important.

The reduction of glare for nonusers is most important for persons in residential areas adjacent to the freeway, who in some locations are continually disturbed by headlights during the night.

Reduction of noise in the environment of nonusers is

primarily an urban benefit. A freeway may reduce noise on city streets because of the transfer of traffic to the freeway or bypass; the expanded right-of-way of the freeway provides space for noise reduction and for the placement of sound-buffering materials.

Nonusers Perception of Landscape Form (Stationary Viewing)

Nonusers perceive landscape form from a stationary point, in contrast to the moving view of the highway user. The landscape viewed by the nonuser contains the shape, structure, and pattern of the spatial relationships created by the freeway (especially in urban areas); the highway and highway structures; modified land forms; and landscape development. Landscape development may partially insulate adjacent property owners from the freeway, thereby increasing their toleration or perhaps appreciation of the highway in their environment.

SOCIAL BENEFITS

Because of the changes that highway improvements bring to regions, communities, and neighborhoods, residents of affected areas experience direct and indirect social benefits and costs. Changes occur in the amounts and kinds of desirable social interaction in which they engage. Rural and urban residents may experience an expanded range of employment and recreational opportunities once it becomes easier and safer to travel longer distances. These and other social effects of highway improvements are examined in the following. A complete, annotated discussion of the social benefits of highway improvements and an extensive bibliography are given in Appendix B.

Individual Effects

Users

Accessibility and Freedom of Choice.—Those individuals using limited-access highways, both as drivers and passengers, stand to gain direct and immediate benefits because they can reduce the time, cost, and effort of highway travel. This benefit is another way of describing the independence and freedom of choice of the user. Through reduction of travel time, the amount of time users may devote to other activities is increased, and the net effect is greater freedom for the highway user to pursue alternative activities. A new freeway provides increased accessibility immediately after the road is opened; in the long run, it also generates increased demand and intensifies development of the areas it serves.

The accessibility benefits, discussed as follows, include freedom of choice in employment, shopping, recreation and travel, residence, educational and cultural activities, public services, and finally health and safety.

By providing access to more jobs, highways increase the variety and number of employment opportunities for workers. Also, highways open up job opportunities for the unemployed and help to equalize job opportunities among users. Greater access to jobs may eliminate the need for workers and their families to relocate in the event that a wage earner changes jobs. Families can avoid not only the economic costs of moving but also the social costs of breaking neighborhood ties and changing schools. Thus, highways make it less difficult for workers to take advantage of regional fluctuations in employment opportunities. Additionally, the chances that a worker will find a well-suited job increase with the additional accessibility provided by the highway. This may promote greater satisfaction with work. Also, the knowledge that one has access to an expanded job market may increase the security of workers and their families.

Limited-access highways provide the users with access to more retail and service outlets. As a result, the shopper has more choice in terms of variety, price, and quality. Highways also allow commodities from distant markets to become more available.

Better access to a particular resource for recreation is a direct effect of highway development. The long-range prospect is to provide opportunities for various outdoor recreational activities by creating access to such areas. There are many areas that hold vast potential for such activities, but they are of little value if one cannot get to them. Accessibility provided by limited-access highways is important especially to the city dweller. Freeways can provide access to existing systems of secondary roads beyond the urban landscape and thus provide greater living space to the urban dweller. Long-range consideration of secondary road systems, combined with freeway planning, can successfully channel heavy flows of recreational traffic from urban centers into secondary road systems outside the city. The findings of the Outdoor Recreation Resources Review Commission (ORRRC) indicate that "driving for pleasure is America's most popular single outdoor recreation activity—this accounts for 2 percent of his total outdoor activity" (*1*). Scenic roads are a means of providing meaningful recreation and educational experiences to travelers.

One of the most important effects of highways is that they increase the number of existing or potential residential areas within commuting distance of jobs, shopping, visiting friends, and other activities. Studies have shown that people move from central cities to suburbs for privacy, cleanliness, safety, and increased space in the house and yard.

Still another important effect of highways—along with such factors as dramatic changes in the school age population of the United States, an increased need for skilled workers, and a rise in auto ownership—is manifested in the expansion of educational opportunities. For example, highways permit college and university students to commute to classes when living at home, thus allowing students who might not otherwise be able to afford higher education the opportunity to pursue this goal. Highways have contributed in a similar way to training in vocational and technical schools. The increase in percentages of school age population enrolled in the public schools and improved attendance rates, since the turn of the century, may also be partially attributable to improved highways. Another way in which highways contribute to benefits is by making libraries, lectures, museums, historical sites, and other educational facilities and activities more accessible to more people. Additionally, cultural activities such as concerts, operas,

and plays are made available to some people who were formerly unable to reach them.

Although there are some public services about which one does not normally exercise choice (such as fire and police protection), there are others (such as bus terminals, airports, train stations, and hospitals) among which highway users may be selective. Highways contribute benefits among these public services by making more alternatives available. Mass transit, for example, is one public service that has definitely expanded recently in conjunction with highway improvements. This has been done in at least three ways: (1) "transportation corridors" or separate lanes for buses have been opened; (2) "wrong-way" bus lanes that use part of the highway servicing "light opposing traffic flow" have been opened in New Jersey, Long Island, Boston, Harrisburg, and San Francisco; and (3) the reservation of a lane for buses, trucks, high occupancy cars, and emergency vehicles has been put into effect for portions of highways. Many benefits can be gained by stimulating mass transit as a public service. Transportation corridors and other means of using highways for buses reduce a family's needs for more than one automobile, thereby giving individuals opportunities to pursue activities normally precluded.

Other direct benefits for the users of the highway are manifested in the reduction of accidents, injuries, and fatalities. The improved design of highways (especially median strips, multiple lanes, control over vehicle access, and more gradual curves) provides users with greater safety than that provided on older roads, thus improving not only the physical health of users but also their mental health because driving fatigue and stress are reduced. Also contributing to highway safety and ease and comfort of travel by auto are such factors as wide, smooth lanes; and fewer intersections, sharp curves, and stop-and-start operations. The care taken to maintain a pleasant view from the road makes travel more pleasant, and is thought to reduce stress and fatigue. The provision of roadside rests enhances beauty, provides recreation, and combats fatigue, thereby also enhancing safety.

Reduced Congestion and Travel Time Savings.—The measure of travel "costs" is not always in dollars. Particularly, for trips in urban areas, the "cost" of a trip is measured in terms of time rather than in dollars because, where no tolls or parking charges are used, the actual dollar cost of the trip is not determined or even recognized.

The savings in travel time via freeways are attributed to the reduction in congestion, the elimination of stop-and-go traffic, and the maintenance of higher continuous speeds. Scenic roads, because of the pleasant driving surroundings they afford, can help to alleviate traffic congestion on arteries that are used more frequently. The reduction of congestion on major arteries will thus help people reach destinations quickly without the traffic jams.

Reduced Congestion and Less Irritability and Stress.—Since traffic congestion is a source of stress and irritability, a reduction in these effects would be beneficial for drivers and passengers alike, improving safety by reducing driver fatigue and hostility and by cutting down on the temptation to speed to make up for time lost in traffic tie-ups. This beneficial effect applies not only to users of limited-access highways but also to users of other nearby roads that may be less congested because of the traffic diverted from them.

For the driver using local streets, the reduction of traffic decreases the uncertainty that he will reach his destination on time, and reduces the number of driving-related stimuli to which he must respond. Thus, travel is quicker and local accessibility is improved; stresses on the driver are reduced, and he is more likely to reach his destination in a better frame of mind.

Nonusers

Health and Safety.—People who do not drive on limited-access highways also benefit from the highway. A new limited-access highway may alter the living environment of local citizens in beneficial ways. For example, the absorption of local traffic by limited-access highways reduces the number of vehicles on neighborhood streets, resulting in fewer accidents on local streets and greater safety for pedestrians in general and school children in particular.

Freeways, while acting as an artery for transportation, also act as a buffer to hazards of fire, explosion, or other calamities that may occur on or beside the roadway. The greater width of freeways provides a measure of protection to adjacent and nearby neighborhoods not provided by older routes.

Additionally, a freeway reduces noise to nonusers. This is done primarily in two ways: (1) vehicles generate less noise on freeways, and (2) freeways remove much of the through traffic from local streets. Sound is attenuated by the atmosphere and by sound-absorbing materials. Because a freeway has a wider right-of-way as compared with a local street, the noise source is at a greater distance from the nearby residents. With freeways, there is also a greater opportunity to use sound-absorbing materials and devices such as plants, acoustical screens, and depressed roads that can channel sound away from adjacent development. Freeways with reduced grades and no intersections eliminate much of the need for trucks to shift gears, a source of considerable vehicle noise.

Reduced Air Pollutants.—Freeways reduce air pollutants by more efficient vehicle operation than is possible on older routes and by shifting through-traffic to less congested areas. Smoothing traffic flow on both freeways and less congested streets can also reduce air pollutants. With a steady average speed of 30 mph and a flow rate of 400 vph, the freeway would produce only 77 percent of the CO produced at the same flow rate on local streets under city traffic conditions. When the flow rate increases to 1,000 vph, the freeway would produce only 38 percent of the CO produced on local streets (*2*). Freeways also permit more efficient and competitive mass transportation that could, in turn, lower air pollution.

Reduced Congestion on Local Streets.—By providing an alternative route that is faster and more convenient, limited-access roads attract motorists away from their old travel patterns, reducing traffic on local streets and highways. This is considered an indirect benefit of the road, because the limited-access highway was designed primarily with the user in mind. The reduction in traffic on local streets facilitates parking, thus improving local functions such as shopping. By removing traffic from local streets,

limited-access highways benefit people who use local streets, even if they do not drive. For the nonuser who lives, works, walks, studies, or relaxes near streets with reduced traffic, a lower level of noise (from motors, horns, and tires) and a similar reduction of dust and fumes are undoubtedly welcome.

Population Effects

Population effects deal with population distribution and change as affected by freeways. The following discussion concentrates on the effect of limited-access highways on the distribution of individuals in the community by age, race, and socioeconomic status.

Socioeconomic Status

Highways influence the socioeconomic status of people in a community in numerous ways. It is known that highways aid economic development, enabling residents of a community to obtain jobs that can enhance their socioeconomic status. Thus, highways contribute to upward social mobility, which has been particularly noticeable in communities located near interchanges.

The same process that contributes to social mobility among people living in a highway community also contributes to the in-migration of families. These in-migrants tend to be better educated, raising the level of socioeconomic status for the community.

The expansion of educational opportunities provided by highways also helps contribute to upward social mobility. Universities, vocational schools, and primary and secondary schools are an important avenue to increased socioeconomic status. As highways make these institutions more accessible, they increase peoples' opportunities for educational attainment and increased socioeconomic status.

The benefits of upward social mobility accrue also to members of the community not directly involved in the pursuit of better jobs or higher educational attainment. Those who do attain higher socioeconomic status provide a tax base that supports public services in the community, from which nearly everyone benefits.

Racial Distribution

By increasing the amount of residential land accessible to employment opportunities, highways have encouraged rapid population decentralization. Limited-access highways in conjunction with the Federal Housing Acts and rising birth rates after World War II interacted to produce unprecedented suburban development. More roads were built to serve the suburban population. Beltway roads that were part of the 1956 Federal Highway Act accelerated the process. Suburban growth, in turn, opened up vacancies in middle as well as lower income housing in places left behind by people moving to the suburbs. The Fair Housing Act of 1968 helped ensure that suburban as well as urban housing could be purchased by any racial group. This chain of events suggests that limited-access highways might now play a role in expanding housing opportunities for minority groups, although many barriers in society still discourage the full achievement of this beneficial effect.

Age Distribution

The age structure of populations living near highways, especially close to interchanges, is likely to undergo an increase in the portion of residents in the 18 to 30 age category, because in-migration to such areas is usually relatively heavy and young adults are more likely to migrate than other age groups. This factor can be a benefit to a community because the young population will increase the demand for consumer goods and add to the productive potential of the labor force.

Community Effects

Community effects include the influence of freeways on: the amount and quality of services, settlement patterns, social interaction and communication, and the effectiveness of the relationship between transportation planning and comprehensive planning.

Amount and Quality of Services

Highways are instrumental in making services financed by governmental organizations as well as private companies available to people. Because of increased accessibility, highways encourage more centralized control of services, and at the same time permit operations of many services to diffuse throughout the community and specialize their functions. For example, schools, parks, and protection services can be located according to the needs of various sections of urban or rural areas, but still be effectivley administered from central locations. The construction and maintenance of utilities, such as water and sewage treatment, is also enhanced by an efficient highway system.

Health Services.—The mobility provided by highways has undoubtedly been an indirect factor in the consolidation of small hospitals into large regional hospitals that are better equipped and have a wider range of specially trained personnel. Highway developments can also promote the use of mobile health testing facilities (such as tuberculosis x-ray units) and emergency vehicles (such as ambulances and fire engines).

Freeways are particularly valuable during large-scale community or regional emergencies. They permit large numbers of physicians and other medical personnel, as well as needed supplies and equipment, to converge on areas experiencing floods, fires, or epidemics. The high standards of construction of limited-access highways help ensure survival in times of flood or other natural disasters when other forms of transportation or communication fail.

Highways have enabled physicians to serve more patients by changing the older practice of doctors making house calls. Now, because the vast majority of patients come to the physician's office, a single doctor is able to take care of a much larger number of patients because less time is spent in transit.

Education.—Probably the most evident indirect benefit of highways for education is that they enable educational institutions at all levels to consolidate; this, in turn, permits the acquisition of superior educational facilities and equipment as well as more specialized teachers. This benefit is particularly felt in rural areas, as seen in the decline of the one-room school house.

It seems plausible that highways have contributed to the development of small state colleges, "branch campuses," and vocational training centers—institutions that have made higher education available to a larger segment of the population.

Highways also permit the consolidation of libraries and museums. As a result, administrative duplication of services and overhead costs can be reduced. The consolidation of services thereby permits the use of more public revenues for the provision of the service itself. Highways have also encouraged the development of mobile libraries to reach remote areas.

Fire and Police Protection.—The most obvious way in which highways directly benefit the amount and quality of fire and police protection is by providing greater mobility for the vehicles involved. This effect can take hold as soon as a highway opens, and it will continue as long as the road is operating. This increased mobility becomes particularly important when there are long distances involved, such as when outlying fire departments are called in to help with a major fire. Improved highways facilitate cooperation between state and local police. Finally, a well-developed highway system permits flexibility in the location of fire and police facilities and may allow more centralized headquarters. Interstate highways can serve—and have served—as emergency air strips for light planes to land and take off.

Recreation.—For those who cannot get to recreation areas, programs have been developed to reach the ill, poor, and handicapped. Mobilized leisure service delivery systems would not be feasible without highways. Bookmobiles, play wagons, and swimming pools are examples. A mobilized recreational system can give opportunities to those who cannot reach them otherwise.

Mobilized leisure service delivery systems might also be a factor in the conservation of energy. If a gasoline shortage or energy crisis reached proportions that would not allow the public much latitude for travel, it would be desirable for recreation departments to bring some programs to the people. Through the use of mass transit, either to take people to the recreation resource or to bring recreational opportunities to them, individual travel would be discouraged.

Recreational services must be as aware of market forces and locational advantages as are other forms of enterprises. They must consider the advantages of locations that are as accessible as possible to potential customers. There are several kinds of commercial recreational activities that are strongly oriented to highway users. For example, highway developments not only have improved the accessibility of campgrounds but also, through stimulating automobile travel, have greatly expanded their markets.

Some types of commercial resorts must balance natural resource advantages with highway locations. For example, many of the newer resort hotels and motels in areas like the Pocono Mountains in Pennsylvania and the Catskill Mountains in New York seek locations with a moderate degree of accessibility to major highways. Other kinds of commercial recreational establishments, such as night clubs, bowling alleys, and drive-in theaters, may seek major highway locations for both visibility and accessibility. Major highway interchanges in suburban locations attract many such types of recreational businesses.

Other Services.—A frequently cited benefit of highways is that they improve the efficiency of postal services. In particular, post office facilities are consolidated, longer rural delivery routes are instituted, and rural carriers can reach areas not formerly served because of low population densities.

Good highways facilitate church attendance. They may also enable a single clergyman to reach more people by having dual or multiple worship services. A well-developed highway system makes the clergyman's task of making calls on his parishoners easier. Finally, by making the church available to more members, consolidation of churches takes place.

Drive-in businesses, such as restaurants, hotels, motels, banks (especially those with drive-in banking windows), and many other privately owned drive-in businesses, benefit from highway development. Community services are enhanced when the profits of these businesses are reinvested.

Private transportation services, such as taxis, buses, and delivery services, benefit directly from improved highways. All private community services depend on highway transportation either directly or indirectly. For example, newspaper deliveries, especially to outlying areas, may be speeded by new highways. In this way, highways enhance the distribution of information in the community. Highways also facilitate the construction, maintenance, and repair of utilities (electric, gas, telephone, water).

Settlement Patterns

Spatial Array of Land Use Activities.—The majority of American urban residents (68.6 percent in 1970) now live in metropolitan areas compared to only a very small minority in 1790 when the first census was taken. The major place of residence today for metropolitan dwellers is the "suburban ring" around the central city. The development of automotive technology and modern highways have helped to bring about these changes.

A modern transportation system is essential for regional specialization in production. Because highways have helped promote the use of motor vehicles, they have also promoted urbanization by providing a significant portion of urban jobs, both in the manufacture of automobiles and accessories and in related businesses, such as insurance and service stations. Trucks and other highway-using vehicles have been instrumental in revolutionizing farming technique, thereby contributing to an oversupply of farm labor and releasing workers for jobs in the city.

Highways stimulate housing development in a number of ways. First, highways make land that previously was too far out from the urban center more suitable for residential development by bringing it within commuting distance of shopping, work, and other activities. Second, by stimulating the economic well-being of an area, highways increase the capability of the residents to afford better housing. Frequently, this entails a move from the central city to a suburb. Third, the highway, both by opening up new areas for residential development and by stimulating the economy and creating employment opportunities, encourages

in-migration. Since in-migrants tend to be of relatively high socioeconomic status, they tend to occupy primarily low-density housing in suburbs or suburban apartments. And fourth, highways facilitate mechanization and consolidation of farms, thereby fostering migration to cities because of the decrease in the need for farm labor. However, recent studies show a growing trend to migration from urban centers to rural and small-town areas, also fostered by highways.

Freeways affect the location of industrial sites because of the importance of highway transportation in receiving raw materials and shipping finished products and by providing a wider area from which labor may be recruited. This is reflected in the increase in value of industrial property, which occurs after a freeway is built.

Because of this enlarged freedom of choice, many industries have elected to move away from central city areas, rebuilding in suburban or even rural areas. In this way, highways have contributed to the decentralization of industry, which had a part in the establishment of industrial parks. Decentralization, particularly the development of industrial parks, has served to provide a more pleasant working environment for industrial employees. In addition, more adequate parking space is available than in downtown areas.

Limited-access roads provide preferred locations for many types of businesses, especially drive-in businesses such as banks, restaurants, and department stores. The highway provides a wide market for these businesses. Besides, proximity to the highway often means visibility to passing motorists, an important form of advertising.

Probably the most prominent feature of the impact of highways in the location of retail outlets is the decentralization of commercial establishments and, in particular, the development of suburban shopping centers. Since the most affluent population lives primarily in the suburban ring, shopping centers tend to congregate near these markets.

A highway passing through a particular area is also apt to trigger development of recreational activities if the natural resources base has suitable prerequisites. Greater accessibility to land-resource based recreation can be viewed as a long-range benefit.

As the highway network develops, public facilities (such as fire and police protection; court houses; terminals for air, bus, and train transportation; and many others) can have a wider range of locations to perform their functions. For example, many parks appear to be underutilized in part because of poor accessibility.

The increasing accessibility provided by highway development is seen in the consolidation of public services, such as the public schools. This has permitted the employment of specialists in such fields as music, art, and vocational training, as well as the acquisition of more, better, and specialized equipment.

The displacement of people in urban and rural areas by freeway construction has received much attention in the literature, primarily in the form of case studies. Usually, these studies conclude that most displaced residents find improved housing when they relocate. Some studies have indicated that housing satisfaction is increased for the majority of relocated families after they have had time to adapt to their new neighborhoods.

Interaction and Communication

Community Values.—Many writers have emphasized the need to design highways in such a way as to optimize community goals and objectives. The literature suggests that this can be done through community participation in highway planning and by integrating highway planning with comprehensive planning. If there is a public demand for highway construction, a new highway enhances community values in a very direct way. It has been suggested that a good highway network bolsters civic pride, both with respect to the highway itself and by promoting identification and recognition of historic sites within a community. Highways can also promote civil pride and community values by removing slums and blighted areas, and by providing scenic landscaping along the right-of-way.

Participation.—By drawing members of the public into the planning process, new highways can help to encourage the habit and ability of people to participate in governmental affairs on all levels. The participation process considers future community, regional, and state goals. This enhances the development of both natural and human resources.

Social Contacts.—Highways affect the amount and the kinds of social interaction which takes place in a community in numerous ways. Highways have increased the frequency of contact among individuals by creating better accessibility. Urban areas are characterized by diverse life styles. Thus, as highways have promoted urbanization, they have brought these diverse life styles into closer proximity, providing the potential for interaction. Such interaction should reduce provincialism and increase the rate of cultural change through the diffusion of customs and life styles.

Because of the additional accessibility provided by a well-developed highway system, an individual can have a wider range of social contacts. By making urban areas more accessible to rural communities, highways have contributed to a greater cultural exchange between urban and rural areas. Highways, if they are constructed along a boundary of the neighborhood, can also promote neighborhood stability.

Comprehensive Land Use and Transportation Planning Effectiveness

As freeways have become more significant in the life of the nation, the effects associated with freeways extend into areas that had not been adequately considered earlier. These effects extend beyond the immediate horizons of the freeway user to the physical development of cities—to their economic, social, and environmental substance and structure.

The physical configuration of cities is affected by highways and transportation facilities in subtle as well as bold ways. Comprehensive urban planning serves as a link between highways and the full scope of their effects. Integrating highway planning and development with comprehensive planning and development makes it possible for cities to become both functional and livable entities.

Joint Development.—The joint or multiuse concept proposes that a freeway right-of-way be used for purposes other than the movement of traffic. Freeways cannot exist

as entities unto themselves; they interact with commerce, industry, housing, public facilities, parks, schools, as well as other uses.

Examples of joint use extend to many different areas, but in most instances it has been used in urban areas. Comprehensive planning is one of the better means of bringing the idea of joint use into the freeway development process.

The use of air space rights over freeways has given planners and designers an important new idea in revitalizing urban America. Specific examples of this can be found in almost every major city. The use of air space rights has allowed urban traffic to grow—at the same time preserving commerce, industry, as well as the urban tax base.

Residential housing is being developed by using air space rights over freeways, successfully when the necessary support facilities such as shops, schools, and playgrounds are developed along with the housing.

Freeway corridors are used for the transmission of municipal services. These services can include power and fuel lines, sewer, water and waste disposal. This makes more efficient use of the right-of-way.

More intensive development of picnic areas, camp sites, and other complementary facilities in scenic corridors makes available previously unused resources. The potential for recreational development afforded by using the highway corridor as an integral part of the recreation resource offers a base for recreation that, as yet, has remained greatly underused.

The identifiction of sites of historic significance in advance of actual highway construction, as part of the planning process, can help a community to maintain its cultural links to the past and preserve irreplaceable assets.

Provision of ample open space, especially for recreation, is an important problem facing the urban sector. Competition for urban open space is very keen. Freeways cutting across, through, under, and around the cities afford an excellent opportunity for innovations in recreational planning and design.

Coordination between Interstate highways and major park development, involving both the multiple use of highway rights-of-way for park purposes and the provision of direct ramp access to recreational facilities is highly desirable.

Large amounts of space are available at interchange sites, rampways, and beneath elevated highway extensions. These spaces can be used for storage and parking; with some creative design elements they could be recreational space.

Land Use.—The idea that a freeway and the land which it abuts have important effects on one another is not new. This idea, however, has grown in importance over time. The growing complexity of land use issues has led to the realization that both freeways and the communities that they serve can benefit by specific consideration of the use of land.

In areas adjacent to Massachusetts Route 128, a limited-access 4- and 6-lane highway, zoning changes have encouraged industrial location. Advantages resulted from both increased accessibility due to the highway and better land use control. Fostering industry has created new jobs and strengthened the local tax base, all of which have been accomplished while partially maintaining the residential character of the area.

Although land use boundaries in urban areas are often blurred, freeways can be planned so that they separate conflicting land uses.

Design Characteristics.—In many instances, there is a delicate relationship between a freeway and the community that it serves. A freeway that lacks certain creative inputs can be harmful to the community; careful design in the planning and development of a freeway can be beneficial, including aesthetic, structural, and conceptual elements.

Design can be both physical and/or abstract. It can include physical changes in the freeway's structure or the relationship between the freeway and urban development.

Freeways play an important role in urban redevelopment by establishing a reciprocal relationship between the city and the freeway. Redevelopment often provides freeway rights-of-way. Freeways, through the joint-use concept, can provide space for housing, commercial, and industrial uses as well as social facilities such as parks and playgrounds. Old housing of low quality occupied by poor people often serves as the reason for the destruction of that housing for freeway right-of-way. Designing the freeway to replace the housing of the displaced is certainly possible.

Transportation/Comprehensive Planning Interface.—The relationship between transportation planning and comprehensive planning is very important in a study of freeway benefits. Transportation planning seeks to establish objective engineering and design criteria on which to build transportation systems. It also attempts to recognize factors that are judgmental in substance as well as analytically quantifiable. Primary among these factors are potential economic changes, land use, social patterns, and community values. These considerations are common to the concept of comprehensive planning. Comprehensive planning represents taking into account community needs, desires, and values in the total freeway equation. As the complexity of the issues surrounding freeway development grows, the relationship between transportation and comprehensive planning becomes more important. A functional, service-oriented freeway cannot be developed in a vacuum.

The relationship between comprehensive and transportation planning means an alternative to haphazard development. Experience in California has shown that freeway construction through or near a community forces the community to make basic adjustments. Changes in social patterns, the need for new homes, and the development of utilities and municipal services to conform to the freeway are examples of adjustments. Comprehensive planning in conjunction with the planning of the freeway can work to preserve the social structure, stimulate urban renewal, attract industry, and develop recreational facilities. Previously, only economic benefits had been considered when planning a freeway. Now, benefits are considered for the entire scope of the community. To the greatest degree possible, an overview of environmental, social, and economic benefits should be considered.

A transportation planner does much to shape the social and physical configuration of a community. The inclusion of comprehensive planners in the freeway planning process can do a great deal to encourage the formulation of urban goals. Development of the multidisciplinary approach helps to establish local and regional goals as well as to include citizens and local officials in the planning process.

The relationship between transportation and comprehensive planners is also important in encouraging urban redevelopment. Urban comprehensive planning can act to clear slums and revitalize business areas. Redevelopment must not take place at the expense of displaced persons, but must replace any housing that is lost.

Regional and National Effects

The Interstate Highway System is designed to interconnect every city of 50,000 or more population. These highways serve as communication links among major population centers. This is particularly evident in the functions of these highways in the distribution of mail, magazines, and newspapers.

It has been speculated that limited-access highways help to enhance national unity. Highways are a manifestation and, perhaps, they are also a source of national pride. In addition, they contribute to functional interdependence among cities, between cities and rural areas, and among regions. Automobile production has come to be centered in Detroit and southeastern Michigan, which supply most of the automobiles for national markets. The steel used in these automobiles is mostly produced in centers such as Pittsburgh and Buffalo. The communications function of highways serves to unite the nation. Finally, access to national monuments, historical sites, and parks, which tourists visit in great numbers each year, may serve to reinforce national pride.

Part of the rationale for the construction of the Interstate system of highways was their utility for national defense. The overhead clearances and other design features of the Interstate System were to accommodate rocket carriers and other motor-vehicle-based weapons systems. Highways undoubtedly serve a role in national defense by facilitating the preparations for defense against nuclear attack. These include such activities as the construction and maintenance of defensive missile sites.

ECONOMIC BENEFITS

Highway improvements, either in the form of a new highway or the upgrading of an existing one, unquestionably generate changes in the functioning of an economy. To some extent the welfare and/or income position of some individuals and/or firms will be altered. Economic effects can be beneficial (positive), where travel time and costs are reduced or land values rise; or they can be adverse (negative), where land values decrease or congestion on feeder roads increases. Rarely is an economic impact clearly all beneficial or all harmful within a community. The more usual case is that some people or firms gain, but others have added costs. For this reason it is important to identify, where possible, a given economic impact; that is, who or what groups in society realize the gains and who or what groups bear the costs.

Much of the literature on the subject makes a distinction between highway user and nonuser benefits. Highway user benefits are largely in the form of travel time savings, reductions in operating costs, and reduced losses from accidents, injuries, and death. User benefits accrue to firms as well as to individuals. Highway nonuser benefits accrue to individuals and firms as a result of the highway, but not from direct use of the highway, and generally come about because of a transfer of user benefits to others in the community. Many individuals in a community receive at the same time both user (direct) and nonuser (indirect) benefits.

Very important problems arise when attempts are made to aggregate economic benefits. The distinction between highway users and nonusers has frequently resulted in overstating the net benefits because many of the direct user benefits are transferred to nonusers; thus, it is not correct to aggregate user and nonuser benefits because double counting will result. A more complete discussion of this concept is given in Appendix C.

Economic Growth and Development

Accessibility

Improved accessibility is the single most important economic benefit arising from highway development. It is primarily a direct highway user benefit. Improved accessibility means that the costs involved in traveling from one location to another are reduced. These reductions in costs come about through a reduction in travel time (which in itself has monetary value to people) and/or vehicle operating costs. Both individuals and firms realize the benefits of improved accessibility. For the commuter, it means more time to spend either on the job or in nonwork activities, as well as possible savings in operating costs. For the firm, it means lower transportation costs, quicker delivery of products to customers, and quicker delivery of needed raw materials; or, for the highway-oriented retail establishment, a larger flow of customers.

Savings in time and operating costs free resources that can be used to increase productivity. There can be no doubt that a modern and highly efficient highway transportation system has stimulated a great deal of economic development through the release of large amounts of resources.

Highways, by altering the relative accessibility of different locations, play a significant role in the location decisions of firms and individuals. Transportation-intensive firms and businesses catering heavily to highway users seek land near major highways with ready access. Many housing developments are located to take advantage of the accessibility to jobs, shopping, and other household travel needs. For the community through which a new highway improvement passes, the impetus for economic growth and development is apt to be great. Any such community growth, however, must be considered within the context of the larger regional economy or even the national economy. If community growth reflects primarily a relocation of economic activity from some other region, then the net economic benefits are much less than the immediate benefits to the community itself.

Shifts in economic activity because of changes in accessibility can encompass rather large regions. The construction of Interstate 80 through central Pennsylvania resulted in the shift of a considerable amount of traffic from the Pennsylvania Turnpike in the southern part of the State.

Improved accessibility may be reflected in the behavior of the highway user. First, the trip itself may not involve any change other than driving over the improved route, or there may be a shift from an old route to a new route. Second, there may be a shift in travel modes, for example from rail to auto. Third, there may be a shift in travel patterns, such as from old to new shopping areas. Fourth, additional trips may be undertaken because of the improved ease of access, often referred to as induced demand.

Locational Advantages.—Highway transportation has become the dominant form of intraregional transport, and for some kinds of goods (high value relative to weight or bulk) it is the dominant form of interregional transport as well. Sites with a high degree of accessibility to a modern highway network are most desirable locations for industry, commerce, and residences.

The fact that highways have influenced the location decisions of many firms is readily apparent in the developments around interchange sites, on feeder (access) roads, or even along the highways themselves away from the immediate vicinity of interchanges. Major highway locations, besides providing better accessibility for customers, employees, and suppliers, also benefit firms by giving them better exposure or advertising prominence.

Reduction of Travel Time and Operating Costs.—Reduction of vehicle operating costs is a direct benefit to highway users. Such savings are achieved through better highway design enabling the motorist to maintain more even driving speeds and, in some cases, to reach his destination by a shorter route than formerly. Elimination of intersections and direct highway access from adjacent property and reduction in highway grade and radius of turns reduce speed changes and stops. In urban areas where congestion is more of a problem, multilane highways are able to handle a larger volume of traffic.

Besides reducing vehicle operating costs, modern highways have also reduced the time it takes to drive between locations by increasing legal speed limits, by reducing impediments to the smooth flow of traffic, and, in some cases, by shortening the trip distance. There is an important psychological aspect to travel time savings that may be more important to the motorists' satisfaction than the actual dollar value: motorists usually select the quickest route between two locations and are dissatisfied with slowdowns, stops, and delays.

Studies have shown that a value of $2.50 to $3.00 per hour per person driving automobiles appears reasonable as travel time savings (*3, 4*). From the tables in Ref. (*5*), which show the value of travel time of intercity cargo vehicles by type of vehicle and by regions of the country for 1965, savings per hour ranged from about $4 for small commercial vehicles to about $8 for large trucks.

The Federal Highway Administration reports (*6*, p. 3) that an average 10-percent reduction in travel time between cities has been made possible by the Interstate Highway Program. "If the travel on the Interstate system were to be held throughout the program to the lower speeds prevailing on the routes which the completed sections replaced, the added travel time would cost $212 billion at $1.50 per man hour for passenger car occupants and $5.56 per vehicle hour for commercial vehicles."

A number of secondary benefits arise directly from travel time savings and a reduction of vehicle operating costs. For some businesses, more frequent truck deliveries can mean smaller inventories. For retail food stores, it can mean fresher produce.

Although highway developments often have been cited as causing the shift of retailing activity from central city to suburban locations, this has not been the case for all kinds of retailing. Freeways have increased the accessibility of downtown areas and improved the efficiency of the central business district, favoring the kinds of specialized retail activities that still find such locations advantageous.

Employment, Income, and Production

To the community through which a new or improved highway passes, the impetus to economic growth can be momentous. For many rural communities near interchanges along major Interstate highways, the rapid growth of gas stations, truck service stops, motels, restaurants, and other commercial activities serving motorists has been phenomenal. In addition, many kinds of industries have sought such locations if a local labor market exists. In communities within reasonable commuting time of major urban areas, housing developments must be added to the list of new or expanded land uses near interchange sites.

Nationally, the motor vehicle and the highways which serve it account for about 1 out of every 5 jobs, or about 14 million workers in 1968 (*7*). In that year, Americans spent about $90 billion to buy, operate, and maintain their vehicles; of this amount, $24 billion alone was in service station business. In 1968 the average American consumer spent about $0.11 out of every dollar for items automotive. In 28 of 50 states, recreation or vacation travel is one of the three most important sources of income.

These figures should not be interpreted as *net* contributions to national income. Expenditures would have to be made for alternative means of moving goods and people if highways were not available. Moreover, an interchange community's gains in employment and income, although important and real to that community, must be netted out when considering the broader region, for they may represent only relocational effects.

An important benefit may arise, however, from relocation or shifting of economic activity. The disparity of per capita incomes between regions can be reduced, which has been the principal goal of the Appalachian Regional Development Act.

Caution must be exercised when attributing regional and community gains in employment and income to highway development. Highways can serve as an accelerator of change that would occur later in the absence of the highway. One should always attempt to compare the highway development effects to the conditions that would likely exist in the absence of the highway improvement.

In rural communities an indirect effect of highway development may be to provide more off-farm employment, thus hastening a consolidation of farm units. Other indirect effects include suburban movement, school and church consolidation, improved public services, better opportunities for nonwork activities, and upgrading of residential properties through urban slum removal.

Increases in productivity can come about as a result of improved location and greater efficiency through expansion, consolidation, reorganization, or even less employee tardiness. Decentralization of industry through locating in industrial parks in suburban areas can mean not only a better working environment for employees but also lower taxes. A large number of studies have examined the growth of business activity in the immediate vicinity of highway improvements. Appendix C contains a discussion of the findings of the more significant studies.

Expenditures by nonlocal highway users, through the multiplier effect, generate additional income (often termed indirect income) in a region through which a highway passes, through economic linkages between the regional sectors. Sectors purchase goods and services from each other, and generate income to many businesses and persons in the region, who may seldom use the highway themselves. This is the principal way direct user benefits get transferred to nonhighway users.

Perhaps a more important source of indirect income is from the industries that locate in a highway community because of locational advantages or accessibility as a result of highway improvements. Although the income of an industry may not come directly from highway users as in the case of motels, restaurants, and gas stations, the concept of the multiplier effect and indirect income is still applicable. For many highway communities these new industries contribute significantly to the economic base; although, in terms of net benefits for the broader region, they may only represent locational shifts.

One might conceive of income and employment benefits arising indirectly from highway improvements other than through the multiplier concept. Some kinds of business firms are directly related to highways but derive their revenue from nonhighway users. Chief among these is the billboard and outdoor advertising industry.

Agglomeration Economies and Economies of Scale

An efficient transportation system is a prerequisite for the smooth functioning of a modern technological society. Specialization in production is the logical consequences of technological innovation, but consequent increases in the productivity of land, labor, and capital can only be realized with a help of an adequate transportation system. The transportation system expands to meet the demands for it. In time, the transportation system that becomes established will greatly influence the spatial form or settlement pattern of society.

Economists generally agree that, if it were not for the modern highway network, we could not have achieved the degree of urbanization that we now have. Such urbanization contributes to, and is also influenced by, certain kinds of internal and external economies of production. One of the indirect benefits of highway improvements is to enhance the likelihood of agglomeration economies and economies of scale for many firms in urban areas.

Interchange Development

Interchange areas, because they represent the focal point of accessibility to major highways, are highly desirable for commercial, industrial, residential, and other types of urban land uses. Not all interchange sites experience growth, particularly those in rural areas. Because of the complexity involved in locational choice and decision-making and the great number and variety of factors at any interchange site, it is difficult to predict the amount and type of development that may concentrate around a particular site.

The development occurring near interchanges has been one of the most studied phenomena related to highway improvements. Studies not only have documented the kind and number of activities locating at interchanges, but they also have attempted to explain the factors causing such growth. A number of these studies are reviewed in Appendix C.

Joint Development

The concept of joint development involves the use of a highway corridor for purposes other than a roadway. It is relevant primarily to urban areas and serves to improve the corridor with multiple and complementary uses as part of the total urban environment. It involves not only the development of a wider corridor but also the utilization of the air space above the roadway itself. Joint development offers an opportunity for economic benefits through an increase in land values, the elimination of substandard housing, and the provision of more open space for recreation.

Land Values

One of the principal ways in which user benefits (reduced travel time and vehicle operating costs, improved safety, and greater ease and comfort) get transferred to nonusers is through the real estate market. Land values in close proximity to most (but not all) limited-access-highway interchange sites appreciate significantly. Buyers of land at these locations, in effect, are purchasing accessibility benefits. The future savings in travel time and operating costs have been effectively discounted to their present value and transferred to the sellers of land. This is as true for the industrial firm faced with shipping cost savings for factor inputs or products as it is for the householder faced with commuting costs. For the commercial establishment catering to highway users, expected higher future earnings because of locational advantages have been discounted into present land values.

The net gains to society as a whole as a result of land value appreciation around highways are difficult if not impossible to ascertain. In the short run, from the viewpoint of the total economic system, the increase in land values merely represents a transfer of wealth between members of society. In the long run, the benefits to society

from increased land values are contingent on the way in which resources are employed. All the evidence, however, points to very substantial increases in net benefits to society.

While the influence of regional access on property values is felt most keenly near a major highway, it is important to point out that these influences extend also to land quite remote from the highway—although, in such cases, the effect on value will be much less. Thus, a major highway, such as a beltway around an urban area, will affect the accessibility of all land in the area.

Many highway-related studies have examined land values near major highways before and after construction and inferred that the increase in values results from highway improvements. Such conclusions are not well founded because no attempt was made to account for the influence of nonhighway variables on land prices. Nonhighway-induced growth in the area might account for significant land value increases. Most of the studies reviewed present specific data on land and/or property value increases. A few studies examined the adverse effects of highways on property values.

An indirect effect of property value increases resulting from highway improvements is quite often a change in public revenues and expenditures at the local level. Tax revenues increase as a result of (1) higher valuations of the land component of real property and (2) more capital improvements on the land, assuming assessment ratios and millage rates remain about constant. However, in many growing municipalities, assessment ratios and tax rates do not remain constant but increase to meet the rising demand for more municipal services. Such a situation then raises important questions concerning the distributional effects of public revenues and costs.

In rapidly growing areas many municipalities are hard pressed to keep up with the demand for more and better public services: water, sewage disposal, education, police and fire protection, health care, and the like. Although total assessed values rise dramatically, tax rates also rise in order to provide sufficient revenues. For some landowners, particularly farmers, such tax burdens become tremendous and can result in premature shifting of land out of agriculture. For some prehighway residents of the jurisdiction who may have benefited only slightly from land value appreciation because of their location away from the highway, it is very likely that their tax increases will exceed their gains from expanded municipal services. Tax revenues may not be sufficient to cover municipal costs, particularly if the community is largely residential and has no substantial amount of industrial land on the tax rolls. In assessing the merits of an increasing tax base resulting from highway development, a careful analysis must be made of the relative shifting of tax burdens and benefits. It is important to identify those individuals in the community who might, on balance, gain from tax changes and those who might be harmed, and to estimate the magnitude of these effects. One of the reasons many people actively oppose growth in their communities is because of the large tax burden that generally accompanies such growth, together with what they perceive to be a noncomparable increase in quantity or quality of community services.

Most studies report the gross effect on tax revenues and do not balance this against the added costs of municipal services. Communities that attempt to direct growth in an orderly fashion through zoning and other land use controls appear to benefit the most from increases in land value.

Improved Health and Safety

Accidents, Injuries, Fatalities

One of the clearest benefits resulting from freeway improvements is the increased safety they offer for highway users. Studies have repeatedly shown that the traffic accident rate is lower on modern expressways as compared to uncontrolled access highways. The separation of opposing traffic lanes, the ability to handle large volumes of traffic at higher speeds, the elimination of intersections and stops, and the control of access have all contributed to this achievement.

The Automotive Safety Foundation reported in 1964 (*8*) that urban accident rates on fully access-controlled highways were about 150 per 100 million veh mi, but on highways with no controlled access they were about 500 per 100 million veh mi, and produced twice as many fatalities compared to highways with full access control.

The Federal Highway Administration (*6*) estimated a total of $15.8 billion for the saving in accident costs between 1956 and 1974, the year the Interstate System was expected to be completed. This estimate is based on the costs of property damage, injuries, and fatalities that would result if travel accidents on the Interstate System were at the same rates as on the formerly traveled routes. It can be said that the Interstate System is almost twice as safe as the older roads.

Accidents are costly to motorists not only in terms of out-of-pocket costs for vehicle and property repairs and medical expenses, but also in terms of earnings lost as a result of long convalescent periods or permanent disability. Indirectly, such lost time can be costly to employers, and, under certain circumstances, such costs may be passed along to consumers through higher prices. Higher accident rates also mean higher insurance premiums for vehicle owners.

To such monetary costs must be added other costs of accidents, such as the inconvenience of being without a vehicle and overseeing the repair of damages not to mention physical and mental suffering.

Health Care Delivery

The benefits associated with health care from highway improvements are both direct and indirect. Transportation improvements have enabled the development of more sophisticated mobile health units, such as mobile x-ray vans, to reach more people. Public health inspectors and nurses have better access to people in remote areas, and can make more visits in a day.

Highways appear to be of greater benefit to physicians than to patients. The patient bears the cost of travel, not the doctor, and improved highways mean more patients for the physician. Patients do benefit, however, in that they receive faster service. Concentrated health facilities, including regionalized hospitals, mean more specialists available and more modern and better equipment.

Barriers to Fire and Other Hazards

Highways can serve as effective barriers to the spread of fire in both urban and rural areas. In woodland areas they are frequently used as fire lanes for controlling forest fires. However, improved roadways have also made woodlands more accessible to the general public, thus increasing the incidence of forest fires. In urban areas severe conflagrations can jump narrow city streets; modern expressways, however, serve as effective barriers.

On flood plains beside rivers and streams, highways can serve as effective dikes to flooding. Modern expressways can provide partial protection by acting as buffer zones or barriers separating hazardous activities from other industrial, commercial, or residential areas in which damages might be excessive in case of accidents. On the other hand, users of the highway will be exposed to greater risks than if the traffic were routed at a more distant location.

Operational Effects

Bypass Effects

There are two important effects from bypasses. The first has to do with the lessening of the volume of traffic on the old route, which benefits many people in those communities as a result of less congestion on local streets. The second effect is the impact of the bypass on local business establishments.

Not only will it be easier and more convenient for local residents and others to get around, but there should also be a reduction in noise, air pollutants, and other objectional effects of heavy traffic. Congestion should be reduced on more than just local streets. More parking spaces will be available for local people, and there should be shorter waits for service in businesses catering to motorists. For some kinds of local business establishments in communities that are heavily congested from through traffic, the rerouting of this traffic may actually result in an increase of sales and income as the local people find it more convenient to shop downtown.

Not only will rerouting the traffic mean fewer accidents, but it will improve the safety of schoolchildren and other pedestrians on local streets. Besides the cost savings in fewer accidents, local motorists will benefit from lower vehicle operating costs as traffic flow is improved, and fewer and shorter stops will be necessary. An additional benefit will be the reduction in risk from major hazards, particularly from trucks hauling dangerous cargo.

The change in accessibility occasioned by bypasses will be felt by local business establishments, but will not be felt equally by all establishments. Businesses catering largely to the needs of transient motorists will be adversely affected if they remain near the old route. Businesses serving largely the needs of local residents may be little harmed, if at all, and some may even realize an increase in business because of reduced congestion. For the community as a whole, however, the important question is the net effect of the bypass on economic activity. For bypass highways, as for any development involving large public expenditures, some individuals may gain and some may lose. However, bypasses are justified in the expectation that they yield net benefits to society as a whole.

Analysis of 24 bypass studies (*9*) showed that retail establishments catering mostly to motorists (service stations, restaurants, and motels) were the most adversely affected. Service stations and restaurants in some cases were able to adjust by reorientating their merchandise to local trade, but motels and hotels could not readjust. Total service station sales in all bypassed towns showed little change after the bypass; restaurants sales showed a 13-percent decline; and motel and hotel sales showed a 23-percent decline. Total retail sales for all establishments (highway and nonhighway oriented) showed an 8.5-percent increase after the bypass became operational.

Relocational Effects

For some persons and businesses relocated as a result of highway development, there are several possible beneficial economic effects. First, the quality of houses or other structures may be upgraded. For the community as a whole, significant upgrading of housing and other structures as a result of relocation, balanced by the elimination of older more run-down structures in the new highway right-of-way, will result in a net economic benefit—at least in the short run. If the occupants of the better housing after relocation permit their homes to deteriorate over time, however, the community may be no better off.

A second possible benefit is that the new location may provide better accessibility to employment opportunities, shopping, recreational facilities, and other nonwork activities.

Local Streets

A relatively minor indirect effect of major freeway construction, but one that might have significant meaning to some small rural towns, is the upgrading and improvement of feeder roads to interchanges and cross roads by widening, grading, and paving. The reduced traffic load on local downtown streets following a bypass may mean lower maintenance costs for some municipalities. Snow removal and traffic control chores also would be easier and less time consuming for municipal employees.

Energy Savings

A modern highway requires less energy to move the same number of people or tons of freight than an old highway with its steeper grades, greater congestion, and more frequent speed changes and stops. A substantial portion of the cost saving is in fuel. A 3-percent grade compared to a 6-percent grade results in a 20-percent fuel savings for cars and a 70-percent saving for trucks (*10*). To this extent, modern highway improvements are contributing in a direct and real way to achieving a reduction in energy consumption.

Improved Efficiency in Public and Private Services

The efficiency of many kinds of services, both public and private, is in some measure a function of the quality of the highways—police, fire, medical, education (school busing), postal, and banking services are a few examples. The concentration and regionalization of facilities, enabling

the provision of better services and more modern equipment, the broadening of the trade area, and the capacity to serve more customers in a day, apply to many kinds of services. They are characteristic of modern economy and describe some of the most important indirect benefits of highway improvements.

Buses are completely dependent on the highway system for their existence. Many of the benefits that accrue to other highway users, such as motorists, also accrue to bus passengers. Where special freeway lanes are reserved for bus use only during commuting hours, efficiency in bus transport is increased significantly. The higher costs of energy today would seem to indicate a greater demand in the future for bus service. There should be a corresponding decrease in congestion during rush hours, a more saving of fuel, and a further reduction in travel time and costs.

Buses that travel on local streets for all or part of their trips gain indirectly from highway improvements to the extent that freeways, by reducing congestion on these local streets, improve efficiency of bus operation.

Police, ambulance, and fire fighting services are able to respond more quickly to emergency calls when good highways are available and there is less congestion on local streets. Quick police response to emergency situations can be a strong deterrent to crime.

Other indirect benefits can be identified in the form of improved standby service as a result of improved mobility. A major highway linking nearby communities can obviate the need for extensive emergency equipment in each community. By concentrating better equipment in one central location, over-all savings can be realized and better quality service can be rendered through more highly trained personnel.

Busing of school children, both public and private, has grown apace with the development of highways. Because school buses do not commonly use limited-access highways but instead travel more on local streets, the benefits are more indirect in nature and arise in large part from reduced traffic and congestion on the older roads.

Freeways can provide much better access for emergency vehicles and for relief shipments of food, clothing, and medical supplies to communities suffering from a major disaster. Earthquakes, tornadoes, hurricanes, floods, and fires may quickly devastate a community and leave it without sufficient resources to survive in the short run. Not only would major highways speed relief shipments, but they also would make evacuation of the injured easier. Major freeways, built to more rigid specifications than older roads and with greater width, would likely hold up better and survive a major catastrophe in usable condition.

In 1969, the U.S. Post Office Department operated about 59,000 vehicles that traveled more than 550 million miles and carried about 78 billion pieces of mail (*7*). Without an adequate high-speed highway system, such volumes of mail could not be moved without costly delays. Highway improvements have meant a consolidation of post offices, reducing over-all costs of the service.

Mobile homes and preconstructed homes are now the main source of new housing for lower income families, and are completely dependent on highways for delivery to their final sites.

Most of the delivery of coins, currency, and cancelled checks to banks is done by motor vehicles. An antiquated highway system might seriously jeopardize the efficient operation of our banking system, resulting in higher costs for all.

Resource Substitution

All types of waste products are created in our society, many of which could be used in highway construction and maintenance. The use of such substitute materials can be beneficial in two ways: (1) by lowering construction and maintenance costs and (2) by conserving scarce resources. Many types of materials have been suggested for highways, including municipal wastes, power plant wastes, and mining wastes (the latter being a major source of waste material). As the more common aggregates and other highway materials become shorter in supply, substitute materials from growing supplies of waste material will become more competitive and find increasing use in highway construction and maintenance.

CHAPTER THREE

APPLICATION AND SUGGESTED RESEARCH

APPLICATION

The primary purpose of this study was to assemble within a single document all the known beneficial effects associated with the construction and use of freeways. An effort was made to provide a ready source of information that would be helpful to highway officials in two important ways. First, this study should help to improve the quality of environmental impact statements now required by law for all federally funded highway construction projects. Opposition to highway construction by many environmentalists has resulted in a heavy emphasis in environmental impact statements on correcting the adverse effects. Although this in itself is not necessarily bad, it has been accomplished at the expense of giving a full and proper accounting of the beneficial effects of highways. Environmental impact statements are supposed to be unbiased estimates of the total impact of highways on the environment, people, and communities; thus, the statements should include the good

features as well as the bad. It is hoped that this study will make highway officials aware of all possible highway benefits and will provide references to which they might turn for more detailed information.

Second, this study should be helpful to highway planners, designers, and engineers in the early stages of highway corridor selection and design. If highway engineers were more aware of some of the likely benefits that might be realized through only slight modifications in location or design, these might be considered in the design process. Some of the environmental benefits appear to be particularly suitable for inclusion at the design stage. By attempting through the highway design process to enhance environmental benefits and, thereby, minimize the adverse effects, some of the opposition of environmentalist groups might not only be lessened, but, if real imagination were used, the support of some former opponents might even be won.

A Matrix of Beneficial Effects

Chapter Two, which summarizes only the more significant beneficial effects, is intended to provide the reader with a broad overview. The researchers felt that a categorical listing in tabular form of all but the most minor effects, together with certain descriptors of these effects, should be helpful. Consequently, the following matrix of beneficial effects was developed and could be used as a checklist.

Within the matrix, the effects are arranged in the same order in which they are discussed in the three appendixes. The first group, environmental benefits (see Appendix A), are those associated primarily with the physical, biotic, and aesthetic attributes of the highway corridor and include effects on air, water, soils, rocks, plants, animals, and the aesthetic qualities as viewed by both users and nonusers.

Group II, the social benefits (see Appendix B), deals with the manner in which highway improvements might influence individuals; population distribution and change; various community services; settlement patterns; social interaction; interrelationships between comprehensive, land use, and transportation planning; and regional and national considerations.

Group III, the economic benefits (see Appendix C), deals with the beneficial influence of highway improvements on economic growth and development arising from improved accessibility; land values; improved health and safety; various operational aspects such as congestion, bypasses, relocation, and energy; efficiency in the delivery of public and private services; and resources substitution.

To the right of the described beneficial effects are 6 columns indicating certain descriptive characteristics associated with each of the major effects. These characteristics are: urban and rural, short run and long run, and direct and indirect. A 7th column gives the page number in the appendixes where a detailed discussion of each beneficial effect begins. The reader should refer to the appendixes for more detailed enumerations and descriptions of benefits.

Within the first 6 columns, the "P" stands for primary importance and the "s" stands for secondary importance; if neither appear, the effect is of very minor consequence. The choice of primary or secondary largely reflects value judgments on the part of the research team members. Admittedly, there are many gray areas where it is difficult to state unequivocally that an effect is of primary or secondary importance. The relative importance of benefits will differ with each highway situation and its relation to a specific community. For specific highway improvements the user should reorder the designations where necessary to describe the particular effect in a given location.

Considerable difficulty was encountered in defining urban and rural areas in a manner satisfactory to the three broad classifications of environmental, social, and economic. A rather loose concept was adopted that merely denotes rural areas as being beyond the normal suburban residential area surrounding a city.

Most beneficial effects occur in both urban and rural areas, but usually are of greater significance in one area or the other. For example, reduction of air pollutants (environmental), noise (social), and congestion (economic) is of greater importance in urban areas. Reduction of travel time and fewer accidents accrues economic benefits of major importance anywhere in the highway system. Relocation benefits are found almost entirely in urban areas; some of the beneficial effects on plants and animals are confined to rural areas.

Whether the benefit is short run or long run in time depends in part on whether the recipient is a user or a nonuser. Reduction of glare, noise, and air pollutants for highway users is relevant only to the immediate trip, although there may be longer secondary benefits such as reduced stress. To the highway nonuser, however, reduced glare, noise, and air pollutants endure for the life of the highway. The actual lengths of time cannot be satisfactorily defined because there is far too much variation. The time period must be considered within the context of the kind of benefit and who the recipient may be.

Many benefits have both short-run and long-run implications. Where both are important, "P" is used in both columns. Travel time savings are clearly important both in the short and long run, but benefits of land value increases are of primary significance only in the long run.

The direct-indirect delineation is not quite identical to the user-nonuser classification. In most cases, users are direct beneficiaries and nonusers are indirect beneficiaries. Reduced congestion is a direct benefit to highway users in that it reduces travel time; but, at the same time, it may reduce traffic loads on local streets, thus making them also less congested and safer for pedestrians—these are clearly indirect benefits.

The more noteworthy literature dealing with each benefit is reviewed in the appendixes. The discussion of the more important effects includes a description of who or what benefits and in what way. Many highway effects can be both beneficial to one group and adverse to another. A new highway may improve accessibility for some people or businesses, but adversely affect accessibility of others.

Limitations

Some words of caution appear in order concerning the interpretation and application of some of the beneficial effects of freeways. Determining the benefits from a

MATRIX OF HIGHWAY BENEFITS

Beneficial Effects	urban	rural	short run	long run	direct	indirect	page number
I. ENVIRONMENTAL							
A. Physical							
1. Air							27
a. Reduction of pollutants (carbon monoxide, oxides of nitrogen, hydrocarbons, particulates)	P[1/]		P	S[2/]		P	27
b. Urban climate (cooling, warming, air exchange)	P		P	P		P	28
2. Water	S	P	P	P	P	S	28
3. Soils and rock (drainage, exposure)	S	P	S	P	P		28
B. Biotic							30
1. Plants							31
a. Diversity	S	P	S	P	P	S	31
b. Preservation		P		P	P	S	32
c. Fire breaks	S	P	S	P	P	S	33
2. Animals							33
a. Terrestrial animals							33
a.1 Food (naturally occurring, operational effects)	S	P	S	P	P		33
a.2 Cover (nesting sites, burrows)	P	P	S	P	P		34
a.3 Dispersal and range extension (movement)		P		P	P		36
b. Aquatic and amphibious animals: habitat enhancement	S	P	S	P	P		37
c. Financing ecological studies	S	P	S	P	P	S	38
C. Aesthetic Quality of the Environment							39
1. Users							41
a. Highway functions (actions influencing aesthetic quality)							41
a.1 Visual access	P	P	P	P	P		41
a.2 Visual experience	P	P	P	S	P		41
a.3 Replace or reduce displeasing land uses	P	S	P	P	P		42
a.4 Design standards enhancing visual quality	P	P	S	P	P	S	42
a.5 Reduction of headlight glare	P	P	P		P		43
b. Perception of landscape form (dynamic viewing)							43
b.1 Spatial relationships	P	S	P	S	P		44
b.2 Highway and highway structures	P	P	P	S	P		44
b.3 Modified land forms	S	P	P	S	P		44
b.4 Landscape development	P	P	P	S	P		45
2. Non-Users							46
a. Highway functions (actions influencing aesthetic quality)							46
a.1 Provide open space	P		P	P	P	S	46
a.2 Replace or reduce displeasing land uses	P	S	S	P	P	S	46
a.3 Design standards enhancing visual quality	P	S	S	P	P	S	47
a.4 Reduction of headlight glare	P	S	P	P	P	S	47
a.5 Reduction of sound	P	S	P	P	P		47
b. Perception of landscape form (stationary viewing)							49
b.1 Spatial relationships	P		S	P	S	P	49
b.2 Highway and highway structures	P	S	S	P	P	S	50
b.3 Modified land forms	S	P	S	P	P	S	50
b.4 Landscape development	P	S	S	P	P	S	50

[1/] P = primary importance

[2/] S = secondary importance

Beneficial Effects	urban	rural	short run	long run	direct	indirect	page number
II. SOCIAL							
A. Individual Effects							
1. Users							58
a. Accessibility and freedom of choice							58
a.1 Employment	P	P	s	P	P	s	58
a.2 Shopping	P	P	s	P	P		59
a.3 Recreation and travel	P	P	P	s	P	s	59
a.4 Residential	P			P	P		59
a.5 Educational, cultural activities	P	P	s	P	s	P	60
a.6 Public services	P	s	s	P	s	P	60
b. Health and safety							61
b.1 Reduced accidents, injuries, fatalities	P	P	P	P	P		61
b.2 Comfort, pleasure, stress, fatigue	P	P	P	s	P		61
b.3 Noise reduction	P	s	P		P		62
b.4 Reduced air pollutants	P		P		P		62
c. Reduced congestion							62
c.1 Travel time savings	P	P	P		P		62
c.2 Less irritability, stress	P	P	P		P		62
d. Pleasure driving	s	P	P	s	P		62
2. Non-Users							63
a. Health and safety							63
a.1 Reduced accidents, injuries, fatalities	P	s	P	P		P	63
a.2 Noise reduction	P	s	P	P	s	P	63
a.3 Reduced air pollutants	P		P	P	s	P	63
b. Reduced congestion on local streets	P	s	P	P		P	64
c. Less irritability, stress	P	P		P	s	P	64
B. Population Effects							64
1. Population distribution							64
a. Socioeconomic status	P	s		P		P	64
b. Racial distribution	P			P		P	65
c. Age distribution	P	s		P		P	66
2. Population change	P	s		P		P	66
C. Community Effects							67
1. Community services (amount, quality)							67
a. Health	P	P		P	s	P	67
b. Education	P	P		P		P	67
c. Fire and police	P	P	s	P	s	P	67
d. Recreation	P	P	s	P	s	P	67
e. Transit	P	s	P	s	P	s	68
f. Other services	P	P	P	P	P		68
2. Settlement patterns							68
a. Spatial array of land use activities							68
a.1 Residential	P	s		P	P	P	68
a.2 Industrial	P	s		P	P	s	69
a.3 Commercial	P	s		P	P	s	69
a.4 Public uses	P	s		P	P	s	69
b. Density	P			P		P	70
c. Relocation	P	s	P		P		70

Beneficial Effects	urban	rural	short run	long run	direct	indirect	page number
3. Interaction - Communication							70
a. Implement community values	P	P	S	P	P	S	70
b. Public participation (highway planning, community organizations)	P	P	P	P	S	P	70
c. Social contacts	P	P	P	P	P	S	71
4. Comprehensive/land use - Transportation planning effectiveness							72
a. Interchange development and by-passes	P	P	P	P	P	P	73
b. Joint development	P		S	P	P	P	75
c. Land use (buffer zones, etc.)	P		P	P	P	S	76
d. Design characteristics (conceptual)	P	S	S	P	P	S	76
e. Transportation/comprehensive planning interface	P	P	P	P	P	S	77
D. Regional and National Effects	P	P	S	P	P	P	78
III. ECONOMIC							
A. Economic Growth and Development							89
1. Accessibility							89
a. Locational advantages	P	S	S	P	P	S	90
b. Travel time and operating costs	P	P	P	P	P	S	91
2. Employment, income, and production							92
a. Direct	P	P	S	P	P	S	93
b. Indirect	P	P		P		P	94
3. Agglomeration economies and economies of scale	P	S		P		P	94
4. Interchange development	P	P	S	P	P	S	95
5. Joint development	P	S	S	P	S	P	96
B. Land Values							96
1. Private	P	P	S	P	S	P	97
2. Tax base effects	P	P		P		P	98
C. Improved Health and Safety							99
1. Accidents, injuries, fatalities	P	P	P	P	P	S	99
2. Health care delivery	P	P	P	P	P	S	100
3. Barriers to fire, other hazards	P	P	P	P	P		100
D. Operational Effects							100
1. By-pass effects							100
a. Reduced congestion	P	S	P	P	S	P	101
b. Local businesses	P	S	S	P	S	P	101
2. Relocation effects	P			P		P	102
3. Local streets	P	S		P		P	102
4. Energy savings (reduced fuel consumption)	P	P	P	P	P	S	102
E. Improved Efficiency in Public and Private Services							103
1. Public transit	P	S	P	P	P	S	103
2. Emergency services	P	P	P	P	P	S	103
3. Education	S	P	P	P	P	S	104
4. Civil defense	P	P	P	P	P	S	104
5. Major disaster relief	P	P	P		P		104
6. Other	P	P	P	S	P	P	104
F. Resources Substitution	P	P	P	S	P	S	104

specific highway improvement project is not an easy or clear-cut task. Some real and difficult problems are involved, and if the highway official preparing benefit statements is unaware of these, his report will lack the validity he should attempt to achieve.

Highway benefits are not uniform, in terms of their nature or their magnitude, from one highway situation to another. Benefits are a function of a particular highway design within a particular environmental, social, and economic setting. A certain type of highway may produce a "package" of benefits in one setting, but in another setting a different package of benefits is likely to emerge. Conversely, one highway design may generate a mix of benefits different from another design, holding the setting or community constant. Even more troublesome is the fact that people's perceptions of beneficial and adverse effects and their relative importance varies. What one person views as a benefit, another person may view as a disadvantage. The stimulus highways give to community growth is an excellent example.

For these reasons, one must exercise caution and good judgment when interpreting the beneficial effects in specific highway situations. Five important problem areas must be kept in mind:

1. *The Problem of Identification*—Two aspects to the identification problem are (a) identifying the nature of the effect, that is whether it is beneficial or adverse; and (b) identifying the recipients of the effect. The two aspects are closely related and identifying one often helps identify the other.

An effect that is viewed by one person as being beneficial is often viewed by another as adverse. People have different sets of beliefs and values; live in different parts of the community; have different incomes; come from different backgrounds; and differ in many other social, economic, and physical ways. The increase in land values occasioned by a highway improvement will be viewed as beneficial by the individuals owning such lands, but will be regarded as adverse by the retiree on fixed income renting an apartment, or the lower income family aspiring to purchase land and move into the community. Highways stimulate employment and growth, which are good for the younger person wanting to upgrade his income and for the local retailer, but may not be good for the family seeking certain community attributes and not wishing to see these altered by outside influences. An effect can be both beneficial and adverse. Moreover, most individuals experience a mixture of effects from a highway improvement—some beneficial, some adverse. The established family may oppose the highway on the basis of antigrowth feelings, but welcome the highway because of the increase in land values.

Interregional as well as community effects must be considered. A major highway improvement may benefit one region in terms of stimulus to growth and employment, but may do so at the expense of another region served by older highway routes. The interregional effects of I-80 on the older Pennsylvania Turnpike illustrate this point.

Fortunately, the highway official does not have to determine each effect of the highway on each individual in the community. Nor can he make judgments as to the net effects, considering all aspects, on the community as a whole. What he must do, however, is recognize and show all the effects and upon whom they will fall. It is the community, collectively, that must make the judgment as to whether the highway development, on balance, is good or bad.

2. *The Problem of Measurement*—It would be helpful to be able to measure in quantitative terms all the various effects of a highway improvement, but it is not possible given the present state of the art. Some effects, of course, can be quantified: the saving in travel time, the reduction in accidents, improved accessibility. Some effects can be measured, but only with considerable difficulty because, for one reason, it is not always clear how much of the change being measured is related to the highway. For example, land value increases near a highway might be due in part also to other forces of growth, or population changes due to factors apart from the highway.

Other effects, such as those related to design features, aesthetics, and social factors cannot be adequately measured. However, they still must be recognized and discussed for a highway effects analysis to be complete.

3. *The Problem of Exclusivity*—The highway official must be careful that economic benefits are not added more than once, so that double counting and overstating the true economic effect will not result. This is most common when vehicle operating cost reductions and travel time savings (expressed in dollars) are added to land value increases to express the net economic effect on a community. The direct user benefit of operating and travel time cost reductions is usually transferred to landowners in the community in the form of higher property values and thus becomes an indirect or a nonuser benefit. The problem of exclusivity is discussed in greater depth in the introduction to Appendix C.

4. *The Problem of Categorization*—At times it may be difficult to distinguish between some of the effects listed under the broad social and economic categories. For example, the health effect of highway improvements in terms of reduction of accidents, injuries, and fatalities certainly has its social effects as well as economic, and is listed in both sections. The reader should keep in mind the context in which the effects are being discussed.

5. *The Problem of Relative Importance or Priority*—No attempt was made by the authors to attach any weight, importance, or priority to the beneficial effects presented in this report. In fact, it would be impossible to do so, because their relative importance will vary depending on different highway situations and different community characteristics. Some benefits, of course, are of lesser significance than others. But to order benefits in some hierarchical fashion fails to recognize that people hold different sets of values, and that one cannot *a priori* state that one person's set of values is better than that of another.

SUGGESTED RESEARCH NEEDS

Environmental

More research is needed on methods of propagating native grasses, flowers, and shrubs on highway rights-of-

way. So far, most of this work apparently has been done in the prairie states.

The technique of highly selective use of herbicides to arrest plant succession—pioneered by Egler, Way, Niering, and Goodwin, and others—should be tried on highway rights-of-way. Apparently some states, including Minnesota, are already doing this.

Closely related to manipulation of native vegetation is improvement of habitat for birds and small mammals on rights-of-way. There are few published studies of the over-all effect of highways on mammal, bird, reptile, and amphibian numbers. It is known that many of these animals are killed on highways because of improved habitat on the rights-of-way. On the other hand, some kinds of reptiles and amphibians can be almost totally eliminated along highways.

Where highway-caused mortality causes significant depletion to desirable animals, or where collisions are a hazard to human lives and property, research is needed in the design and placement of fencing to keep wildlife off the pavement. If it is possible to keep deer off the pavement, while permitting them to browse on right-of-way vegetation, freeways could become an asset rather than a hazard to deer.

With modest expense it should be possible to modify freeway overpasses, bridges, and culverts to make them usable as nesting and roosting sites for desirable birds, especially in rural areas.

The feasibility of acquiring wider rights-of-way should be investigated from several standpoints, including:

1. Possibility of preserving or creating more habitat for desired wild plants and animals.
2. Building hiking trials, bikeways, fishing ponds, and other outdoor recreational facilities on rights-of-way.

The role of highways in dispersing hunting, fishing, hiking, and other outdoor recreational activities from overcrowded areas near cities to more distant regions needs more study.

Methods of improving access from freeways to such water-related activities as fishing and boating should be investigated.

There is a need to assemble and document all influences, positive and negative, on the aesthetic quality of the environment. A study comparing benefits and disadvantages in detail would be helpful. Definition of visual quality determinants in order to promote uniform acceptance of factors affecting aesthetic quality would be part of the suggested research. The importance to the motorist of intangible benefits such as a pleasant visual experience, a sense of orientation, and reduced stress should be investigated.

Research should include an ordering of visual determinants and ranking them against political, social, ecological, and economic determinants. A significant contribution would be a visual analysis technique which: (1) incorporates an evaluation of the elements which influence the landscape forms perceived by the motorist (topographic configuration and relief, vegetation density), and (2) considers views of various scales (the view of features immediately adjacent to the roadway, distant views, and intermediate views) and their importance to the motorist at differing speeds and at various geometric design and traffic situations.

A comprehensive highway design process that includes a visual analysis procedure would be very useful for highway planners. Aesthetic inputs would be necessary in all phases of the design process, from site reconnaissance through final design, to assure aesthetic design objectives in the completed highway and its relationship to the surrounding environment. For example, aesthetic considerations should be integrated with such other factors in the location of the highways, the geometrics of the alignment, the articulation of grading, and the design of bridges and structures as noise reduction barriers, signs and guard rails, and the landscape development of the corridor.

Social

Better accessibility will affect recreational development. Demand for resource-based recreation is a function, in part, of travel time and cost. Improving accessibility through highway development will affect the demand for recreation at any specific site.

The relationship between expanding facilities for mass transit on limited-access highways and energy consumption needs more investigation. Not much has been done to examine the social effects of noise and other traffic-generated pollutants on residential areas adjacent to freeways. More attention needs to be directed toward the use of freeways by the aged.

Such questions as the following need answers. Does reserving lanes for buses during commuting hours result in more bus ridership? Do the daily activities of families living next to major highways differ from those farther away?

Economic

In reviewing the literature pertaining to economic benefits from highways, a number of research needs become apparent, such as the intercommunity or interregional effects. When a major new route is opened, what are the net effects after weighing the gains within the new corridor against the losses in the older corridors? The opening of I-80 through Pennsylvania (and certainly other states as well) shifted traffic off older routes, primarily from the Pennsylvania Turnpike and US 322, 22, 422, 6, and 11. Many communities along I-80 have benefited much, but these benefits should be compared to the losses experienced by communities served by the older routes in order to estimate the net benefits.

Highway development is a form of land use serving other land uses such as urban and rural settlement within a region. It exerts a powerful influence on how land is used, but little good research has been done in this area. Such research will be more significant when the relationship between energy consumption and settlement patterns is considered.

Economists recognize the importance of identifying the individuals or groups in society who benefit from highway improvements and those who suffer losses in one form or another. The same individual or group may experience both gains and losses. Although it is not too difficult to

identify the immediate gainers or losers, with most public developments indirect effects can be quite pervasive through many segments of society. Highway planners need more information as to the total nature of the effects of highway development.

The use of highway corridors for more than just the movement of goods and people is recognized as a more efficient use of resources in some instances. There has been little research, however, on the nature or magnitude of the benefits and costs from such ventures and the total economic effects on the community.

The economic effect of relocation on the people displaced by highway developments has received considerable attention, but not much has been done to examine the broader, more indirect, and longer run economic effects on the over-all community.

REFERENCES

1. U.S. DEPARTMENT OF COMMERCE. *A Proposed Program for Scenic Roads and Parkways* (1966) 254 pp.
2. LARSON, T. D., and MCKELVEY, —., "Environmental Impacts of Transportation Facility Design Decisions." Course notes, The Pennsylvania Transportation Institute, The Pennsylvania State University (1973).
3. LISCO, T. E., "The Common Economics of Travel Time Value." *Technical Paper and Note Series No. 13,* Office of Research and Development, Illinois Department of Transportation (1973) 33 pp.
4. THOMAS, T. C., *The Value of Time for Passenger Cars: An Experimental Study of Commuters' Values.* Stanford Research Institute (1967).
5. WINFREY, R., and ZELLNER, C., "Summary and Evaluation of Economic Consequences of Highway Improvements." *NCHRP Rep. 122* (1971) 324 pp.
6. U.S. DEPARTMENT OF TRANSPORTATION, FEDERAL HIGHWAY ADMINISTRATION, *Benefits of Interstate Highways* (1970) 37 pp.
7. *The Highway Transportation Story in Facts.* National Highway Users Conference (1969) 42 pp.
8. AUTOMOTIVE SAFETY FOUNDATION, *What Freeways Mean to Your City.* Washington, D.C. (1964) 56 pp.
9. HORWOOD, E. M., ZELLNER, C. A., and LUDWIG, R. L., "Community Consequences of Highway-Improvement." *NCHRP Rep. 18* (1965) 37 pp.
10. SOLOMON, D., "Environmental Research and Highways." *Public Roads,* Vol. 37, No. 8. pp. 297-305 (Mar. 1974).

APPENDIX A

ENVIRONMENTAL BENEFITS

Environmental effects of freeways vary with the placement, degree of interdisciplinary planning, care in building, and in the type of management of the finished highway. Environmental effects are sometimes easier to demonstrate than they are to evaluate, because they will vary with the nature of the effect; what is affected; and with the goals, priorities, and value systems of the evaluator. This appendix concentrates on beneficial environmental effects that have been shown to occur or that are possible with enlightened management. Others have amply pointed out the detrimental effects that have occurred. It is hoped that this discussion will help increase benefits and reduce damages from freeways.

In preparing the section on physical and biotic benefits, several biologists and two archeologists were consulted, in addition to a survey of the literature. Many were surprised that any benefits to plants and animals could result from freeways. Although the net effects to date have been harmful, freeways can be an asset to wildlife.

Hopefully, freeway planners will consider possible ways of applying the practices discussed in the following pages to specific highway projects, so that their maximum potential for multiple use can be realized. Although freeways that are planned, constructed, and managed with no consideration of wildlife can aid a few species, most benefits will not result accidentally. Legislation has been instrumental in a few cases in forcing consideration of ecological concerns, but more often benefits are the product of voluntary cooperation between state highway departments and diverse specialists such as archaeologists, paleontologists, botanists, wildlife managers, fisheries specialists, geologists, land use planners, and meteorologists. Probably, the single most important action that highway planners can take to maximize ecological and scientific benefits is to notify these specialists of proposed freeway routes and designs in the preliminary stages, when plans can be modified without undue cost and delay.

CLASSIFICATION

Environmental benefits have been divided into the major categories of A. Physical, B. Biotic, and C. Aesthetic

Quality of the Environment. Environmental factors may be classified as belonging to either the physical environment or the biotic environment.

Beneficial effects concerning the physical environment have been classified in the categories of 1. Air, including effects on urban climate; 2. Water; and 3. Soils and Rock. Beneficial environmental effects relating to air are primarily urban effects. It must be cautioned that in some cases the effect may be a direct benefit in a limited environmental context, while being adverse to other sectors of the environment. Beneficial effects on water, soils, and rock are primarily rural effects of a direct nature. Benefits to the physical environment may be short run and/or long run, but it is important to note that some effects occur for only a very short duration and must be considered in this transitory context.

Benefits to the biotic environment deal with either 1. plants or 2. animals, the latter being divided into the categories of terrestrial animals and aquatic and amphibious animals. In general, benefits to plants and animals are primarily rural, of long duration, and direct. Enhancement of animal's habitat due to the construction of a freeway is an example of this type of benefit.

Aesthetic quality of the environment deals with man's perception of the environment. Inasmuch as the benefits in this section relate to the effect of the highway environment on man's senses, the benefits discussed have social relevance in addition to environmental significance. However, it was determined by the research team that since the benefits are closely related to environmental changes resulting from highway improvements, the environmental section is the most appropriate location in the classification system to enumerate and discuss aesthetic quality.

The aesthetic quality benefits have been divided into user and nonuser categories. Simply, users are persons who are driving on the freeway, and nonusers include persons not using the freeway. The nonuser classification is most relevant to persons who occupy the land near a freeway (e.g., home owners whose property abuts the freeway right-of-way). Someone living in a residential area adjacent to a freeway, who uses the freeway to commute to and from work, would be considered both a freeway user and nonuser, depending on his particular activity at the time the effect was felt.

Within the framework of the user and nonuser classification, the aesthetic quality benefits have been further divided into benefits of functions created by the highway and benefits from the perception of landscape form. This form and function classification is used to make a distinction between (1) actions, processes, and movements that facilitate the perception of aesthetic quality of the environment; and (2) the components of aesthetic quality that are a product of highway-induced changes of landscape form. Function benefits may include, for example, situations where the construction of the freeway replaces or reduces displeasing land uses, whereas benefits of landscape form would include spatial relationships (especially of the urban pattern) or the form of the highway and highway structures. Forms are elements of the view of the landscape in much the same way as the elements in the composition of a painting or photograph. Generally, the perception of landscape form for nonusers is from a stationary viewpoint, analogous to the view of one photograph; whereas, for freeway users, the landscape form is perceived dynamically, analogous to viewing a series of photographs or a motion picture.

It is important to note that all benefits of freeways found by the research team are presented in this report; hence, the reader is cautioned to recognize the context of the incidence of the effect and not to consider the benefits as being additive.

A. Physical

Physical environmental effects of freeways are discussed under three headings: 1. Air, 2. Water, and 3. Soils and Rock.

In general, air environmental effects of freeways are aspects of air pollution, gaseous emissions, and temperatures. Water effects pertain to aspects of water quality, changes in runoff, and retention of ground and surface water. Environmental effects of freeways on soils and rocks are concerned with infiltration, erosion, and salvage of materials of interest to earth scientists and archeologists.

1. *Air*

a. *Reduction of Pollutants.*—The quality of air is partially determined by the amount of pollutants (carbon monoxide (CO), hydrocarbons (HC), oxides of nitrogen (NO_x), lead, and particulate matter) from motor vehicles discharged into the atmosphere. The amount of pollutants varies with respect to, among other factors, vehicle speed, gear changes, number of stops, and speed from which stops are made. Freeways reduce most of these pollutants because the number of stops and gear changes are reduced, and the vehicle speed is generally more uniform and higher than on roads without access control.

The sustained, higher speeds of freeways as compared to nonaccess-controlled roadways create air movements that mix the pollutants produced and disperse them over a larger area where their effect is reduced. The wider area of multiple-lane freeways also facilitates natural air currents to disperse pollutants over a larger area.

Data on lead and particulate matter are not sufficient to determine any relationship between quantity of these pollutants produced and driving conditions. Factors other than highway characteristics, such as engine condition and adjustments, appear to be more significant in producing particulate matter. Lead emission can be estimated from the amount of leaded fuel consumed with about 80 percent exhausted to the atmosphere with the remainder being removed with the oil filter.

Smith and Rocco (*202*) evaluated the air quality following the opening of an Interstate route in Memphis using two models: a diffusion model that identifies the large-scale impact of construction of major freeways on a metropolitan area, and a line source analysis model that calculates the concentration of contaminants in the vicinity (1 km or less) of the roadway.

Revis (*178*) indicates that traffic flow techniques that reduce delays, idling periods, and stops and starts result in lower emissions of most vehicle-generated pollutants,

but NO_x emissions increase with vehicle speed. It was also found that improvement in the public transportation systems (by utilizing freeways) can reduce pollution significantly by shifting riders from automobiles to mass transit.

Horowitz and Pernela (*101*) report that emissions of all pollutants are approximately proportional to the vehicle miles of travel. Diurnal evaporative hydrocarbon emissions, however, are independent of travel behavior. Trips that are longer and faster than the average tend to have carbon monoxide and hydrocarbon emissions slightly less than proportional to the vehicle miles of travel. Greater quantities of nitrogen oxides, however, are produced by long trips than are produced during shorter trips.

The report of the Advisory Committee on Highways and Air Quality (*96*) found that air quality is directly related to vehicle miles of travel and that contaminants emitted per vehicle mile traveled decrease as the average speed increases. It was noted, however, that a California Air Resources Board study found NO_x to increase as average speed increased. Although the Air Quality Workshop group concluded that, in general, air quality benefits to be derived from improvements in traffic flow would be comparatively low, the greatest improvement in air quality would be obtained where vehicle speeds are low (that is, increasing average vehicle speeds from 10 mph to 30 mph would result in greater improvements than a similar increase at higher speeds). This would indicate that, although the reduction of stop-and-start operations on local streets would be of considerable benefit, greater benefits would result if much of this traffic were transferred to a limited-access freeway where speed changes are minimized.

The U.S. Department of Transportation (*237*) reports that air pollution levels caused by autos operating in urban areas reached a peak for hydrocarbons (HC) in 1964, for carbon dioxide (CO) in 1966, and for oxides of nitrogen (NO_x) in 1971. By 1973, HC had been lowered to 0.565 of the maximum rate, CO to 0.660 of its maximum rate, and NO_x to 0.950 of its maximum rate. The reasons for the reduction appear to be a combination of tighter emission standards, improved urban roads, and more vehicle miles of travel. Urban freeway systems increased during the 1960's, which apparently contributed to the reversal of CO and HC emissions, but NO_x emissions continued to increase because, unlike CO and HC, NO_x production increases with increasing speed.

b. *Effects on Urban Climate.*—Freeway rights-of-way also facilitate the movement of air and provide a cooling effect (*216*). This will tend to offset the increase in temperature because of the energy absorbed by the pavement and other structures. Although the effect on the climate is limited to the area containing and immediately adjacent to the roadway, this effect can be the difference between an icy or ice-free pavement in the winter.

2. *Water*

Much of the literature on the effects of highways on water quality is addressed primarily to the negative effects resulting from the construction and operation phases. For example, during construction, both the surface and ground waters can be disturbed. Removal of the vegetative cover in the construction site can result in fine material being washed into the streams or carried into the aquifers, reducing both their capacity and their permeability. Fuels, oils, and chemicals used during construction can be flushed into the nearest water supply, whether it be surface or underground.

During operation of the roadway, fuels and oils used in the vehicles, as well as various chemicals accidently spilled while in transit, can find their way into a water source. Deicing salts used for snow removal are eventually carried into the nearest water source. In almost all cases, these compounds are considered undesirable, although their adverse effect is not universal or well established.

Hanes et al. (*85*) have found that, while deicing salts find their way into nearby water sources, the concentration of salts in ponds, lakes, reservoirs, rivers, and underground water supplies is such that deicing salts do not appear to be contaminating these sources to any great extent, particularly in relation to other sources of contamination.

Parizek (*162*) points out the effect of beheading an aquifer by a highway cut. Interruption of the natural flow of ground water can draw down an aquifer, providing a source of free flowing water and improving the characteristics of the land immediately adjacent to the highway. This diversion of water, however, may be at the expense of users elsewhere relying on the aquifer for their source of water.

3. *Soils and Rock*

Both soil and rock will be disturbed in areas through which highways pass—particularly freeways with their wider widths, flatter grades, and longer radius curves than roads built to less demanding standards—generally with damaging results. Higher standards require deeper cuts and higher fills. Load-carrying capability is also greater for freeways and limited-access roadways than that usually required for other types of roadways. However, as will be seen in the following, there are some situations in which the construction of a highway benefits the soil and rock.

a. *Changing Drainage Characteristics.*—When a roadway is constructed through an area, in a large percentage of the time the existing ground cover is removed in much of the right-of-way whether the section will be in a cut or fill. Because the surface layer of soil is disturbed, the rate of surface water infiltration will be changed.

When the original soil cover acted as a barrier or impervious layer to moisture, permitting at best only slow percolation to the substrata, disturbance of this soil cover can increase surface water infiltration. On the other hand, disturbing the original cover can reduce infiltration where fine-grained material seals the surface of the soil.

The removal of the cover, whether it be vegetation or bare soil, will also result in a change in the gradation and other characteristics of the soil remaining through the action of wind as well as water. Fine-grained material will be removed and deposited elsewhere, in watercourses, in underground water systems, or on plants and animals affecting their health and well-being. Organic material carried to other locations by erosion deprives plant life

where it is removed, but aids plant growth for either general flora or agricultural plants where it is deposited.

Cuts made during highway construction modify the topography in the immediate area of the roadway such that drainage patterns, and the rate of leaching of soil constituents and rate of weathering (*123*), are changed. This change in topography and surface drainage may accelerate the formation of sinkholes and underground caverns in limestone areas and may have either beneficial or adverse effects, depending on how local water supplies are affected. The formation of such sinkholes usually has been considered an adverse effect (*162*), but it could be beneficial if ground water supplies are recharged via this mechanism without, at the same time, carrying pollutants into the water system.

In specialized locations, such as the mining areas of Pennsylvania, the exposure of pockets of acid mine water by highway cuts can be quite harmful to not only the surface soil conditions but to plant life, to the surface water, and to animal life depending on the water, such as fish in the streams, livestock, and wildlife that utilize the streams as a source of drinking water. If adequate hydrological studies are conducted prior to excavation, it may be possible to design the highway alignment such that the acid mine water problem will be ameliorated rather than aggrevated.

Areas containing soil with little potential for commercial or industrial utilization in their natural state, such as swamps or marshy areas, may benefit when a highway is constructed across them. In order to provide a stable foundation for the roadbed, techniques for strengthening the existing soil are required, the effects of which often extend well beyond the limits of the highway. A well-known example of this situation is the New Jersey Turnpike across what is known as the Jersey Meadows. To improve the load-bearing capacity of the soil, vertical sand drains and a horizontal sand blanket were placed along the highway right-of-way and surcharged to hasten consolidation. A foundation of adequate strength was achieved for the roadway, and other areas of the meadow were later developed either because the land was improved as a by-product of the construction of the highway or the technique utilized was later applied in another location. Draining of the swamp and disturbing the marshland, however, will be detrimental to the specialized plants, and animal life that inhabit these areas. The effect is, therefore, both positive and negative.

There are some locations where a perched water table exists because of an impervious layer such as hard pan. Breeching this impervious layer during highway excavation will alter the condition of the water table—that is, cause it to be lowered—thus permitting infiltration into the lower layers. If water supplies made use of this perched water table, then the loss would adversely affect these users. The change in the water table and eventual change in the soil condition could, however, be of a beneficial nature.

b. *Exposure of the Subsurface.*—The exposure of subsurface rock formations can have a number of benefits. Elsewhere in this report it is pointed out how these exposed rock strata, because of highway cuts, have aided the geologist and other soil and rock scientists as well as paleontologists and archeologists. The effects of the highway cut on the rock itself are basically of two types: (1) it increases the effect of weathering, and (2) the blasting required fractures the rock in a variety of patterns depending on the composition of the rock, how it was formed, and its condition at the time of excavation.

Exposure of the rock to air, water, and temperature changes increases the effect of weathering. Loosely consolidated layers of sandstone overlain by a more resistant layer, such as lava, will erode more rapidly and cause undercutting of the upper layers with some fracturing and collapse at some time in the future.

The blasting of rock to facilitate excavation frequently results in fracturing of the rock to some depth beyond the surface exposed. The depth and extent of this fracturing will be a result of, among other things, the characteristics of the rock, the pattern of drill holes used for blasting, and the amount of material removed with each blast. Some rock can be drilled and blasted to result in a near perfectly smooth surface. Others will be deeply fractured, permitting the intrusion or escape of water and other fluids. Fractured rock faces can contribute to the aesthetic enhancement of the roadside by providing small waterfalls, flowers, and flowering shrubs during the spring and summer and ice sculptures during the winter.

Freeways may aid scientific research by exposing geologic structure, unearthing fossil deposits, and enabling archeological salvage. Road cuts can be of great benefit to geologists, paleontologists, archeologists, and others. Freeways, particularly, concern archeologists because without proper coordination and planning, cuts can be disastrous, totally destroying irreplaceable scientific and historical materials.

The importance of road cuts to geologists is reflected in the guidebooks for the tours that are often a part of geological conferences. Road cuts are often relied on almost entirely in demonstrating local geologic features, especially in the humid, well-vegetated eastern United States. College classes take field trips to road cuts to study deposits, materials, and processes.

Usually these benefits are short-term on nonrocky sites because of the need to prevent erosion on newly cut slopes by establishing a vegetative cover as quickly as possible. Even where it is not necessary to cover the surface of the cut, small gullies may soon wash soil down, obscuring details. Natural vegetation often manages to get footholds on the cuts, covering up still more of the cross section.

Road cuts can also be marked for the edification of passing motorists. Roadside signs in West Virginia, for example, name the exposed geologic formations and their economic importance. Interstate 70 west of Denver cuts through the Hogback of the Morrison Formation, famous as a source of dinosaur bones. Sixty million years of earth history are exposed in the cut, which has been officially designated as "Colorado's Sixty Million Year Nature Center."

Rocks laid down in marine and fresh-water environments in the geologic past often contain fossils of marine invertebrate animals and terrestrial plants. Road cuts expose fresh unweathered fossils and new fossiliferous pockets and strata. In the East, fossil deposits are almost always

naturally covered by soil and dense vegetation except along the banks of certain streams and rivers. Probably a majority of these fossils come from road cuts, quarries, and other man-made excavations.

Freeway cuts expose many fossils, but they are not always accessible to collectors. In Pennsylvania, for example, the State Police do not allow fossil hunters to park alongside freeways and prospect on road cuts. With planning it might be possible to develop safe parking sites and prospecting methods.

Remains of fossil vertebrates (fishes, amphibians, reptiles, birds, and mammals) are rare compared with those of invertebrates and plants. Many, especially larger specimens such as dinosaurs, big fishes, and large mammals, must be collected by trained personnel who have adequate equipment and sufficient time to complete the required painstaking work. The geologic horizons yielding the specimens must be identified precisely, because without adequate geologic information the specimens lose much of their scientific value.

Road cuts that are constructed with consideration of the vertebrate fossils they may contain can be beneficial to paleontological research; but indiscriminate road cuts may totally or partially destroy large specimens or rarities of any size.

The need for advance planning and cooperative agreements between highway departments, contractors, and paleontologists is important. The "Policy and Procedure Memorandum 20-7," first issued by the U.S. Department of Commerce, Bureau of Public Roads, in 1956 and revised on August 24, 1959 (*227*), establishes a policy for the use of federal highway funds in paleontological and archeological salvage. This document states that, if a proposed new or improved road is to be built in an area where historical objects may be encountered, an appropriate authority should be notified to survey the area. If it is found that destruction of a site or deposit is likely, alternate highway routes should be considered. If historical objects are unearthed during highway construction, the appropriate authority should be notified immediately and steps taken to preserve the objects if possible.

The Archeological and Historical Conservation Act of 1974 (*226*) requires that the U.S. Secretary of the Interior be notified in advance of any major federally funded construction, including highways. The Interior Department is authorized to prospect any promising paleontological or archeological sites that would be affected, or it may delegate the investigation to other qualified institutions. Up to 1 percent of the funds appropriated for construction may be used for salvage.

Paleontologists at the Cleveland Museum of Natural History were delighted that excavation for a freeway would reexpose an important fossiliferous shale that had been effectively locked away by urban development. A salvage agreement with the U.S. Bureau of Public Roads and the Ohio Highway Department (*186*) not only aided in obtaining fossils but it also helped in financing the work.

The federal highway salvage program is even more important to archeologists, the people who study the buried remains of past human activities, from Indian villages and burial mounds to settlements of early white settlers. Painstaking excavation, including the preparation of maps and diagrams that record the horizontal and vertical position of each item recovered, is necessary if the full scientific and cultural value of the sites is to be realized.

Some states were quick to set up cooperative salvage programs between archeological and historical institutions and their highway departments. Nebraska has an agreement with the Nebraska State Historical Society for the salvage of archeological material similar to the one it has with the University of Nebraska State Museum for vertebrate fossils. One man, paid from state highway funds, is responsible for the preliminary search for both artifacts and fossils (*66*). New York and Arizona (*12*) are other states with outstanding programs.

Many states, which formally lagged in this area, are now recognizing the importance of cooperation with museums and archeologists. In the early 1970's, three sites important to archeologists were totally destroyed when Interstate 79 was built through Bridgeville in Allegheny County, Pennsylvania. However, in 1973, the Carnegie Museum and the Pennsylvania Department of Transportation finally signed an agreement. The Department now sends the Museum maps of the rights-of-way of proposed new or improved highways before they are constructed. The first site to be salvaged was the Gnagy Site on the new, US 219 highway in Somerset County. This is an important Indian village site dated at 950 A.D.; federal salvage money financed the dig, which was completed in 1974.

B. Biotic

The building of freeways modifies the biotic aspects of the environment, which generally will vary with: the width and length of the freeway, which determines the area involved; the soils, soil configurations, and landforms of the area; the degree of environmental understanding and planning in construction; and the maintenance of the right-of-way. Any given effect may be positive or negative, depending on the particular species present or the value systems of the evaluator.

In 1971 Interstate highway rights-of-way occupied an estimated one million acres in the United States (*158*); if the entire 42,500-mi Interstate System were built as planned, the land area that would be occupied is 1,773,000 acres (*146*).

Preventing erosion and providing for the safety of motorists must be the principal goals of highway departments, especially in planning and managing vegetation. Several of the management priorities concerning the environment are: maintaining proper drainage; maintaining high visibility for drivers; preventing vegetation from impinging on the pavement; keeping roots from beneath the pavement; and, in the northern United States, preventing vegetation build-up that could trap and accumulate drifting snow on the pavement. Way (*246, 249, 251*) has been especially helpful in reviewing these practices in England.

Providing a pleasing aesthetic experience for users and nonusers is another important management consideration. In the past, neatness was stressed, and this led to endless miles of rights-of-way planted with a limited number of nonnative grasses kept short and "weed" free by frequent close mowings or liberal, indiscriminate applications of

herbicides. The results were monocultures of benefit to relatively few species rather than a diverse environment of general ecological benefit. The escalating costs of trying to make rights-of-way look like lawns, coupled with increasing interest in multiple use of these areas, have brought dramatic changes in management in many states.

Biotic effects, are discussed, as follows, in terms of effects on plants and on animals.

1. *Plants*

Effects of freeways on plants vary. For the purposes of this report they are grouped into the following: a. diversity (how a freeway may cause a more diverse environment); b. preservation (with examples of how freeways have helped maintain disappearing species); and c. firebreaks.

a. *Diversity.*—It is considered sound ecological management to encourage a diversity of plant species, which, in turn, may produce a diversity of wild animals dependent on them. Freeway rights-of-way offer a significant acreage where such a diversity can be realized—for example, in heavily built-up urban areas, rights-of-way may be among the few suitable growing sites for vegetation; in uncultivated forested or arid regions, rights-of-way may be planted with species that do not occur naturally, again providing diversity.

Freeway rights-of-way are sometimes the largest pieces of land suitable for plants in heavily built-up urban regions (*54*). Interchanges, in particular, provide large blocks of growing space. When land is acquired for new freeways, highway departments often must purchase irregularly shaped land parcels, only parts of which are needed for the freeway itself. If these parcels are retained instead of being resold, they can be converted into small parks and gardens. If wide rights-of-way are acquired, these parks can be of substantial size—for example, a Garden State Arts Center of 250 acres is proposed on the right-of-way of the Garden State Parkway in New Jersey; it will include a botanical garden and nature trails (*20*).

The Bronx River Parkway in New York City is an early example of the potential value of an improved highway. Constructed in the late 1920's and early 1930's, the parkway replaced a decaying slum area with a beautiful tree-lined road. The public gained access to the water's edge in a park-like setting; and today the area produces wild Canada geese despite the high human population densities.

Unfortunately, high land values in cities usually make it unfeasible to acquire wide rights-of-way. Sometimes no land at all is available for planting, or at most only enough for a single line of trees or shrubs. Plants in urban rights-of-way must be able to tolerate a high level of air pollutants from vehicles, and, in more northern climates, heavy applications of deicing salts. Planting and maintenance are very difficult on highway segments involving extensive cut and fill.

A different kind of diversity may be realized on rights-of-ways in open, arid, or highly cultivated lands by planting species that grow sparsely or not at all in the surrounding area. For example, a chain of conifers, deciduous hardwoods, flowering trees, and shrubs has been planted along Interstate 80 in western Nebraska as part of the Chain-of-Lakes project. Besides providing scenic diversity for motorists in a monotonous landscape of semiarid grassland, the plantings offer cover and food for wildlife (*255*). Graham (*82*) noted that shrubs and trees planted alongside highways across the barren Texas plains supported many birds. Trees and shrubs planted in roadside rests are important for more than the shade and windbreak afforded to travelers. Unfortunately, mowing practices frequently exclude shrubs from roadsides.

Although exotic species may be beneficial to the environment, often they are not. In general, it is preferable to use native species on rights-of-way.

Diversity may sometimes be brought about inadvertently. For example, in the arid Southwest, native shrubs grow more densely along paved roads than they do in the surrounding desert. Roadside creosote bushes in California's Mohave Desert tend to be larger and keep their leaves longer. Runoff of rainwater from the pavement and translocation of water to the subgrade under the pavement (because of the thermal gradient created by different solar energy absorptive characteristics of the pavement and the adjacent soil (*114*)) give these shrubs a significant advantage in their harsh environment.

In response to rising maintenance costs and the realization that rights-of-way can be put to multiple use, state highway departments are making increased use of native vegetation; sometimes it is possible to leave much of the original vegetation. The western part of the New York State Thruway (I-90) is an outstanding example, often mentioned as an exceptionally pleasant freeway driving experience. A large part is through forests; the trees have been left on the right-of-way and in the median, relatively untouched except for selective cutting, and the fences outlining the right-of-way are set in the woods about 50 ft from the edge of the pavement. Parts of the Johnny Appleseed Highway (US 33) in Ohio have an unusually wide right-of-way that has not been artificially planted; these portions are said to be more attractive than the planted segments (*87*).

Several eastern states are now making extensive use of native vegetation and natural succession on rights-of-way, including Maryland (*67, 68*), Tennessee (*29*), Kentucky (*74*), North Carolina (*185*), and Wisconsin (*187, 188*). On some sites, native species may be able to reclaim grass sods seeded for initial erosion control. In other instances, woody plants must be hand planted. Mowing is reduced or even eliminated on more inaccessible parts of the right-of-way. Wisconsin has a program for maintaining brush cover on its non-Interstate rights-of-way (*28, 97*). Grasses and legumes are planted to attract wildlife as part of the program.

Often it is not feasible to allow nature to take its own course in revegetating a rght-of-way. One reason is that road cuts must be revegetated as quickly as possible after construction to minimize erosion. Native plants may not be able to establish erosion-resistant cover swiftly enough in such poor growing situations. Nor can large or even small trees be permitted to remain or grow to maturity immediately aside the pavement because of hazards to motorists. Thus, right-of-way vegetation usually must be managed; but one should not attempt to totally dominate natural processes. Rights-of-way maintained as neat,

closely mowed lawns or sprayed indiscriminately with herbicides to destroy "brush" (a common practice in the 1950's) have little ecologic value and are very costly.

Landscape architects and maintenance personnel working for state highway departments are now cooperating with plant ecologists to find techniques for taking advantage of natural processes in right-of-way management. Egler (*63, 64, 65*) has been a pioneer in developing a management concept that involves establishment of persistent native communities and sparing use of herbicides against selected unwanted plants. In experiments on abandoned fields and a powerline right-of-way in Connecticut, young trees were selectively killed with herbicides 15 to 20 years ago. With this initial elimination of competition, native shrubs established dense, continuous growths able to resist invasion by new tree seedlings. Moderately stable native grasslands also evolved. The technique allows rights-of-ways to support a great diversity of low growing plants—including grasses, ferns, flowering and berry-producing shrubs, and small trees. Highway rights-of-way managed in this way would have natural beauty and be of great value to wildlife (*154*).

b. *Preservation.*—Freeways affect rare, endangered, and uncommon species of native plants, as well as the natural assemblages of vegetation that ecologists call plant communities. Roadside rights-of-way can be among the last places where native plants can grow in intensively developed regions where almost all the land is cultivated or preempted for other uses. This is true of the lower lying portions of Great Britain, where many rare plants grow on long, established rights-of-way. Way (*250*) has compiled charts of unusual and rare plants growing on roadsides in England, along with summaries of what county highway departments are doing to preserve them. Because of their value as "native reserves," right-of-way management in Britain has been well studied, particularly by Way (*245* through *251*). He has investigated different techniques of mowing to determine which do the least damage to the existing diversified vegetation while keeping unwanted species out. He has also tested various herbicides and growth retardants. He recommends using grass species with naturally short blades (a given grass blade grows only to a certain length whether or not it is cut) where periodic mowing is required—both to reduce mowing costs and to avoid disturbance of desirable wild species. As a result of this kind of research, it is now possible to to assist desired native plants in reclaiming new rights-of-way.

As the United States becomes more densely populated, use of freeway rights-of-way as special habitat will gain in importance. For example, the Minnesota Highway Department recently revised its spraying and mowing policies. Rights-of-way are now usually managed to blend in with the surrounding landscape. Mowing is kept to a minimum, and selective "spot spraying" enables native plants to reestablish themselves more quickly on recently constructed right-of-way. The Minnesota Highway Department and the Federated Garden Clubs of Minnesota have embarked on a joint project, "Operation Wildflower" (*76*). In this case, Garden Club members provide wildflower seeds, some of which will be gathered from the fields, and the Highway Department will do the planting.

In some instances transportation corridors have helped preserve native floras. When the white man reached North America, the entire central part of the continent was covered with a sea of prairie grasses. Since then, much of the tall grass prairie has been virtually wiped out; of the 250 million acres that once existed, only a few patches remain in old cemeteries, railroad rights-of-way, and other fragments of land. The wide rights-of-way associated with modern freeways might have served as a protective reservoir of the various prairies. Unfortunately, by the time the Interstate Highway System was approved, there was little tall grass prairie left to save.

However, freeways are of value in the growing interest in prairie restoration. Prairie grasses and broad-leafed herbs provide forage for livestock, habitat for wild animals, control of erosion, and are aesthetically pleasing (*151*). Tough and adapted to local weather conditions, prairie grasses can often perpetuate themselves better on suitable sites than exotic species can. Once established, mowing can be minimized or even dispensed with except along the berm. Unmowed rights-of-way provide food and cover for game birds, including the prairie chicken, an endangered species in parts of its range. Fire can be used for maintenance and control because prairie communities are fire-adapted. Native grasses are excellent in holding and building up the soil.

Visiting the remnants of the original prairie, botanists have collected seeds and are experimenting with mixtures for use in pastures, home gardens and yards, and roadsides. Obtaining large quantities of seed, however, is still a problem because most commercial seed producers lack experience with native varieties and do not grow them. The Soil Conservation Service is domesticating prairie plants for use on rights-of-way (*136*). Several thousand acres of grass, including native species, are planted for seed production in the Texas Panhandle and can be purchased by highway departments (*59*).

The Iowa State Highway Commission and the Department of Botany and Plant Pathology at Iowa State University have collected the seeds of more than 65 prairie species. These were planted in experimental plots, and, beginning in 1967, large-scale planting of prairie grasses on Interstate rights-of-way was begun, starting with the Loveland Overlook along Interstate 80 in western Iowa (*56*). Biologists are also experimenting with tall and medium-height grasses along county highway roadsides in Linn County, Iowa (*151*).

In areas that are heavily suburbanized or likely to become so in the foreseeable future, rights-of-way can maintain native species. As discussed earlier, in the acquisition of land for new freeways, complete or severed parcels of land must be purchased even though only a part is required for the roadway. Highway departments generally sell this remnant or excess land. In Maryland, before any such parcel is sold, the Bureau of Landscape Architecture of the State Road Commission inspects it to determine if it has present or future landscape or scenic value. Hundreds of acres have been retained for use as highway buffers, small parks, rest area sites, and other public uses (*8, 9, 10*). The Baltimore-Washington Parkway right-of-way shields the suburbs through which it passes with a wide strip of native trees and shrubs. This right-of-way is now one of

the only remnants of the original vegetation in the more built-up suburbs.

Use of native grasses and other plants is not entirely free of problems, however. Some people regard all unmowed or unknown plants as weeds, and may demand that rights-of-way be closely mowed to make them look neat. It may be necessary to educate the public on the importance of prairie grasses and other native species. An indication that such education can be successful comes from an experiment in North Dakota. Alternate patches of right-of-way along I-94 were left unmowed in the spring and early summer to improve the nesting success of game birds that utilize the rights-of-way. A majority (82 percent) of 182 motorists interviewed had not noticed the unmowed segments, but said they preferred the mowed plots when asked to make a choice. Many wanted to change their answers when they learned of the value of delayed mowing for wildlife (*157*).

Farmers may also object to limited mowing and spraying programs, fearing that rights-of-way may become reservoirs of weeds that can then infest adjacent croplands and pastures. Way (*247*) has reviewed this issue in Britain, and he believes farmers do have reason for concern but that their fears are exaggerated. Gabiou (*76*) touches on the same problem in Minnesota.

Rights-of-way are often harsh environments for plants. They may be too hot, too cold, too wet, or too dry. During construction most, if not all, of the topsoil may be removed, and the structure of what is left is disrupted and compacted by heavy grading equipment.

Many prairie grasses and desirable wildflowers are perennials and take at least two years before they produce seed and flowers. As much as five years may pass before prairie grasses are so well established that they crowd out annual species, some of which may be unwanted weeds. From then on, prairie grasses can resist invasion by undesirable herbs.

As any botanist knows, it is often extremely difficult to artificially construct a suitable habitat for a desired plant. The seeds of some wild plants will germinate only under specialized conditions. For example, attempts to seed sumac on roadsides in Minnesota have been unsuccessful because the thick seeds coat must be weathered and cracked before it can germinate. In nature, this is accomplished by periods of freezing and thawing. Ways that highway maintenance crews can artificially crack the seed coats are being investigated since 1974 (*76*).

Marshes and brushland can also be preserved in freeway rights-of-way. For example, many areas bordering the Susquehanna and Chenango River in New York are swamps and brush-covered sites that provide wildlife habitat. In improving Route 17, the entire area between the edge of the roadway and the edge of the river was acquired whenever possible. Thus, the land was preserved from future development (*72*). Over-all, though, new freeways have destroyed far more wetlands than they have preserved.

Firebreaks.—Freeways and their rights-of-way are effective fire breaks in fire-prone regions. This has proven to be so evident that roads are often used as boundaries in managed burns. They also make possible speedy transport of men and equipment to the scene of a forest or brush fire.

2. *Animals*

Benefits to wildlife accruing from freeway construction generally depend on the width, topography, geographic location, soil configuration and vegetation of the right-of-way. Proper planning, design, care in construction, and subsequent right-of-way management will also influence the benefits to wildlife. All animals must have food, shelter, and a place to breed. If a freeway right-of-way supplies one or more of these needs to an animal species, it has the potential of benefiting them, especially if it is an item lacking in the existing environment.

Some wildlife species will be benefited by freeways without specific planning, but the adverse effects will usually outweigh the benefits unless new freeways are routed and managed with wild plants and animals in mind. Some of the more important adverse effects are:

1. Changes in land use patterns brought about by greater accessibility of undeveloped areas and agricultural lands, resulting in the destruction of wildlife habitat.
2. Destruction of wildlife habitat by the new freeway. The routing of new freeways through coastal wetlands is a special problem.
3. Severing seasonal migration routes. This has been a problem with deer and other large-hoofed animals in the West and with amphibians and turtles separated from the ponds in which they breed.
4. Pollution of air by vehicle emissions; and of water by sediments, deicing salts, oil and grease, toxic metals, and other contaminants.
5. Destruction of fresh-water habitat by shortening and channelizing rivers and streams.
6. Mortality of wildlife attributable to highway vehicles. McHarg (*135*) outlines techniques for minimizing the adverse effects of freeways and maximizing benefits.

Freeway rights-of-way may be beneficial to wildlife in both rural and urban environments, but they are likely to be most significant in urban and highly cultivated regions where living space for animals is scarce. As mentioned in the section on plants, rights-of-way are important in densely populated Britain, especially in areas where almost all of the land has been preempted for nonwildlife uses. Way (*245*) found that 20 of 50 British mammals, 6 of 6 reptiles, 40 of 200 birds, 25 of 60 butterflies, and 8 of 17 bumblebees breed on rights-of-way or on the closely associated hedges and ditches.

Few studies involving formal tabulation of data have been done on the effects of highways on wildlife in the United States. Most of those that do exist are counts of animal carcasses on highways or casual observations. Apparently several studies are in progress now, but have not yet been published. Among these are studies of the impact of freeways on small mammals and songbirds in northern Maine (conducted by the Maine Cooperative Wildlife Research Unit at The University of Maine), Orono, and in northern West Virginia (conducted by the Division of Forestry at West Virginia University).

a. *Terrestrial Animals.*—

a.1. Food. Animals may feed on plants growing on the freeway right-of-way and along the margins of artificial

ponds created during freeway construction. The plants growing on freeway lands are considered, for the purposes of this report, to be a naturally occurring food source regardless of whether the plants were established as a consequence of natural seeding or were planted by man. In contrast, animal feeding may be enhanced by food that is introduced to the animal's environment through operational aspects of the freeway, such as grain spills, and grit for gizzard functioning.

Some wildlife species utilize the plants occurring on freeway rights-of-way, including those that are planted with or without wildlife needs specifically in mind, as well as the adventitious grasses and legumes. Pennsylvania deer along I-80, where the road passes through heavily forested areas, comprise a notable and troublesome example. Deer are numerous; and deer food is in short supply in this region. Deer do not merely cross the freeway but regularly visit the right-of-way to feed on the grasses, legumes, and other cover planted there.

> The rights-of-way may be visualized as long narrow pastures bisected by high-speed highways. When deer wander about these pastures they follow the natural and man-created contours of the rights-of-way (including the median strip) and thus provide a hazard to the driver. Because the pastures are narrow, the chances of deer crossing the highway are high, further increasing the hazard (*23*, p. 16).

Fewer deer were seen and less mortality occurred on another segment of the same freeway in an agricultural area where deer food is abundant off the right-of-way. Because of the hazard that deer-vehicle collisions entail to property and human lives, deer could be permitted to feed on rights-of-way only if a means of keeping them off the pavement were devised. Fences do keep some deer off the freeways, but many manage to get past them. Bellis and Graves (*23*) have suggested putting fencing along the shoulder of the road rather than at the edge of the right-of-way. Puglisi, Lindzey, and Bellis (*170*) studied the frequency of deer kills along I-80 across the entire breadth of northern Pennsylvania and its relation to the type and position of fencing and the kinds of vegetation. The location of the fencing was found to be the most significant factor influencing mortality. Kills were most frequent where fences barred deer on forested areas from desirable food on the rights-of-way. If fences could be suitably designed and positioned, freeway rights-of-way might eventually become an asset to deer. However, most research so far has concentrated on ways of keeping them off the rights-of-way entirely by fencing or by planting vegetation unpalatable to deer.

Some microtine rodents, also known as meadow mice or voles, have benefited from grass-planted freeway rights-of-way that are not managed for wildlife (*19*). Stands of introduced grass that are not grazed, or mowed, or otherwise disturbed are the best habitat for these grass-eating mice (*218*). The clearing of the eastern forests and their partial replacement by pastures, and the tens of thousands of acres of highway and railroad right-of-ways, have allowed certain meadow mice to significantly increase their numbers. Mice (*Microtus pennsylvanicus*) captured in Wisconsin were presented with an assortment of native and nonnative food plants and their choices recorded. Introduced grasses and legumes, including bluegrass, quackgrass, and brome grass, were preferred over prairie grasses and native herbs. The first choice was white clover picked from roadside gravel with a minimum of organic matter, nutrients, and moisture. Meadow mice collected in stands of prairie grass also preferred nonnative grasses even though they had never eaten them before. Meadow mice, some deer mice and white-footed mice, and shrews probably have higher population densities on rights-of-way than in the adjacent countryside. Doucet, Sarrazin, and Bider (*57*) found that overpass embankments support large numbers of meadow mice and woodchucks in southern Ontario and Quebec.

Birds of prey that eat meadow mice may be indirectly benefited by freeway rights-of-way. Kestrels (sparrow hawks) and other hawks often hunt on rights-of-way in the United States and Britain.

Grain on roadsides, which results from spills from passing vehicles, is important to the survival of Hungarian partridges in the northern Great Plains of Canada and the United States. Here winters are long and very cold, and snow covers the ground for long periods of time. The shoulders of roads, swept free of snow by snowplows, offer a readily available source of food because considerable quantities of grain are spilled from trucks. The birds also find gravel and grit, essential for their digestion, along highways (*238, 252*). Undoubtedly, other seed-eating birds, including pheasants and other species of grouse, sometimes make use of spilled grain on roadsides and use highways as a source of grit.

a.2 Cover. Freeways and associated structures, as well as the physical and biotic features of the right-of-way, can enhance the habitat of terrestrial animals. Beneficial effects by which freeways contribute to or provide cover for animals are: (1) structures that provide nesting and roosting sites, (2) soils (especially embankments) that are used for burrows and nesting sites, and (3) vegetation in the right-of-way that provides cover for nesting and escape.

Highway bridges and overpasses provide shelter to several species of birds and certain mammals and reptiles. Structures suitable for wildlife use must have spots relatively inaccessible to predators and human intruders (especially children), should be sheltered from extremes of temperature, and have ledges or rough surfaces to which the animals can cling or build their nests.

Bats often use highway bridges for temporary night roosts, and can utilize some of them for shelter during the day. In Arizona, bats use two types of concrete bridges for day-roosts (*47*): (1) open expansion joint bridges that have one or more open transverse joints that are closed above by paving material but open below, allowing the bats to enter; and (2) open end bridges, with inspection openings at each end, which lead into rather large cavelike chambers within the terminal foundations. Newer types of bridges with longitudinal metal undersupports are not usable as day roosts.

Several insect-eating birds attach their nests to the undersides of bridges. In general, wooden bridges provide the best nest sites, old style concrete bridges are moderately good, and steel bridges are the least useful. Cliff swallows, barn swallows, phoebes, and the red-shifted flickers often

utilize bridges. In the West, water ouzels use bridges over water for nest sites. In urban areas, pigeons, starlings, and house sparrows may roost and nest under highway structures.

Phoebes and barn swallows also nest in concrete highway culverts. The cave swallow, which once nested only in the twilight zone of caves, has learned to use rectangular culverts and has expanded its range in southern Texas (*139*). Birds normally do not breed in smooth metal culverts because they cannot attach their nests to the sides.

Bridges, overpasses, and culverts could be slightly altered to make them useful for roosting and nesting by desirable species of bats and birds. Phoebes and barn swallows abandoned their natural nesting sites long ago and are almost completely dependent on man-made structures today. They are now losing their nest sites as old-fashioned small wooden bridges and open barns and sheds are torn down. Old style small highway bridges are being replaced with round pipe or concrete culverts that are cheaper to install and maintain but cannot be used by birds. In an attempt to replace the lost habitat, Whitaker (*254*) designed simple wooden nest supports that can be nailed or screwed into the tops of culverts. The eastern phoebe and barn swallow in Delaware readily nested on these supports.

It has long been known that vertical barn walls and similar structures can be made usable for cliff swallows merely by nailing up horizontal strips of wood on the outsides so that the birds can attach their nests (*36, 142*). Six-in. wide shelves within barns or nailed 8 in. under the eaves will make the same barn suitable for nesting barn swallows and phoebes. It would probably be simple to design highway bridges with built-in nest supports and ledges for these species.

As of 1974, Delaware has made it State policy to install nest supports in all new culverts and to provide nesting areas under new bridges as they are built. Maryland and New Jersey are considering adopting a similar policy (*254*). Boy Scouts, conservation groups, and interested individuals could be recruited to install supports in existing culverts. Nest sites of many species are limiting factors in population growth; this situation could be improved by incorporating nesting needs in design and management.

For some burrowing mammals, birds, and reptiles, highway embankments and roadcuts are excellent digging and lookout sites.

Pocket gophers in parts of the Southwest have used highway rights-of-way to extend their ranges across areas unsuitable for digging. This phenomenon is discussed in greater detail later.

Woodchucks and their burrows were observed on 21 freeway overpass embankments in Ontario and Quebec (*57*). The average density of woodchucks was estimated at 45 per 100 acres, much higher than estimated densities on open flatlands (10 to 18 per 100 acres). The sand used in most of the embankments seemed to be favored by the animals. The well-drained slopes, abundant food, suitable sunning sites, freedom from agricultural activities, ban on hunting, and good visibility (enabling the woodchucks to watch out for predators) make embankments excellent woodchuck habitat. However, many predators including hawks, dogs, cats, foxes, and possibly coyotes hunt on the embankments. Probably, they are attracted by the large numbers of meadow voles (*Microtus*) more than by the woodchucks.

The right-of-way of the Taconic Parkway in New York State is another good area for woodchucks. In 1962 a population of approximately 2 per 100 acres was estimated (*138*). This is much lower than the estimate from southern Canada by Doucet et al. (*57*). Although rights-of-way may benefit burrowing animals and motorists who enjoy seeing wildlife along the highways, woodchucks may be traffic hazards and cause maintenance problems. Since woodchucks do not hesitate to cross the pavement, roadkills may be the most important cause of death.

Swallows whose nests are in burrows dug in embankments sometimes use roadcuts in proper substrate. Spencer (*206*) located 26 bank swallow colonies in Pennsylvania and Vermont. All but one were in man-made excavations; five of them in road cuts. The bank swallow, which nested exclusively in river banks before the white man provided artificial banks, prefers a sandy-loam cut with a southern or eastern exposure. The rough-winged swallow also nests in burrows in roadcuts.

Various kinds of lizards in Africa use the built-up edges of roads for surveying their territories and digging shelters, and hunt their insect prey on the roads (*166*). Lizards in certain parts of the United States may do the same.

Properly managed rights-of-way are clearly beneficial to nesting ducks, pheasants, and other groundnesting birds. This has been documented in experiments on the Great Plains and Midwest.

Between 1968 and 1970, a study was made to determine the effects of reduced mowing on a 23-mi segment of the right-of-way of I-94 in South Dakota (*37, 157, 158*). The freeway runs through rolling grasslands with many potholes that are homes for several kinds of ducks. At the time the study was done the right-of-way was kept closely mowed, either by adjacent landowners who used them for hay or by the North Dakota Highway Department. The authors knew of many studies in the prairie states and provinces that showed that game birds often selected rights-of-way as nesting sites even though their acreage was small in comparison with the total areas studied.

Alternate miles on both sides of the Interstate were left unmowed from September 1967 to the end of the experiment. Both the unmowed and mowed plots were searched three times a year for nesting ducks, and to determine whether or not the eggs hatched. In the first year, 74 percent of nesting ducks were found on the unmowed segments. In the following two years, even more ducks chose the unmowed segments. More nests were successful in the unmowed plots, and they suffered less predation, possibly because traffic frightened predators away. Many other birds nested on the rights-of-way, including upland plovers, bitterns, sharp-tailed grouse, and pheasants.

Page and Cassel (*161*) found that a railroad right-of-way was also valuable to nesting waterfowl. Portions of the right-of-way were mowed for hay; others were not. Almost six times as many nests were found on the unmowed segments as on the mowed. The unmowed portions pro-

duced six times as many ducklings per acre. Again, these findings are applicable to highway rights-of-way.

On the basis of these results, the North Dakota Highway Department altered maintenance practices on 78 mi of Interstate right-of-way by delaying and reducing mowing. Wildlife ecologists could probably suggest similar studies and probable benefits in every area of the country.

Pheasants are another beneficiary of reduced mowing of rights-of-ways. Hen pheasants in two study areas in Nebraska selected roadsides for nest sites two to nine times as frequently as other cover types, even though roadsides constituted only 1.36 percent of the study areas (*21*). Hoffman (*98*) recommends that roadsides in Colorado should not be mowed before early August or sprayed with herbicides if they are tc be optimum nesting sites.

In Illinois, a considerable acreage of former nesting areas for pheasants was being destroyed as farmers converted from hay, pasture, and small grains to row crops (*111, 112*). Some roadside segments were seeded to a grass-legume mixture and left unmowed until after August 1; others were not seeded, but mowing was delayed until the same date. The remaining roadsides in the study area were mowed as usual, beginning in May or early June. Whereas 3.0 nests per acre were established on the seeded roadsides, and 2.0 per acre on the unmowed, unseeded roadsides, only 1.5 nests per acre were found on the mowed controls. Nests on the seeded, managed rights-of-way were only slightly more successful than on the managed and unmanaged controls, but the greater density of nests resulted in an over-all greater productivity of chicks. The cost of tilling and seeding the roadsides was estimated to be about $139 per mile for each side of right-of-way, which varied in width from 8 to 25 ft (3.1 acres per mi). The cost might be reduced as much as 50 percent by modifying the seeding operations to eliminate application of lime, fertilizers, and chemical defoliants (*113*).

South Dakota hen pheasants often selected roadside ditches for night roosting (*86*). The nesting ducks and pheasants in the previously mentioned studies also favored ditches, with their dense growths of vegetation.

In southern and western Minnesota, pheasants and jackrabbit numbers declined 80 percent between 1960 and 1971 as fields of small grain and hay and pastures were replaced with row crops (*144*). Today, roadsides are the only permanent nesting habitat remaining in that part of the State. However, only 30 percent of the roadsides there provided good nesting cover in 1973; the rest had lost their value to wildlife because of excessive mowing, spraying, burning, grazing, or planting to crops. The Minnesota Highway Department, the Soil Conservation Service, and the Department of Natural Resources are cooperating in studying landowner attitudes toward roadside management and in printing a brochure on management of roadsides for wildlife. In the summer of 1975 college students were scheduled to survey randomly selected roadsides for wildlife use.

Many midwestern states have adopted an arrested mowing program to improve game bird habitat, including Minnesota, Illinois, North Dakota, South Dakota, Nebraska, and Ohio. The program also benefits highway departments by sharply reducing mowing costs.

Dense right-of-way vegetation may also shelter undesirable species. In State College, Pennsylvania, roadside plantings of crown vetch were the nucleus of a rat problem because the vetch banks supplied denning cover. Rabbits, mice, and gophers sometimes damage or kill vegetation planted on roadsides and medians in Minnesota (*149*). The problem is most troublesome in metropolitan areas where natural predators are scarce.

a.3. Dispersal and Range Extension. Freeways can have noticeable effects on the movement of individual animals and on the entire populations or species. Whether the effect is beneficial to the animal or species being considered depends on whether it makes use of the right-of-way and travels parallel to the pavement or perpendicular to it. Parallel use is often beneficial; perpendicular use is often harmful.

Right-of-way corridors in suburban areas that are planted with shrubs, tall grass, or other cover may make possible the survival of certain medium-sized mammals, including skunks and raccoons, which use them as corridors in their day-to-day activities.

Certain birds and mammals have extended their range within historic times via highway rights-of-way. In 1928, pocket gophers (*Thomomys*) began to extend their range across a 50-mi stretch of sandy desert in southern California between the High-Line Canal and the Colorado River near Yuma, Arizona (*104*). This area does not have enough soil moisture or desert plant life to support gophers, although other rodents better adapted to the desert do live there. At first a primitive dirt road let across the hills, which was replaced in the 1920's by an oiled plank road. In 1928, a concrete road was completed, and within 12 years the gophers had advanced 37 mi eastward from the canal. While the other rodents suffered a huge loss because of traffic, gophers, which rarely travel above ground, did not. Huey (*104*) attributes the gopher's success to two factors: increased soil moisture and the resulting luxuriant plant growth.

Pocket gophers (*Thomomys bottae*) have greatly increased their range and numbers on the Edwards Plateau in southwestern Texas. The suitability of highway rights-of-way for gopher burrows is apparently the reason (*45*).

Highways have played a role in the range extension of the cave swallow into central Texas. The bird formerly nested only in twilight zones of caves and sinkholes in karst areas in Texas and New Mexico, although it has been known to nest in houses in Mexico. Now the bird has begun to use rectangular highway culverts and has expanded its range (*139*).

Some animal species may have invaded new territories via highway bridges. In Africa, road bridges may permit animals, such as baboons, to cross large perennial rivers, and may even permit species to colonize new areas (*166*). For many years kangaroo rats (*Dipodomys ordi*) had been blocked in their northward dispersal in the Pacific Northwest by the Columbia and Snake rivers. Perhaps the rats used a half-mile long highway bridge to cross the Snake near its mouth; but it is possible that they were carried across on farm trucks or floating debris (*32*).

The California ground squirrel (*Citellus beecheyi*) has also been extending its range northward in historic

times. About 1915, the animal crossed the Columbia into Washington near White Salmon, and by the mid-1950's it had spread at least 45 mi north of the entry point (*32*). Again, bridges may have been the key to range extension.

b. *Aquatic and Amphibious Animals: Habitat Enhancement.*—The general effects of freeways on aquatic and amphibious animals have been summarized earlier.

Montana's Stream Preservation Law is an outstanding example of how state fish and game and highway departments can cooperate in the planning of new highways to reduce losses of aquatic life or even use highways to benefit wildlife (*164*). The law was first passed by the State legislature in 1963 and reaffirmed in 1965 after a 2-year trial period. In 1963, the Montana Fish and Game Department made a survey indicating that 354 mi of river channels had been altered by highway construction in recent years. Other studies showed that the altered channels had one-fifth the number of game fish and one-seventh the weight of game fish of natural channels.

The law requires that the State Highway Department notify the Fish and Game Department of all proposed highways upon completion of preliminary design and before final design begins. Between 1963 and 1969, the Fish and Game Department reviewed legal notices for 259 projects. One third of these were earmarked for special consideration.

In some, substantial alterations were made to the original plans. Road alignments have been moved to avoid encroaching on rivers. New artificial meanders have been built to replace those destroyed during construction. In other instances, extra bridges have been constructed to preserve existing meanders. Bushy floodplain vegetation destroyed by construction has been replaced. Channel excavation has been limited to times when fish are not spawning. The Highway Department can purchase land parcels cut off by new highways and turn them over to the Fish and Game Department for management.

During periods when fish are quiet and not feeding, they often retreat to deeper pools and shelters where light intensities are lower. These spots frequently are under bridges, especially if large rocks and stumps are lodged there. Predatory fish may use such places to conceal themselves, and many cold water fish seek shade in these pools during the warmer periods of the year.

Abundant roadfill is essential for freeway construction. Some of this fill is derived from roadcuts, but much also comes from borrow pits. Borrow pits are frequently excavated where there is abundant, easily obtained gravel adjacent to the freeway under construction. Generally, borrow sites are selected because they are the most economical sources of fill, and ecological factors are not an important consideration. Often these sites have a high water table and quickly fill with water from spring seepages. The contractor may continue removing gravel from the pit until the rising water level becomes a significant hinderance, or he may continue to remove fill by dredging. Other borrow pits with relatively impermeable bottoms can collect and store water.

The fill derived from roadcuts and borrow pits is used in constructing elevated roadways, overpasses, and interchanges. These embankments will collect and store runoff unless provision is made to drain them. Since diking and damming is a standard procedure in wildlife refuges, there is an opportunity for highways to be utilized in this capacity, as has been done in a number of states.

Abandoned borrow pits that fill with water are often capable of supporting fish, waterfowl, and other aquatic and marsh-dwelling animals. With the increasing destruction of natural wetlands by intensified agriculture and spreading urbanization, these man-made ponds could be important for breeding and migrating ducks and for amphibians in the future.

One of the most ambitious projects is the Nebraska Chain-of-Lakes along I-80 from Grand Island to Chappell in the western part of the State (*105, 208, 255*). This portion of the freeway traverses the valleys of the Platte River, the South Platte River, and Lodgepole Creek. The valleys are filled with deep deposits of sand and gravel laid down by the action of glaciers and rivers from the Ice Age to the present time. The streams themselves are wide and shallow, and there may be no surface water in dry periods. Underground, the porous fill is saturated with water. The ground water level is usually just below the surface, and any excavation fills with water and maintains the same level as the ground water height in the vicinity.

The Chain-of-Lakes is an outstanding example of cooperation between the State Game and Parks Commission, the Department of Roads, contractors, private land owners, and communities along the freeway. The then Director of Game and Parks, approached the Department of Roads and the Governor requesting that dredges be used instead of conventional earthmoving equipment so that a 200-mi-long chain of artificial lakes could be created along the new freeway. Eventually the Department of Roads adopted the plan. The water-saturated gravels and sands they excavated were actually a help in highway construction.

Originally some of the borrow pits to be excavated were at a considerable distance from the new freeway, but the Chain-of-Lakes plan called for their location alongside it when possible. Provisions were made to purchase land immediately alongside the highway, dig borrow pits there, and give the Game Commission title to the land and pits. Hauling fill from distant pits as originally planned would have been very expensive. Under the new plan construction costs for the freeway were reduced, and at the same time the State acquired land of great value for wildlife and recreation.

Most of the lakes, which range in size from several acres to more than 50 acres, have been stocked with fish and are open to fisherman. During the spring and fall migrations, many waterfowl and other aquatic birds take advantage of the lakes.

The largest borrow-pit ponds are adjacent to interchanges, which required the greatest amount of fill. Some of these have been developed into roadside parks, the so-called "Road Ranches" with facilities for overnight camping, picnicking, swimming, and fishing.

In Montana, the Stream Preservation Law has made it possible for the Fish and Game Department to buy land cut off by highways. Land adjacent to the Clarks Fort River that was cut off by I-90 includes borrow pits that have been converted into duck ponds (*164*).

Five and one-half miles of I-40 in Arkansas have been constructed on 264 acres of the Wattensaw Game Manage-

ment Area. The Arkansas State Game and Fish Commission worked in cooperation with the State Highway Department to select borrow pit sites that were ultimately developed as small fishing lakes. As a result, the Wattensaw Game Management Area gained 9 small lakes that have been stocked and opened to fishermen (*234*).

The Connecticut Board of Fisheries and Game and the Water Resources Commission have been involved in the development of borrow-pit ponds. Borrow pits for the Illinois Toll Road near Chicago have been developed into ponds and have been turned over to the Cook County Forest Preserve for recreational use.

Heusmann (*88, 89*) and Moulton (*147*) studied 8 ponds created during construction of I-71 in the Connecticut River Valley, Massachusetts. They had been excavated in 1959 and 1960 in deep beds of glacial gravels and sands with a high water table. The larger ponds (up to 15 acres) and those rimmed with aquatic vegetation attracted waterfowl during the spring and fall migrations. Three nearby older artificial ponds that were not a product of highway construction had more birds in the spring migration, probably because they were in a more advanced stage of ecological succession and offered the birds more food and cover. During the fall, however, the largest borrow pit pond (the only one with waterfowl) attracted more birds than the older ponds, perhaps because hunters did not harass them there. (Hunting is prohibited within 500 ft of any paved road in Massachusetts).

Moulton makes several recommendations to those who would like to make use of borrow pits as fishing ponds. He stresses that the location of the pit is most important. Studies of soil chemistry and land use should be made before sites are selected for borrow pits. He gives specific details on how the ponds should be graded and ideal depths. Fish should be introduced in accordance with the characteristics of the pond.

Artificial ponds support many other kinds of wildlife, including mink, muskrat, cottontail rabbit, bobwhite quail, raccoon, mourning dove, and many nongame species. The Massachusetts borrow pits were important for recreation as well. Some had been developed for swimming. Nearby residents sunbathed, canoed, rafted, picnicked, fished, gigged for frogs, trapped, watched birds, and engaged in limited hunting around the larger ponds. Some of the ponds can be used for irrigation of nearby farms and for fire protection. They also beautify the roadside.

Highways can do double duty as dams and dikes for impoundments for aquatic and marsh animals. Reservoirs as large as 1,000 acres have been created in this way. An outstanding example is the Thousand Acre Marsh in Delaware, which is diked by a State road. Up to 50,000 ducks have fed and rested on this impoundment at one time. Eagle Feather Lake on the Rosebud Indian Reservation is dammed by State Rt. 63 in South Dakota. It is used for fishing and other recreation. Sullivan (*214*) lists other projects in Pennsylvania, Michigan, and Tennessee. He saw the Interstate highway construction program as a wonderful opportunity to make new reservoirs, especially in areas where natural wetlands and lakes are scarce.

Dikes commonly serve as low standard roads in waterfowl refuges. However, higher speed highways cannot generally be used as dams unless the planners of the highway incorporate that use into its design. Only slight modifications that do not add much to the cost are needed (*214*). These include antiseep drains with a rise, some additional fill, a core trench, toe drains, and perhaps riprapping at the water line. Sometimes these impoundments can also be used to contain flood waters.

In the prairie states aquatic birds make extensive use of roadside ditches. Small marshes and shallow ponds for waterfowl can be established by installing simple water control structures at the heads of secondary road culverts (*223*). Salamanders, frogs, and toads often breed in highway ditches. A terraced, planted roadcut at Etna near Pittsburgh has trapped several small ponds on the "steps" of the terraces. They are used by several kinds of breeding amphibians. Unfortunately, roadside ditches are not necessarily beneficial to wildlife. In Minnesota's 19-prairie pothole counties they have facilitated the drainage of approximately 100,000 acres of natural wetlands that were important to breeding waterfowl (*257*).

c. *Financing Ecological Studies.*—Highway departments may finance ecological studies as a means of finding out about the impacts of existing or proposed freeways on certain animals or entire ecosystems. The studies may go beyond consideration of the freeway itself and produce a great deal of additional useful biological data.

An example is the Desert Tortoise Relocation Project in southern California's Mojave Desert, where a 9-mi segment of State Highway 58 is being relocated. Desert tortoises move in a circular pattern, and highways do not appear to disrupt it. Tortoises that wander across highways are at a mercy of high-speed traffic (*194*). Volunteers, Department of Fish and Game personnel, and faculty members and students from two state colleges are involved in the project of relocating tortoises picked up in a mile-wide corridor along the new highway (under construction as of 1975) to suitable new habitat and finding out if they will stay there or return to their old territories. Some tortoises have been equipped with radio transmitters so that their movemens can be followed at a distance. The ongoing study, entirely funded by the California Division of Highways from 1972 through 1975, has greatly contributed to knowledge of the habitat preferences, feeding, burrow construction, movements, homing and social behavior of this fascinating creature (*27*).

Another example is the two-part study directed by Douglas and Johnson (*58*) of Prescott College. The study was funded by the Arizona Department of Transportation in an effort to predict the ecological effects of two alternate routes for a proposed new highway (State Route 279) in the Verde River Valley in northern Arizona. The highway, which would run through largely undeveloped country adjacent to the Sycamore Wilderness, would provide faster north-south access to Grand Canyon National Park. Environmentalists objected to the new highway, citing possible damage to wildlife as one of their reasons (*258*).

The Prescott College team first studied existing highways in the area. Since they could detect no measurable highway effects on wildlife, density of bird life was correlated with vegetation characteristics. Groups of Prescott College

students made detailed inventories of the vegetation on selected plots along the existing and proposed highway routes. A deer pellet study was done to compare deer usage of various representative areas. They went on to theorize on the decline of the deer population in this part of Arizona between 1960 and 1971. Overhunting, overgrazing by domestic livestock, and climatic changes were identified as the major causes. The team pointed out that overhunting and habitat destruction are an indirect result of new highways. Cottontail and jackrabbit pellet counts were done in an attempt to find habitat preferences. Much of the data is basic and of general interest to ecologists and game managers.

C. Aesthetic Quality of the Environment

Benefits may accrue to highway users and nonusers by enhancing the individual's perception of the aesthetic quality of the environment. Difficulties, however, arise in attempting to clearly define aesthetics; hence, it is necessary to develop a framework for evaluating the aesthetic quality of a highway environment in order to better describe and justify these beneficial effects.

Bagley et al. (*18*, p. 9) has stated that ". . . unlike the definition of pi., explicit definitions of what constitute aesthetics tend not to be accepted as binding outside the particular culture that produced them. . . . Like beauty, then, the word has no clear and agreed-on definition that is operative. . . ." In accordance with *Websters Seventh New Collegiate Dictionary*, aesthetics has been simply defined as "a branch of philosophy dealing with the nature of the beautiful and with judgments concerning beauty."

The aesthetic quality of the environment as related to highways may be considered in several contexts:

1. The perception of the visual quality of the natural or man-made environment as seen from the highway in terms of the forms, lines, patterns, shades, tones, contrasts, and other artistic characteristics that are salient in the landscape.
2. The aesthetic directly related to the highway—specifically, the aesthetics of the integration of the highway alignment with the landscape, the geometric aesthetics of the alignment, and the aesthetics of structural features associated with the highway (bridges, etc.).
3. The aesthetic quality of the environment in the context of the total sensory realization associated with the highway, including the perception of sounds and odors in addition to visual perception.

Aesthetic quality of the environment as discussed in this report has as its central focus the interactions of the highway with the landscape. The artistic elements of visual quality, although not a discrete topic of discussion in this report, are essential to the presentation of highway benefits. For example, the urban freeway may generate visual and functional coherency in the lines and forms that constitute the urban pattern.

The aggregate human sensory response to the highway environment is related to man's comfort, health, and safety, and is manifested in feelings of pleasure or stress. Freeway improvements that ameliorate the effects of sound and glare are considered here to be a contribution to the aesthetic quality of the environment.

Without actually defining aesthetics, Peterson (*165*, p. 14) has established some parameters for relating aesthetics to highways: "Things that are physically discordant, relative to their objectives, are neither good art nor good engineering. To the extent that highways are aesthetically and functionally ugly, they are in discord with the objectives they are intended to serve."

Spooner (*207*, p. 1) provides a history and introduction for the investigation of the positive aspects of the aesthetic quality of the freeway environment, as follows:

> Principles of visual design have existed in one form or another for more than 2,000 years, but, whilst they have continuously dominated the fields of art and architecture, there is very little evidence of their application to roads. Indeed, apart from formal avenues which were conceived for military as much as aesthetic reasons, and a brief preoccupation with sinuous alignment at the height of the English landscape movement, highway aesthetics were not considered until the early part of this century . . . Contemporary highways, designed to accommodate a much greater volume of traffic traveling at speeds in excess of 50 m.p.h., have proved to be incapable of integration in the traditional manner. Their width and comparative inflexibility deny any chance of random adjustment, yet the very restraints which make their assimilation so difficult—the easy gradients, extended transitions and large radius curves necessary for safety at such high speeds—have endowed contemporary highways with a purity of form which has unique aesthetic potential. To exploit this rare potential and at the same time find new means of integration is a task which demands the utmost aesthetic sensibility.

Several problems are evident in assessing and dramatizing the significance of highway aesthetics. Traditionally, it has been difficult to place a value on the importance of aesthetics in highway design, and likewise it is difficult to use preservation or enhancement of aesthetic quality of the environment as a justifying determinant in highway location and design decisions. Yet, it is necessary to consider aesthetic impacts in the same planning context as the more commonly recognized design determinants—such as, an engineer may determine the location of a highway to be impractical when the difficulty in the excavation of underlying material will be extreme and a practical alternative exists; or, the influence of land value in right-of-way acquisition will encourage highway location on least-cost land.

McHarg (*134*, p. 1) has dramatized the need for aesthetics and other "social values" as design determinants as follows:

> The major deficiency in prevailing highway route selection method has been the inability to include social values, including natural resources and aesthetic values, within the criteria utilized. In this study, an attempt has been made to identify components of social values, natural resources, and scenic quality, and to locate these geographically. It is presumed that the area of lowest social value, if transected by a highway, incurs the least social cost. The normal determinants of highway route selection, topography, soils, etc., have been expanded to include management or impairment of ground and surface water resources, susceptibility to erosion, etc. When highway corridors of minimum social cost and minimum

> physiographic obstruction were revealed, they were tested against their effect on scenic values. The object of providing an excellent scenic experience was considered as a social value created by the highway. The corridor of least social cost was next tested against the degree to which it could create new and productive land uses where these would be necessary and welcome. The sum of least social cost and highest benefit alignment was identified. It is described as the rate of maximum social benefit.

Historically, there may have been difficulties in demonstrating the authenticity of aesthetic concerns in highway planning. But, today, there exists little doubt in the reality of these concerns; rather, the problem of incorporating aesthetic quality considerations in the highway design process lies in the difficulty of quantifying the aesthetic factors of the environment in a manner that is universally applicable.

Some factors of environmental quality are not difficult to assess; for example, water quality can be analyzed in a laboratory, the components being universally measured, defined, and discussed in terms of parts per million, etc. The methods by which visual quality is analyzed are less definitive and certainly less widely accepted. Nonetheless, assessment of the visual quality of the landscape is not impossible, and, in recent years, numerous studies (several of which relate specifically to highways) have been done by Leopold (*122*), Jacobs and Way (*108*), Sargent (*184*), Appleyard et al. (*11*), and others (*34, 70, 165, 174, 175, 212, 260*), which demonstrate the potential to assess visual quality of the landscape and evaluate visual impact of land use development. A review and analysis of several of these studies is contained in the EPA publication *Aesthetics in Environmental Planning* (*18*).

In addition to the characteristic problem of finding uniformity and certainty in the definition of aesthetics and the approach to the assessment of aesthetic quality, several other problems have appeared repeatedly throughout the literature search. These problems deal with the validity of beneficial effects found in literature references to scenic highways, design characteristics of freeways, and landscape development. Therefore, it is necessary to qualify the inclusion of literature citations relative to these three areas, and at the same time to reflect the nature of the highway-related aesthetic quality literature in the recognition and discussion of beneficial effects.

The essence of the problem arising in references to scenic highways is the contrast between some highways defined as "scenic roads" and the reality that all highways to some degree are scenic. Beneficial effects relating to the aesthetic quality of "scenic roads" (see *228*) are considered to be relevant to this report, excepting those discussions pertaining to the provision of specialized facilities and structures.

Rapuano (*176*, p. 1) provides a sensible resolution:

> Do we need scenic roads? Perhaps that question is best answered by another question: can we avoid scenic roads? Implicit in the first question is the widely-held notion that scenic attributes are qualities we build into our roads, not unlike the way we determine the concrete mix for an interstate highway pavement or the bituminous pavement for a park road, when in fact the scenic attributes are the inherent qualities of the landscape or environment through which the road passes. To say we do not need scenic roads is also to say we do not need the landscape or environment through which the road passes.

Frankland (*73*, p. 53) has also given definition to this problem in the following manner:

> The compatibility of scenic highways with the basic purpose of highways, allegedly to move traffic, has been questioned. Some make a distinction between the two purposes: people who drive scenic highways are not necessarily interested in going from one point to another; whereas people on primary highways are. The purpose of the scenic highway is viewing, and the purpose of other highways is to move traffic. These two purposes seem inconsistent to some people. . . . Maybe the word 'scenic highway' needs to be clarified. We think in terms of the motorist enjoying a pleasurable experience as he goes from one place to another, whether it is at 80 mph or 20 mph. The standards and criteria for design and beautification and construction all are aimed at making beauty a compatible element of whatever type of highway is planned.

Concerning design characteristics, the comparative advantages of one highway alignment over another cannot be construed to be beneficial effects, although citations of benefits attributable to intrinsic freeway design characteristics have been included.

Several of the beneficial effects discussed in the section pertaining to landscape development, especially those relating to the functional use of plant materials in the corridor, should, in some situations, be regarded as being auxiliary to the highway in nature. These benefits are applicable in the "Complete Highway" context. (The "Complete Highway" is a term coined by the Roadside Development Committee of the Highway Research Board in 1943, and is defined as "the total highway development possessing the optimum of safety, utility, beauty and economy" (*6*, p. 64).)

The relevance of this approach to highway landscape development is seen in the following statement (from *93*, p. 73).

> In our Nation's growing understanding of the need for total environmental planning and design, the highway is not now seen as a right-of-way with a relatively narrow band of pavement and some immediately associated appurtenances, but as one element in an environmental complex—a visual corridor within which roadside development has a major function to provide a transition between the pavement and the adjacent landscape or cityscape, a foreground to the controlled progressive display of natural scenes and man-made developments. In short, we are now more than ever concerned with the 'Complete Highway.'

The applicability of these concerns to the effects discussed in this report is illustrated by a statement of scope of the Roadside Development Committee of the Highway Research Board concerning the committee's range of operation, which includes the following (*93*, p. 3):

> . . . all phases of the broad field of roadside development and related functions contributing to the conservation and development of the highway landscape to further the aesthetics of the highway and its structures—all directed toward the goal of the complete highway that combines safety, utility, economy, and beauty.

1. *Users*

a. *Highway Functions (Actions Influencing Aesthetic Quality).*—The process of planning and constructing a freeway can cause changes in the landscape, which enhance the aesthetic quality of the environment or facilitate the highway users perception of aesthetic quality. Changes generated by the freeway are called highway functions in this report in order to distinguish actions influencing aesthetic quality from the elements of landscape form. The freeway can influence the aesthetic quality of the environment for highway users by: providing visual access and a pleasing visual experience, reducing or replacing displeasing land uses, enhancing visual quality through design standards and controls, and reducing headlight glare.

a.1. Visual Access. The majority of the literature reviewed in this section discusses the improvement of existing views, the development of new views, and the control of views in both the urban and rural landscapes. The benefits are generally discussed as a function of the horizontal freeway alignment, the vertical alignment, and the effect of plantings in a freeway corridor.

Sargent (*184*) states that freeway construction may improve and enhance scenic access. He discusses the importance of identifying those scenery types, through a measure of distance and variety of the scene, that may control the views from a freeway. An understanding of Sargent's "distance effect" is important to the highway designer as he attempts to provide for the optimum in visual access for the highway. "A scenery classification of a road is for the purpose of possible action to improve and enhance scenic access" (*184*, p. 13).

Rapuano (*177*) reports that freeways can provide a series of evolving views of a city's outstanding physical features. This direct benefit is also recognized by many other authors (*14, 172, 222*) as they discuss the importance of views associated with the upgrading of an existing road or the development of a new freeway. The importance of freeway locations as a design element is discussed by Tunnard (*221*) as he defines how the location may provide a vantage point for dramatic views. The significance of new and diverse vantage points, often provided by freeways, is aptly stated by Pushkarev (*172*, pp. 7, 10) as he discusses the impact of several freeways on the New York City environment:

> Before the era of Robert Moses, New York had its famous skyline, which could be seen only from a boat; it had large bodies of water which could be seen only from the top of some skyscrapers; and it had a few, large isolated parks accessible by subway through miles of disjointed and undifferentiated urban tissue. The series of five or six parkway and expressway belts that were built did . . architecturally decisive things for New York: They made New York's two greatest visual assets, its skyline and its water, accessible to public view providing an unsurpassed dynamic progression through space. They provided a set of magnificent gateways and landmarks in the form of new bridges.

Halprin (*83*, p. 23), noted Landscape Architect, states:

> In the city new vistas unfold because of the elevated freeways; vast panoramic views are disclosed which were never seen before. The great vivid skylines of the city can be seen, all of a sudden, not as a static picture, but as a series of constantly changing impressions which move by like the frames in a motion picture.

The positive impact that freeway development has had on view development through studies in location, use of elevated structures, and development of rest stops and overlooks is discussed at length by a variety of authors (*13, 14, 61, 108, 127, 132, 184*).

a.2. Visual Experience. Literature dealing with urban and rural visual experience is both abundant and varied (*83, 127, 134, 145, 225*). Of utmost importance is the report that is now considered to have provided the framework for many of the studies quoted in this text—the U.S. Department of Commerce publication *A Proposed Program of Scenic Roads and Parkways* (*228*). It was in this report that the significance of a complete understanding of visual quality was presented, hence generating much of the writings on visual quality that are considered significant today. As stated in this work (*228*, p. 5), appropriate design and location of the scenic roadway may ". . . deepen the observers grasp of the meaning of the environment; to help him understand the use, history, and nature of the corridor and its surrounding landscape. . . ."

Aesthetic experience, or visual enjoyment, may be enhanced by providing access to historic and cultural features (*134, 228*) or by reducing stress so the driver has a clearer sense of order and orientation (*80*). Halprin (*83*, p. 23) states that:

> Some of greatest new urban experiences are those of driving into a beautiful city on a freeway, particularly at dusk when the tall buildings are silhouetted against a setting sun and the lights are beginning to flick on in random patterns against the black forms. Whole new images are suddenly seen; the city comes alive in ways which were never there before. The freeway has opened up dimensions of experience—color, form and shape—seen suddenly through motion on a vast expanding track plummeting into the distance. We are in a brilliant kaleidoscope of motion which has enriched our lives and opened up whole new vistas of experience.

According to McHarg (*134*), a pleasing visual experience can be gained by exposing the physical and cultural identity of a region. Sears (*192*, p. 51) relates that:

> Each region has its individual identity whether topographic through geological evolution or man made through industrial or commercial history. Good highway locations will not detract from this uniqueness but capitalize on it by displaying it to the traveler and by helping to define and reinforce the elements which gave it character.

Sears also discusses, in this report (p. 52), the importance of the quality of detail to the aesthetic experience of both the highway user and the highway viewer:

> He (the driver) feels and appreciates visual continuity expressed in good cross-section design, in rounded warped slopes, in daylighted outside berms, in medians that physically and psychologically remove him from the danger and strain of facing opposing traffic, in plant masses that have both functional and aesthetic reasons for their choice and placement.

While recognizing that some of these criteria have been used on most recently built highways, it should be noted that few have met all the criteria necessary for providing

a pleasing visual experience. Much of this can be attributed to a lack of consensus of what are the criteria and what is the relative value of each unit.

Lewis (*127*, p. 15), in his study of the environmental values in the Wisconsin landscape and in his attempt to map and value Wisconsin's "environmental corridors," has summarized the importance of the highway in the corridors. He states that: "Part of planning for a better region then, is not only the realization of the natural corridor as a concentration of recreational activity, but the development of the highway—the man-made corridor—as more than a means of travel, but as an experience in itself."

Many techniques have been proposed relative to defining a pleasing aesthetic experience and the visual components of that experience, yet few are based on empirical research or are applicable as suitable techniques in all situations. For example, a study by Leopold (*122*) of the visual analysis of river valleys has not been related to freeway design. Others (*11, 34, 100, 108, 165, 184, 260*) have devised methods or techniques of rating visual quality that lack consistency or agreement and, thus, have only been proposed and tested in isolated situations.

a.3. Replace or Reduce Displeasing Land Uses. The majority of the literature dealing with the benefits derived from the elimination or reduction of the extent of displeasing land uses discusses this in reference to strip commercial, industrial, and deteriorated or blighted areas of the urban environment. Riedesel et al. (*180*, p. 36) state:

> In commercial and industrial areas there is often little attempt at landscaping and little variety in the setback of buildings. The replacement of commercial strip development by a more dynamic grouping of facilities . . . would . . . help to insure a pleasant driving experience and a feeling that the people in the city care about their environment.

These authors also explain that a freeway can actually serve as a stimulus to industrial or blighted areas to clean up their surroundings and improve their image in the community. Discussing a related aspect they state (p. 122):

> From the point of view of the traveler on a road there is little disadvantage in going through an industrial area. It provides a contrast from other parts of the city. It reveals the economic base of the community and it can be exciting to pass through.

In contrast to this beneficial effect of exposing the variety of the city, which is not necessarily a benefit accepted by all, the freeway may also act indirectly as a stimulus to speed up urban blight and deterioration of an area of the city. Unfortunately, this situation occurs much too often. But, in some situations where the location or upgrading of a freeway has eliminated blighted housing, the benefit may be twofold. First, the highway user is afforded a more pleasant view; secondly, the community may benefit not only from the removal of substandard housing, but in some cases also from the creation of new housing. For example, a project is currently underway to develop urban renewal replacement housing in the air rights over I-95 in Washington, D.C. (*231*). A similar but completed freeway-associated housing project occurs in New York City where four 32-story apartment buildings were constructed over the roadway of I-95 (*231*).

The incidence of the benefit from the elimination of blighted housing is dependent on the assumption that relocatees do not contribute to substandard housing problems in another area of the city. Buffington (*33*, p. 38) studied the economic consequences of freeway displacement to residents relocated under the 1968 and 1970 relocation programs and concluded that: "Relocatees who originally lived in substandard housing tended to move into standard or better replacement housing." The economic and social benefits that are generally considered to be of an indirect nature are discussed elsewhere in this report.

The increased exposure to ugliness as provided by many of our urban and suburban freeways has acted as a stimulus to the public to request, and in some cases demand, a better quality environment in and adjacent to freeways. This citizen pressure has promoted a significant benefit. It has resulted in new and more comprehensive concepts in the planning and design of our nation's roads and freeways. As more and more attention is given to the appearance of the land in a freeway corridor, there is a corresponding increase in both the visual quality and the environmental quality of the surrounding areas.

a.4. Enhancement of Visual Quality through Design Standards and Controls. The literature reviewed in this section divides into two distinct groups: that dealing with geometric and other design standards that affect human performance and safety, and that which discusses their relationship to visual quality of the highway and the highway environment.

In the past, design standards of geometrics, cross-sectional elements, and sight distances have been studied and related directly to the safety aspects of the highway. With increased awareness of the importance of the visual quality of the highway, design standards are assuming another important functional role. It is now accepted that the geometrics of a highway can provide positive visual benefits. Geometrics are responsible for controlling views and vistas, in evoking predetermined behavioral responses of the user, in providing visual continuity, and in presenting intrinsic design characteristics of the highway as a design element (*171, 180, 192, 221, 222, 228*).

Gradual, rather than abrupt, changes in alignment make driving easier and enhance appreciation of views. According to a study by the U.S. Department of Commerce (*228*, p. 39):

> Highways with long, easy curves that blend into the landscape minimize driver tension and fatigue . . . and . . . a fluid road alignment that emphasizes a variety of topographic features instead of long, straight slashes pays dividends in safety. It makes the driver feel that he is approaching his destination.

In discussing the attainment of "visual continuity" Sears (*192*) describes the effects of rounded slopes, earthwork, medians, plant masses, and other geometric standards and their importance.

One of the more indirect benefits of freeways is that, because of their complex nature, we have been more cognizant of their intrusion into the landscape. Thus, we have made great strides toward achieving, through improved design standards, roadways that provide visual continuity through optical guidance (*192*).

The importance of a median of a limited-access highway is that this median has the benefit of "physically and psychologically removing him (the driver) from the danger and strain of facing opposing traffic" (*192*, p. 5).

Tunnard (*221*) discusses the importance of utilizing the geometrics of a highway to their fullest extent in relating that it would be significant in design studies to recognize the influence of crest curves in dramatizing the views of a great river valley.

The reduction of visual clutter along a highway by controlling billboards, structures, guardrails, medians, informational signing, and other cross-sectional elements can reduce the stress of the motorist (*80, 192, 221, 228*). Godschalk (*80*, p. 23) states:

> Thus, perhaps both beauty and safety are involved in a satisfactory system of information about environmental order. Under conditions of stress, the most attractive scenery is merely extraneous information. By viewing the highway environment as a total system, we can utilize studies by psychologists of perception and behavior as influenced by stress.

In discussing the effects of the Highway Beautification Act of 1965, Thiel and Yasnowsky (*217*) have related that the reduction in the number of billboards, as a result of the Act, can serve to increase the quality of the billboards permitted in an allowable area. This is a long-term benefit for freeway users and nonusers alike.

> Also, some landowners in commercial and industrial areas where signs are permitted may find that their land is more valuable as a sign site and may receive an increase in rental income. This will result from the decreased supply of land for signs and the probability that this scarcity of land will result in signs of a higher quality in order to increase their effectiveness.

Unfortunately, the foregoing premise is only partially true in practice. In many situations, there is an increase in the quality of signs as a function of their corresponding reduction in numbers. In other cases, owners and advertisers have determined deficiencies in the law regulating signs and billboards and have, by erecting signs beyond the required setback, increased the ugliness of their signs. They have created the age of the super-sized signs and thus, in some cases, increased the clutter and lowered the visual quality of the urban and rural freeway.

It has also been suggested that removal of such visual clutter as billboards for advertising may provide a direct benefit to the public by increasing safety. In quoting a portion of a report from an engineering firm studying the New York Thruway, Robinson (*182*, p. 134) states:

> Our analysis of the data for the last two years showed, however, that almost one-third (32.6 percent) of the 1,550 accidents attributed to driver inattention on the Thruway Mainline occurred on the one-eighth of the Thruway mileage upon which motorists were exposed to advertising devices. The relative number of such accidents per mile in areas with advertising devices, therefore, was three times greater.

Although no cause and effect relationships can be shown to exist, it suggests that motorists' attention may be diverted by billboards.

The American Association of State Highway Officials (*7*) has given credibility to the process of measuring the community effects of urban highway locations. Of significant importance to this discussion is their suggested measurement of aesthetic impacts, which is defined in miles of compatible development and dollars of aesthetic improvements, but this and other factors and measures are considered tentative.

Winkel's paper (*260*) describes a method to determine user attitudes of the design quality of selected portions of urban freeways. By using a photo retouching technique, he measured and rated the response of a group of 80 observers. The findings presented in this paper, such as the absence of utility poles and overhead wires being readily detected by the observer group, give credence to the necessity of specificity of design and cross-sectional elements in the highway corridor.

Concern is often expressed with the elements of the actual legal right-of-way of the highway and not with the entire scenic and visual corridor (*61, 125, 131, 140*). The importance of controlling more than just the legal right-of-way and the associated benefits was dramatically recognized in a 1966 Department of Commerce publication (*228*). The scenic corridor may insure the conservation and protection of environmental, historical, cultural, and otherwise valuable scenic elements of the landscape, by preventing encroachment of undesirable uses. Defining and controlling a scenic corridor larger than the actual legal right-of-way may help protect the visual element from destruction. It may also protect the zone within the corridor from man-made visual encroachments, such as billboards, signs, and incompatible land uses. The expanded controlled right-of-way may then result in creating a benefit of improvement of the driver's view from the road. The significance of the expanded right-of-way is summarized by Sears (*192*, p. 52) as follows:

> . . . we might well study the possibility of creating totally independent directional lanes separated by hundreds or even thousands of feet and the advantages of returning the spaces between them to compatible land uses under easement control.

a.5. Reduction of Headlight Glare. The majority of the literature dealing with headlight glare suggests two important factors to consider: (1) planting and (2) geometrics.

Deakin (*55*) reports of a survey of 12 state highway departments, which confirms not only the need for screening of glare but also the effectiveness of utilizing plant material for such purposes. A suggested list of plant material useful in screening glare is included in his report. The benefits are then twofold: first by providing a source of positive visual interest for the user, and secondly by improving safety associated with the reduction of glare (*48, 49, 50, 52, 53, 179*).

Many authors have discussed the additional benefit associated with wider medians and independent roadways at different levels, which were designed with reduction of glare in mind (*5, 6, 13, 55, 93, 217, 222, 228*).

b. *Perception of Landscape Form (Dynamic Viewing)*. —The freeway influences the form of the natural and man-made landscape by additions to the elements comprising visual quality and by modifications of the shape, structure, and patterns of the physical elements of the landscape.

The highway user is afforded a moving view of the freeway-influenced landscape. Additions and modifications to the landscape resulting from the construction of a freeway, which can be beneficial to the aesthetic quality of the environment, include: the spatial relationships created by the freeway (especially relative to the urban pattern), the highway and highway structures, modified land forms, and landscape development.

b.1. Spatial Relationships. The literature dealing with the visual relationship of space can be divided into one group, which deals with comprehension of urban scale through the views provided by the freeway, and a second group in which the authors relate the freeway and its ability to provide visual and functional structure to the city. The writings on this topic most often relate to the urban environment and not the rural (*83, 148, 177*).

According to Riedesel et al. (*180,* pp. 87, 26) "A freeway can act as a spine for a neighborhood lacking any strong centralizing structure" and a freeway may "reinforce the urban pattern." Riedesel et al. also recognize that the opposite may occur; rather than following and reinforcing the urban pattern, inadequate planning may bring about a destruction of this pattern.

As presented in the proceedings of the Hershey Conference on Freeways in the Urban Setting (*13,* pp. 8, 13), the views from the freeway and the landmarks that are seen from the freeway give "orientation to the urban area" and "make the scale of the metropolis comprehensible to the individual."

The Sagamore Conference on Highways and Urban Development (*15,* p. 7), while discussing primarily the relationship of highway planning with land planning, also reinforced the concept of the freeway giving structure to the city: "It can help to preserve homogenous areas on the one hand, and on the other, to divide residential sections from industrial sections, or to effect desirable separation of other dissimilar land uses." This benefit applies to both the visual and functional importance of structure in land use patterns. If the freeway can help to define existing or potential city districts, then it has the associated benefit of providing visual order to the environment.

Lynch (*132*) also discusses this long-term benefit of providing visual order and visual orientation to both the user and nonuser. Although much of Lynch's hypotheses are untested with specific field studies and results, it is important for the highway engineer or designer to weigh Lynch's theories and discussions of "imageability, legibility" and the "mental value of orientation."

Pushkarev (*172,* pp. 7, 10) summarizes the perception of urban landscape form most dramatically in discussing the important effects of 5 or 6 expressways on New York City:

> They linked the hitherto isolated open spaces into a continuous, interconnected system eminently fitted to both the natural topography and to the man-made order of the street grid. They articulated a hitherto incomprehensible urban mass into visually distinctive chunks, with a visually comprehensible silhouette or mass, cleaning up and upgrading junky dilapidated edges of the urban tissue.

b.2. Highway and Highway Structures. Few citations express better the importance of the sculptural aspects of the freeway than that presented by Tunnard and Pushkarev. These long-time investigators of the impact of highway geometrics to the sculptural and visual quality of the roadway and its related environment have suggested that freeways create a sculptural form of art or expression in their own right. Their writings note that the undulating ribbons of pavement are a basic tool of spatial expression. This is an important aspect of freeway design in realizing optimum visual quality. They reflect this importance in their discussions of the internal harmony of the freeway and its external harmony. The internal harmony is derived from lines, forms, scale, and shape achieved through a control of the horizontal and vertical alignment, medians, and proportions of its cross-sectional elements. The external harmony is derived from the way the paved ribbon fits in the total sculpture of the landscape and its visual relationships to the landscape. Tunnard and Pushkarev (*222,* p. 177) state:

> Both are equally important, though perhaps the internal harmony should take precedence over the external. For the intrinsic flaws in the design of an object cannot be eradicated by the beauty of its setting—an ugly house in a beautiful garden still remains ugly. Faulty grading and ugly structures can be screened out by trees, but no amount of planting can screen out an ugly alignment of the pavement itself, which the driver is compelled to see constantly, on and on. Hence the importance of the internal harmony—the fundamental approach, as contrasted with the cosmetic approach, post-factum "beautification" of the roadside.

Lynch's discussions on paths and edges provide additional understanding of the importance of these lineal elements on visual quality. Paths (streets, roads, freeways, etc.) have an intrinsic visual continuity as well as a functional necessity.

As mentioned previously, bridges have added to one's ability to view and appreciate the "magnificent gateways and landmarks" of New York City (*172*). Additional understanding of the importance of highway structures as a positive influence on visual quality of the highway can be gained through a study of the engineering creations of the noted Swiss engineer, Maillart.

Air rights, as discussed in another section of this report, have a significant relationship to highway structures. Structures that are now taking advantage of a once unusuable space above the freeway have considerable impact on the highway user. "The restaurant on a bridge becomes a landmark in the uneventful Oklahoma landscape" (*222,* p. 270).

The opportunity to provide a unique view for the patrons of a restaurant above the freeway may only be a beginning into new concepts for utilizing the air rights of urban and rural freeways (*180*).

b.3. Modified Land Forms. Traditionally, the literature relating highway aesthetics to land forms has promoted the desirability of fitting the highway to the existing topography (*43, 192, 203, 207, 222*). In aesthetic, environmental, and economic contexts, it is generally agreed that an alignment minimizing cut and fill is more desirable than an alignment resulting in giant cuts and extensive fills. However, rock cut slopes, which are frequently created by freeway construction, may be considered in a beneficial aesthetic context.

The exposed geologic structure may be a point of unique scenic interest, not only capturing attention through visual dominance but also expanding the highway users awareness of environmental features. Tunnard and Pushkarev (*222*, p. 210) have described the nature of this effect as follows:

> Natural rock strata are always to be considered and used to the best visual advantage in rock cuts. Exposed rock formations give the driver the same sense of reality and permanence that exposed structure can give the observer of architecture. Besides, driving through a succession of rock cuts can become the experience of a living geological museum, sharpening a person's awareness of how his planet was built. Rock carefully cut along natural strata and natural faults can bring forth the most exciting sculptural forms, aside from eliminating "fallen rock zones."

A novel approach for the sculptural modification of landforms has been presented by a Yale research team (*261*, pp. 75, 76) as follows:

> . . . a group of modern American sculptors has become interested in the sculptural opportunities of manipulating large areas of earth and rocks into forms charged with emotion. An exhibition of such earth sculpture was recently held in a New York art gallery. . . . (The) noted 'minimal' sculptor (Dennis Oppenheim) was invited to explore the potential impact upon motorists of large-scale, sculptural masses in the median of a new freeway. Some of these constructions would stretch for 1500 ft. (more than 15 seconds of driving time) suggesting a way in which the dimension of time (i.e., movement) may be utilized to enrich a perceived environment.

It was concluded by this study group that some of the existing proposals would have to be modified in the interest of safety.

In addition to the aesthetic context of modified land forms, geologists find scientific value in studying rock slopes exposed by highway construction, as noted previously in the section on soils and rock.

However, the value of rock cut slopes for aesthetic or other purposes may not be discussed without qualification. Rock falls and other slope stability problems are prevalent along many highways. Parizek (*162*) has provided an excellent discussion of the variety of impacts which deep cuts and extensive fills may have on the hydrogeologic environment. Perhaps recognizing that there may be an ambivalent nature to the value of land form modifications, Tunnard and Pushkarev (*222*, p. 210) have preceded the discussion of the visual value of rock cuts with the following statement:

> Integration with the natural order involves not only the formal but also the structural order of the landscape. The action of sun, wind, and water has sculptured the surface of the earth into very definite patterns, determined by the laws of physics to a very subtle point. Any ignorant and arbitrary intrusion of man into this realm tends to be rectified by nature.

b.4. Landscape Development. Much of the literature reviewed that deals with the importance of landscape development addresses the use of plants and landscape plantings as an element of highway beautification. A second category deals with the relationship of landscape development to the safety aspects of freeways, and a third category discusses the important visual and functional qualities and relationships created or complemented by the use of plant material in highway corridors.

Peterson (*165*, p. 14) states: "Highway beautification is as much a problem in engineering as the design of the highway itself and is in fact a part of it."

The Highway Beautification Act of 1965 was one of the more significant legislative actions to recognize the importance of combining highway landscape development with the basic design and planning of the highway itself.

The benefits of good landscape development are many and varied. Most of the benefits are direct and are applicable in both the rural and urban environments.

Landscape development provides for harmony with nature and acts to conserve and preserve the natural environment (*128, 228*). The buffering provided by the use of plant material and other landscape techniques provides transitions between the freeway and its surroundings (*13, 83, 180*). The use of plantings can increase a city's attractiveness and, in turn, create a more pleasant travel experience through the city and the country (*13, 55*). The use of native wildflowers in the roadside may increase the educational experience of the user and may add an element of color to provide greater visual interest, thus helping to reduce monotony (*136, 255*).

Reduced maintenance provides for the motorist a greater understanding of the regeneration of woody vegetation and natural succession along a roadside (*29*).

Some of the literature reviewed recognizes the psychological importance of the visual quality of the corridor on the driver's state of mind as he experiences the highway. Landscaping and improvement of highways can make the journey a rewarding part of the recreational experience.

Jacobs and Way (*108*) and others (*34, 100*) have considered the effect of plant material as a determinant of visual quality in their attempts to measure this quality. These authors are the exception rather than the rule. The majority of the literature reviewed is nonquantitative in nature and thus cannot be used to provide specific design guides to predict a desired solution. Landscape development is still considered an art and not a science.

Peterson (*165*) has attempted to show the importance of developing a workable model to be able to provide for man a more pleasant visual environment.

Davidson (*46*) reports that benefits derived from scenic enhancement of highways may appear to fall into four basic categories: (1) visual pleasures, (2) changes in accident rates, (3) alteration in the average time of trips, and (4) difference in vehicle operating costs and difference in highway maintenance costs. This research is attempting to enumerate and evaluate the social benefits that may be derived from scenic enhancement.

A detailed discussion of the safety benefits associated with freeway construction appears in another section of this report. It is important though to recognize here the significance of planting as a design element to create a safer route. "Plantings of shrubs and trees can guide traffic at bridges and curves, serve as living snow fences, and help reduce fire hazards and erosion. They also alleviate noise, distractions, dust and monotony" (*228*, p. 38). The neces-

sity of recognizing these potential benefits is also discussed in several AASHO publications (*4, 5, 6*). In discussing the functional aspects of plantings along the highway, Riedesel et al. (*180*, pp. 52-53) state:

> One of the objectives of landscaping should be to maintain the distinction between city and country by reinforcing existing planting on the edge of the city (p. 78). . . . the dense screen on either side of the Park Presidio Boulevard in San Francisco, not only provides protection for the residents, but also makes the drive much more pleasant.

Halprin (*83*, p. 62), in discussing the Park Presidio, states, "Because of high mounding of earth and beautiful plantings in depth on both sides, the adjoining residential neighborhoods are extremely desirable places to live."

Deacon (*55*, pp. 17, 23) has also related that plant material in the freeway right-of-way is important in ". . . framing traffic ramps . . . providing safety in turning movement . . . screening side distractions . . . reducing driver tension . . . and preventing unauthorized (median) crossing."

The roadside rests and service facilities often encountered on freeways provide not only the social and economic benefits of reduced tension and safety but, if properly planned, can contribute to the over-all attractiveness of the highway (*2, 3, 78, 152, 217, 225, 228*).

The benefits of planning and designing for an attractive highway and its related environs were aptly summarized in a U.S. Department of Commerce publication (*228*, p. 73): ". . . it promotes the quality of landscape design for fronting property and enhances both its value and the value of surrounding areas." Further discussions pertaining to landscape development are provided in the following literature sources: Refs. (*43, 51, 84, 92, 107, 183, 203, 243*).

2. *Nonusers*

The literature on visual quality of the urban and rural highways often deals only with those qualities as perceived by highway users. Many of these visual quality benefits accrue also to nonusers.

a. *Highway Functions* (*Actions Influencing Aesthetic Quality*).—The freeway can function to enhance the aesthetic quality of the environment as perceived by the nonusers. The freeway effects, experienced by the nonusers, have a dual nature. Some of the effects can be considered to be transitory or temporary in nature, such as the effect on a person viewing the highway from a restaurant or a person using the highway right-of-way as a bicycle path. Other effects are more permanent, such as those experienced by the person living near the freeway who is constantly exposed to the presence of the highway in his environment. The long-lasting influences of the freeway on these people may be contrasted with the transitory effects that the user experiences while driving but is oblivious to when at home.

The freeway can influence the aesthetic quality of the environment for nonusers by providing open space, reducing or replacing displeasing land uses, enhancing visual quality through design standards and controls, reducing headlight glare, and reducing sound.

a.1. Open Space. One of the most often cited nonuser benefits of the freeway is the creation of open space. This provides visual attractiveness, buffering capabilities, and opportunities for related auxiliary uses. The benefits of open space are most relevant in the urban and suburban environments (*103, 180, 181, 225, 228*).

The creation of new open space in the urban environment is a function of the larger rights-of-way associated with freeways. This open space is normally a rigidly defined linear space that limits development and usefulness to specific types of activities. Hiking and biking trails are one example of such an activity (*103, 177, 192*).

Often the existing undeveloped land (open space) of a city or town is chosen as the location for a new freeway, and the net result may be an actual reduction in the *usable* open space. Riedesel et al. (*180*, p. 22) state:

> The freeway offers, on the strip beside it, a good place for the creation of a linear park because of the lack of cross traffic to break it up. In a residential area it would be easy to plan a pedestrian way through a narrow park, linking residential streets safely to schools, playgrounds, stores, etc., with pedestrian underpasses under secondary streets crossing it.

Large spaces, capable of supporting major recreational activities, are normally not available as part of the urban right-of-way. Some thought might be given to the scenic corridor concept as a means of controlling larger parcels of land specifically for open space and recreational activities. Linear open space that may act as a connection between residential neighborhoods can be and should be developed to satisfy both functional and aesthetic purposes; visually attractive spaces for the user and nonuser, and functional spaces (as connectors) for the nonusers (*103, 180, 181, 228*).

"Well designed, well located highways in urban areas, for example, provide highly desirable greenbelts which help satisfy open space needs" (*228*, p. 93). Also, the freeway should be planned "so that landscape areas on its right-of-way or associated with it are integrated in their distribution and design with the system of city parks" (*180*, p. 22). This concept of linking together freeway-related open space with the existing open space and recreational spaces of the city is one of the more obvious benefits of the freeway to the urban environment (*83, 132, 134, 172*).

The space provided for the development of hiking and biking trails is another benefit of the urban freeway. As urban and regional planners have demonstrated, the need for the development of efficient and safe hiking and biking trails is critical. But, the desires of the community to provide these facilities is stymied by the lack of adequate greenbelts (*83, 103, 134, 180, 228*).

The green spaces designed and created may also facilitate the movement of air, which helps to provide cooling breezes for otherwise hot and humid residential neighborhoods (*216*).

Additional benefits of highway-related open space are presented in the discussions of joint development.

a.2. Replace or Reduce Displeasing Land Uses. The visual benefits associated with freeway construction, as previously discussed under "Users," are also applicable in most situations to the nonuser.

Through condemnation, eminent domain, and outright purchase sources of ugliness may be eliminated. The effect

is a reduction in visual discontinuity to the highway viewer and a possible increase in the entire visual quality of the affected area and the community (*145, 180, 225*).

a.3. Enhancement of Visual Quality through Design Standards and Controls. Discussions by Riedesel et al. (*180*) of the importance of the view of the road and the view by the road relate to the nonuser. These views can be considered a benefit if the design respects the importance of detail in the roadway and its cross-sectional elements. The choice between elevated, at grade, or a depressed freeway must be considered in context with the adjacent development. "If it is an elevated freeway, its height, mass and harshness, and the dark space underneath can be threatening to small buildings and their uses. If it is depressed or at grade, the huge open area created by it can become a no man's land, . . ." (*180*, p. 15).

Tunnard and Pushkarev (*222*, p. 233) discuss the significance of cross-sectional elements, details and elevated or depressed freeways and their effects on the community; with proper attention to these design aspects, scenic quality of the corridor may contribute rather than detract from the visual continuity of the surrounding environment:

> Integration of the freeway with its immediate environment requires that the continuity of significant spaces which the highway intersects be preserved.
> . . . In rural areas, the continuity of large, open lateral spaces usually can be maintained with a sensitive development of the cross-section, by means of flat slopes, generously rounded and blending into the natural forms of the land, as previously described. . . . But in thickly settled areas, where frequent grade-separated crossings are necessary and where there simply is not enough room for very gentle slopes on embankments, preserving the integrity of lateral spaces is an acute problem.

Lighting, guard rails, signing, cuts and fills, medians, depressed freeways, bridges, etc. can, if properly designed, contribute to an improvement in the visual continuity of the corridor and the surrounding landscape (*55, 83, 172, 177, 192, 221*).

a.4. Reduction of Headlight Glare. The reduction of glare, with respect to the nonusers, is most important for persons living in residential areas adjacent to the freeway who, in some locations, are continually disturbed by headlights during the night.

The benefits defined and discussed previously under "users" should also be considered to be benefits to the nonusers. Locations of plant materials, geometric alignment, cross-section design, and depressed and elevated freeways may all serve to reduce glare (*5, 6, 93, 222*).

a.5. Reduction of Sound (Noise). The reduction of noise on city streets is a direct benefit provided by a new urban freeway. This is often accomplished by the simple transfer of traffic from these local streets to the freeway (*235*). Cohen (*41*, p. 75) states the following:

> Bypasses and ring roads have been of help in relieving traffic congestion in the centers of towns with resultant reduction in noise. However, routing of such roads requires careful consideration to avoid bringing heavier traffic close to existing schools, hospitals, and houses in other areas which are more vulnerable to noise than are the shops and commercial buildings which often front main roads.

As a general rule in planning, "The best interest of roadway noise control could be served if new communities would not be permitted to encroach on existing busy roads nor new roads on existing residential areas" (*41*, p. 75).

Brinton and Bloom (*31*) measured the effect of highway noise on nearby residential property and determined 68.5 dBA (decibels on the A scale of a sound level meter) to be a reasonable threshold sound level at which homeowners perceive highway sound to be disturbing. This figure is closely supported by Beaton and Bourget (*22*, p. 1), who establish 70 dBA as the noise level which "usually represents the maximum limit of exposure in a residential area before public complaint ensues."

According to Kugler and Anderson (*117*) noise control can be achieved at three general points: (1) control at the source (e.g., legislative control of vehicle noise limits in California and New York, reduction of vehicle noise at the tire-roadway interface, etc.); (2) control at the receiver (e.g., planning and zoning of new land uses near the highway, reduction of noise exposure through building design that insulates the receiver from disturbing noise levels, etc.); and (3) control along the noise transmission path (e.g., reduction of noise by depressing or elevating the highway, earth berms, barriers, etc.).

Brinton and Bloom (*31*, p. 2) determined from approximately 800 interviews at locations across the northeastern, midwest, and western United States, that "sound from trucks is the most objectionable highway disturbance to persons living in homes, apartments, and farms next to limited access highways, regardless of geographic location." From a comparison of measured noise distribution curves of automobiles, gasoline-powered trucks, and diesel trucks, Beaton and Bourget (*22*, p. 2) conclude "that the major source of highway noise peaks is the diesel truck."

Priede (*169*) describes why diesel engines have greater sound and vibration than gasoline engines, and how some engine and vehicle design trends have been fostering noisier vehicles. According to Priede, the noise of a vehicle is due primarily to the engine, the transmission system and accessories, and road excitation; and to a lesser extent to air buffeting. Kugler and Anderson (*117*) and Priede (*169*) have outlined airborne, structure-borne, and combined airborne-structure-borne vehicle noises from sources including engine vibration, engine inlet, engine exhaust, transmission and drive train, fan noise, road-excited vibration, and road-excited tire noise. Priede (*169*, p. 73) concludes that "from consideration of the characteristics of noise produced by various major elements of a vehicle, it is apparent that any of these can be predominant sources of noise within a particular operating range of a vehicle. The emitted noise of the vehicle is primarily determined by the operational speed." Ventre and Case (*241*), Larson and McKelvey (*120*), and Burt (*35*) discuss the significance of tire noise at speeds equivalent to and greater than normal freeway operating speed. Ventre and Case cite tests on truck tire noise conducted at Wallops Island, Va., by the National Bureau of Standards and the U.S. Department of Transportation, which are aimed at reducing noise at the source.

Characteristics of the traffic and highway and the characteristics of numerous factors along the transmission path

will influence noise from the highway. According to Burt (*35*, p. 25), "in general, noise increases with traffic flow, with the steady speed, and with the degree of hill climbing and acceleration. All three are clearly correlated with the type of road concerned." Williams (*259*) has given the following equations for noise generated by passenger cars for different types of road surfaces: (1) open-textured asphalt: dBA = 28 + 30 log (speed), (2) motorway concrete: dBA = 23 + 30 log (speed), and (3) new asphalt: dBA = 18 + 30 log (speed). Cohen (*41*) discusses a suggestion to reduce structure-borne and airborne roadway noise emission through the development of roadway surface materials that would provide a smooth, fine-grained finish.

According to Scholes and Sargent (*189*), the factors governing the exposure of a dwelling to noise from a road are: the traffic density, composition, nature of flow and mean speed, the distance between the road and the exposed facade of the dwelling, the road gradients, the nature of the ground between the road and a low-rise dwelling, the wind direction, and the effects of reflections from other facades. In discussing the relationship of road gradients and noise levels on highways carrying freeway flowing traffic, these authors (*189*, p. 214) state the following:

> In practice, free flowing traffic slows when climbing gradients and this is particularly so for the heavier vehicles. It has been found that the noise reduction due to the reduction in speed almost cancels out the increase in noise due to the ascent of the gradient (at constant speed) so that in practice, on gradients of up to at least 8 per cent, freely flowing traffic makes only slightly more noise than the same traffic on the level.

Maekawa (*137*, p. 173) states that "when the distance between the source and the receiver is great, of the order of one hundred meters or more, the more attenuation due to atmospheric conditions, i.e. wind, temperature gradients, and ground effects etc. must be considered."

Scholes and Sargent (*189*, p. 215) also discuss attenuation of noise over a distance by the ground, stating that "noise travelling from the road to a dwelling by a path which is close to any ground, except hard paved surfaces, is reduced by ground absorption." In addition, Scholes and Sargent note the effect of wind direction and temperature gradients on the propagation of noise. According to Jones (*110*), relative humidity, as well as wind, affects noise reception by a listener.

Considering the factors that relate to the origin and transmission of highway noise, there are several methods by which noise from freeways can be reduced along the transmission path between the source and the receiver (e.g., the adjacent homeowner). According to Beaton and Bourget (*22*) the acoustical properties that a noise-reducing material should possess are a sufficient mass or density to assure that the material will not vibrate easily and an imperviousness to air flow; optimally, the material should absorb noise, yet be impermeable. Other authors, with respect to reducing highway noise as perceived by persons near the highways, have discussed the use of: (1) land forms (e.g., cut slopes of a depressed freeway, earth berms, etc.); (2) barriers and screens; (3) vegetation; and (4) combinations of the preceding three materials. Relative to these alternatives, the effectiveness of vegetation for noise reduction has been a controversial topic.

Simonson and others have indicated that properties adjacent to freeways may benefit from a reduction of noise due to adequate planting in the corridor (*46, 180, 195, 196, 197, 198, 199, 200, 217*). Simonson (*200*, p. 48) states:

> Appropriate planting of rights-of-way is important as a means of noise abatement. . . . Appropriate planting can help to make the city more attractive and blend the freeway into its urban environment at the same time. A width of 60 feet or more of right-of-way on the outer roadside borders is desirable for buffer planting . . . (it) also insulates adjacent residential and business properties from the noise and fumes of traffic.

A contrasting viewpoint is presented by Beaton and Bourget (*22*, pp. 7, 8).

> Sooner or later the question of planting is brought up during any discussion of noise radiation from highways. This topic should be laid to rest. The simple truth is that plantings possesses none of the physical properties required of a good sound shield. They are porous to air flow, vibrate easily, and lack density. Their permeability to the flow of airborne sound is so great that virtually no acoustical benefit is obtained from planting within the right-of-way depth that is normally available. Their real merit is to improve appearances, and there is some "psychological shielding" that tends to favor public acceptance. Noise benefits are mostly folklore.

According to Aylor (*16*, p. 197), "earlier conflicting reports of noise attenuation by vegetation appear reconciled if ground attenuation is taken into account. Scattering and ground attenuation are the principal factors in sound attenuation by vegetation." Regarding the controversy over the effectiveness of vegetation in noise reduction, Aylor cites a situation where the width of vegetation required to buffer noise for a community was determined to be either 400 ft or 1900 ft wide, according to whose data were used. This author (*16*, p. 205) concludes the following:

> Foliage reduces sound transmission substantially, especially at the higher frequencies where scattering is enhanced, and the effectiveness of the foliage increases with increasing leaf number density, and should increase with increased leaf width and leaf thickness. When little foliage is present, high-frequency sound is reduced mainly by stems.
>
> Diverse forests attenuate nearly the same amount of sound and thus, old or young, planted or natural stands of trees are about equally effective in attenuating high-frequency noise. The ground attenuates considerable amounts of acoustic energy at lower frequencies where scattering is not effective. This is caused by acoustic cancellation, and the frequency of peak attenuation can be varied by altering the ground.

Jones (*110*) also treats the reduction of sound by the ground surface absorption, as related to the nature of the surface (e.g., thick grassland absorbing more noise than a hard reflecting surface). Brinton and Bloom (*31*, p. 33) studied the relationship between tree density and sound level reduction and concluded that density of trees is only slightly related to average sound level reduction. "With a 200-ft. right-of-way, dense trees reduce sound levels only about 2 to 4 dBA more than the reduction due to distance alone, however, failure to screen the highway from adjacent properties within about 5 years will result in more complaints from homeowners."

Others have discussed the width of vegetated areas required to effectively reduce noise from a highway, as well as the "psychological value" of merely screening the highway from view rather than establishing a wide, dense planting. Cohen (*41*, p. 82) states:

> The minimum width of planted areas needed to attain truly significant attenuation of roadway noise is believed to be 200 ft. (60 m.) which may make such treatment measures unfeasible. It must be noted, however, that merely hiding a roadway or other offensive noise source from view by trees and shrubs can offer marked psychological attenuation of intrusive noise, resulting in fewer complaints.

Scholes and Sargent (*189*, pp. 216, 217) consider the reduction of noise as follows:

> Narrow belts of trees and shrubs are almost useless and to provide a reduction in noise exposure of 10 dBA the belt of trees would need to be about 50 m. (165 ft) wide. Furthermore, the growth would have to be dense and extend down to ground level and, to be effective throughout the year, the trees and shrubs would need to be evergreen. There requirements are not likely to be met by chance between a road and a proposed new development and would not easily be met until many years had elapsed after new planting.

Several authors have dealt with the reduction of noise from highways through the use of barriers, screens, and other structures that are interposed between the sound source and receivers to produce an acousitc shielding effect (*22, 41, 110, 117, 137, 189*). Scholes and Sargent (*189*, p. 217) have described the sound shadow that is caused by a noise reduction barrier as being "much less clearly defined than a light shadow cast by an opaque body. The edge of the sound shadow is blurred and the noise reduction increases as the reception point moves away from the edge of the geometrical shadow into the shadow zone."

Cohen (*41*) discusses the increase in sound attenuation attributable to increasing barrier height and/or decreasing distance between the sound source and barrier. This author (*41*, p. 78) also states, "the attenuation for all frequencies increases with increasing barrier height, with the higher frequencies showing more reduction than the low frequencies." According to Scholes and Sargent (*189*), strong winds can affect the performance of a noise barrier positively or negatively depending on wind direction. Strong winds flowing in the direction of sound transmission may reduce the effectiveness of the barrier or, in contrast, winds that oppose the direction of sound transmission may decrease the received noise levels by a greater margin than possible by the barrier alone.

The reduction of noise by landforms and landform-barrier combinations has been considered by Beaton and Bourget (*22*), Cohen (*41*), and others. Beaton and Bourget (*22*, p. 4) compare the use of an 11-ft high concrete wall with an equivalent earth berm, and illustrate a combination of the two that is embellished by landscape development to achieve an aesthetic concept of a noise shield:

> Although as effective acoustically, the use of an 11-ft high earth mound would require more footing width than is usually available along the right-of-way; and an 11-ft high wall might raise objections about appearances; but the combination of a 5-ft earth mound topped by a 6-ft wall can be visually pleasing as well as functional.

In accordance with Cohen (*41*, p. 79):

> The depth of the cutting must be greater than that of the barrier height to cause the same attenuation. A true depression might even produce less attenuation than that noted if reflections from the far wall are considered. . . . Such reflections tend to reduce the effective height of the sound shadow. Sloping walls of the cut can direct these reflected sounds upward and therein eliminate the problem, but also, unfortunately, sloping can reduce the effective barrier height for the sounds coming directly from the source.

Beaton and Bourget (*22*, p. 5) indicate that the addition of an 8-ft noise shield at the crest of the slope adjacent to a depressed highway is "a most effective method for improving the noise protection to nearby dwellings that would otherwise have a direct optical and acoustical exposure to the vehicles." Brinton and Bloom (*31*, p. 31) studied the effect of distance vs. sound-level reduction, highway depression vs. sound-level reduction, and tree density vs. sound-level reduction and concluded that highway depression is potentially the greatest single reducer of sound level:

> . . . the depressed highway or cut shows the most potential for sound-level reduction; however, homes must be out of the line of sound, shielded by some solid barrier, before the maximum sound reduction is obtained.

The expanded right-of-way of freeways provides space for the development of earth berms, a depressed-highway cross section, barriers, vegetation, and other noise reduction measures as well as, simply, a greater distance between the sound source and the receiver in which noise may be attenuated by ground absorption and the atmosphere.

Three studies completed by the acoustical consulting firm, Bolt, Beranek and Newman, for the National Cooperative Highway Research Program provide a suite of practical highway-noise information for the highway engineer. The first of these studies, *NCHRP Report 78* provides guidelines for measuring and evaluating highway noise (*77*). *NCHRP Report 117* summarizes technical considerations in noise calculation procedures, recommends noise design criteria, and provides a "cook book" type design guide (*81*). The third study in the series, *NCHRP Report 144*, presents an evaluation and modification of the noise control prediction procedures that were established in the previous study (NCHRP Report 117) (*118*).

b. *Perception of Landscape Form (Stationary Viewing)*.—Nonusers may perceive landscape form discussed in the corresponding users section; except, generally, the nonusers are viewing the landscape from a stationary point in contrast to the moving view or progression of views experienced by the highway user. The influence of the freeway in the landscape that the nonuser views is seen in the shape, structure, and pattern of the spatial relationships created by the freeway (especially relative to the urban pattern), the highway and highway structures, modified land forms, and landscape development.

b.1. Spatial Relationships. The benefits in this section differ from the highway users' section in that the nonuser is

considered to be a static viewer. The benefits of orientation, landmarks, reinforcement of the urban pattern, etc. to the nonuser are discussed by many authors (*11, 13, 83, 132, 172, 177, 180, 192, 222*).

b.2. Highway and Highway Structures. Structures, such as bridges, are as visually significant to the nonusers of the highway as they are to the users. Lynch (*132*) relates that much of man's perception of the city environment is attributable to the pattern established by the freeway and its structures. Bridges become an important landmark and stimulator of an image.

The majority of the literature citing the importance of the actual paved ribbon and highway structures toward achieving visual continuity deal with these elements in an urban context (*14, 83, 132, 172, 177, 180, 182*).

Tunnard and Pushkarev (*222*, p. 220) relate the significance of the results achieved through sensitive geometric alignments and consideration for the cross-sectional elements:

> Integration with the order of the macro-environment is very important in the overall location of the freeway, but its effect on the public is by no means immediate or obvious. The public, however, is directly aware of embankments, bridges, planting, and a multitude of other design details that the road user can see from the window of his car, or the non-user from the window of his home.

Riedesel et al. (*180*, p. 14) discuss the importance of the view from the road, the view by the road, and the view of the road:

> Freeway geometry . . . can convey to the observer, remote from it in a high building, the impression of a great urban sculpture. This, plus the constant motion on its surface, can produce a variety of responses. It can be an exciting art form and a visual relief to the often mundane cityscape.

Unfortunately, this is not the norm. The urban freeway, too often slices through the cityscape in an indiscriminate manner and, thus, is out of context with the existing urban pattern. "It can also be a conflicting form out of context with the existing urban pattern and thus disturbing to the eye. It can disrupt familiar patterns that the urban dweller is used to" (*180*, p. 14).

b.3. Modified Land Forms. Nonusers viewing the highway right-of-way may enjoy the aesthetic benefit of rock cut slopes, and the associated beneficial opportunity for a geological learning experience. The nature of the effect is basically the same as discussed previously in the corresponding highway-user section, except the nonusers have a static rather than a moving view. Persons inclined to observe geologic features may study the rock in the detail afforded by a stationary position.

Many of the adverse effects of land form modifications have an impact primarily on nonusers. For example, Parizek (*162*) has discussed how a deep cut, which acts as a ground water drain, may reduce water supply to pumping wells located downslope from the highway.

b.4. Landscape Development. The benefits associated with landscape development of the freeway have an influence on both the user and nonuser of the highway. Landscape development of the corridor, whether initiated for safety purposes or aesthetic purposes, may have as a net result the improvement of the scenic quality of the highway (*43, 203*). Whether this improvement is the result of the preservation of the existing natural environment or the creation of a complimentary man-made environment, the anticipated result may be an enhancement of the beauty of the area. Highway designers have been more cognizant of aesthetics as a design determinant recently and have engaged in research, testing, and application of new techniques. The concept of using native wild flowers in the rights-of-way and of encouraging natural succession is discussed by many authors. Reduced maintenance of landscape areas is often cited as an indirect operational benefit (*136, 219, 255*).

In discussing the effect of landscape development of three Chicago freeways, Cherner (*38*) concludes that adjacent property values have increased because the residents consider the attractive landscape areas as a stimulus for adjacent property owners to consider and improve the visual quality of their own properties (see also *216, 228*). "Recognition must be given to the fact that the landscape designs were intended to benefit the driving public and that the by-product has been the enhancement of the areas adjacent to the highway" (*38*, p.7).

ENVIRONMENTAL BENEFITS BIBLIOGRAPHY

1. ACKING, C. A., and SORTE, G. J., "How Do We Verbalize What We See." *Landscape Architecture,* Vol. 64, No. 1, pp. 470-475 (Oct. 1973).
2. AMERICAN ASSOCIATION OF STATE HIGHWAY OFFICIALS, Committee on Planning and Design Policies, *A Policy on Safety Rest Areas for the National System of Interstate and Defense Highways* (1958) 42 pp.
3. AMERICAN ASSOCIATION OF STATE HIGHWAY OFFICIALS, Committee on Planning and Design Policies, *A Guide on Safety Rest Areas for the National System of Interstate and Defense Highways* (1968) 40 pp.
4. AMERICAN ASSOCIATION OF STATE HIGHWAY OFFICIALS, Operating Committee on Roadside Development, *A Policy on Landscape Development for the National System of Interstate and Defense Highways* (1961) 39 pp.
5. AMERICAN ASSOCIATION OF STATE HIGHWAY OFFICIALS, Operating Committee on Roadside Development, *Landscape Design Guide* (1965) 102 pp.
6. AMERICAN ASSOCIATION OF STATE HIGHWAY OFFICIALS, Operating Committee on Roadside Development, *A Guide for Highway Landscape and Environmental Design* (1970) 84 pp.
7. AMERICAN ASSOCIATION OF STATE HIGHWAY OFFICIALS, *A Policy on Design of Urban Highways and Arterial Streets* (1973).
8. ANDERSON, C. R., "Environmental Compatibility of the Highway." *26th Short Course on Roadside Development, Ohio State University* (1967) pp. 25-31.
9. ANDERSON, C. R., "Maryland." *28th Short Course on Roadside Development,* Ohio State University (1969) pp. 149-150.

10. ANDERSON, C. R., "Maryland." *29th Short Course on Roadside Development,* Ohio State University (1970) pp. 154-155.
11. APPLEYARD, D., LYNCH, K., and MYER, J. R., *The View From the Road.* MIT Press (1964) 64 pp.
12. ARIZONA STATE MUSEUM, *Our Cultural Heritage and Arizona Highways.* Univ. of Arizona (1966) 10 pp.
13. AUTOMOTIVE SAFETY FOUNDATION, *The Hershey Conference on Freeways in the Urban Setting* (1962) 18 pp.
14. AUTOMOTIVE SAFETY FOUNDATION, *What Freeways Mean to Your City.* Washington, D.C. (1964) 56 pp.
15. AUTOMOTIVE SAFETY FOUNDATION and JOINT COMMITTEE ON HIGHWAYS OF THE AMERICAN MUNICIPAL ASSOCIATION—American Association of State Highways Officials, *The Sagamore Conference on Highways and Urban Development (Guidelines for Action).* Washington, D.C. (1958) 29 pp.
16. AYLOR, D., "Noise Reduction by Vegetation and Ground." *J. Acoust. Soc. Am.,* Vol. 51, No. 1 (Part 2), pp. 197-205 (1972).
17. BABICH, H., and STOTZKY, G., "Ecologic Ramifications of Air Pollution." *Proceedings of International Conference on Transportation and the Environment,* Part I, Society of Automotive Engineers, Inc.; Environmental Protection Agency and U.S. Department of Transportation (1972) pp. 198-214.
18. BAGLEY, M. D., KROLL, C., and CLARK, K., *Aesthetics in Environmental Planning.* U.S. Environmental Protection Agency (Nov. 1973) 187 pp.
19. BAKER, R. H., "Nutritional Strategies of Myomorph Rodents in North American Grasslands." *J. Mammalogy,* Vol. 52, pp. 800-805 (1971).
20. BARTON-ASCHMAN ASSOCIATES, "Multiple Use of Lands Within Highway Rights-of-Way." *NCHRP Rep. 53* (1968) 68 pp.
21. BAXTER, W. L., and WOLFE, C. W., *Life History and Ecology of the Ring-Necked Pheasant in Nebraska.* Nebraska Game and Parks Commission (1973).
22. BEATON, J. L. and BOURGET, L., "Can Noise Radiation From Highways be Reduced by Design?" *Hwy. Res. Rec. 232* (1968) pp. 1-8.
23. BELLIS, E. D., and GRAVES, H. B., "Collision of Vehicles With Deer Studied on Pennsylvania Interstate Road Section." *Hwy. Res. News, Hwy. Res. Board 43* (1971) pp. 13-17.
24. BELLIS, E. D., and GRAVES, H. B., "Deer Mortality on a Pennsylvania Interstate Highway." *J. Wildlife Management,* Vol. 35, No. 2, pp. 232-237 (1971).
25. BELLIS, E. D., GRAVES, H. B., CARBAUGH, B. T., and VAUGHAN, J. P., "Behavior, Ecology, and Mortality of White-Tailed Deer Along A Pennsylvania Interstate Highway." *Research Publication No. 71,* The Pennsylvania State University (1971) 96 pp.
26. BELLOMO, S. J., and VOORHEES, A. M. & ASSOCIATES, INC., "Providing for Air Quality and Urban Mobility." *Hwy. Res. Rec. 465* (1973) pp. 1-13.
27. BERRY, KRISTIN, personal correspondence (1975).
28. BESADNY, C. D., KABAT, C., and RUSCH, A. J., "Practical Aspects of a Selective Brush Management Program on Wisconsin Roadsides." *North American Wildlife and Natural Resources Conference Transactions,* Vol. 33, pp. 236-248 (1968).
29. BLASER, R. E., and MCKEEN, W. H., JR., "Regeneration of Woody Vegetation Along Roadsides." *Hwy. Res. Rec. 161* (1967) pp. 104-115.
30. BONES, J., "Riotous Flora by a Texas Wayside." *Audubon,* Vol. 77, No. 4, pp. 32-39 (July 1975).
31. BRINTON, J. H., JR., and BLOOM, J. N., *Effect of Highway Landscape Development on Nearby Property. NCHRP Rep. 75* (1969) 82 pp.
32. BROADBOOKS, H. E., "Northward Extension of the Kangaroo Rat in Washington." *J. Mammalogy,* Vol. 39, No. 2, pp. 299-301 (1958).
33. BUFFINGTON, J. L., "Economic Consequences of Freeway Displacement to Residents Relocated Under the 1968 and 1970 Relocation Programs." *Transp. Res. Rec. 481* (1974) pp. 29-42.
34. BURKE, H. D., ET AL., "A Method for Classifying Scenery From a Roadway." *Park Practice Guideline* (Mar. 1968). (Abstract in Bagley, M. D., Kroll, C., and Clark, K., *Aesthetics in Environmental Planning,* pp. 65-68, Environmental Protection Agency, 1973).
35. BURT, M. E., "Aspects of Highway Design and Traffic Management." *J. Sound and Vibration,* Vol. 15, No. 1, pp. 23-34, (Mar. 1971).
36. BUSS, I. O., "A Managed Cliff Swallow Colony in Southern Wisconsin." *Wilson Bull.,* Vol. 54, No. 3, pp. 153-160 (1942).
37. CASSEL, J. F., and OETTING, R. B., "Ecological Considerations May Favor Reduced Mowing." *Pub. Works,* Vol. 101, No. 6, pp. 95-97 (1970).
38. CHERNER, M., "Property Values as Affected by Highway Landscape Development." *Hwy Res. Rec. 53* (1964) pp. 4-7.
39. CLAY, G., "Finding Futures in the Highway Strip." *Landscape Architecture,* Vol. 64, No. 1, pp. 458-465 (1973).
40. CODY, J. B., and QUIMBY, J. R., "Vegetation Management on Utility Rights-of-Way; An Annotated Bibliography." *Appl. Forestry Res. Inst. Res. Dept. No. 27,* State Univ. of N.Y. (1975).
41. COHEN, A., "Location—Design Control of Transportation Noise." *J. Urban Planning and Dev. Div., Proc. ASCE,* Vol. 93, No. UP4, pp. 63-86 (Dec. 1967).
42. COLE, L. C., "Wooden Highway Medians." *BioScience,* Vol. 19, No. 11, pp. 967 (1969).
43. CROWE, S., *The Landscape of Roads.* The Architectural Press, London (1960) 136 pp.
44. CURRY, D. A., and ANDERSON, D. G., "Procedures for Estimating Highway User Costs, Air-Pollution, and Noise Effects. *NCHRP Rep. 133* (1972) 127 pp.
45. DALQUEST, W. W., and KILPATRICK, W., "Dynamics of Pocket Gopher Distribution on the Edwards Plateau of Texas." *Southwestern Naturalist,* Vol. 18, No. 1, pp. 1-9 (1973).
46. DAVIDSON, P., "An Exploratory Study to Identify and Measure the Benefits Derived From the Scenic Enhancement of Federal-Aid Highways." *Hwy. Res. Rec. 182* (1967) pp. 18-21.

47. DAVIS, R., and COCKRUM, E. L., "Bridges Utilized as Day-Roosts by Bats." *J. Mammalogy,* Vol. 44, No. 3, pp. 428-430 (1963).
48. DEAKIN, O. A., "Median Planting for Headlight-Glare Screening." *Roadside Development 1956,* Hwy Res. Board (1956) pp. 63-68.
49. DEAKIN, O. A., "Planting for Screening Headlight Glare and for Traffic Guidance." *Roadside Development 1957,* Hwy Res. Board (1957) pp. 55-73.
50. DEAKIN, O. A., "Median Design as it Affects Conservation of Vegetation and Planting for Screening Headlight Glare and Traffic Guidance." *Roadside Development 1958,* Hwy. Res. Board (1958) pp. 49-54.
51. DEAKIN, O. A., "Design of Rural Highway Landscaping." *Roadside Development 1959,* Hwy. Res. Board (1959) pp. 15-18.
52. DEAKIN, O. A., "Median Planting for Headlight-Glare Screening and Traffic Guidance." *Roadside Development 1960,* Hwy. Res. Board (1960) pp. 21-25.
53. DEAKIN, O. A., "Progress Report on Median Planting for Headlight-Glare Screening and Traffic Guidance." *Roadside Development 1961,* Hwy. Res. Board (1961) pp. 40-45.
54. DEAKIN, O. A., "Planting the Urban Expressway." *21st Short Course on Roadside Development,* Ohio State University (1962) pp. 60-63.
55. DEAKIN, O. A., "Planting for Screening Headlight Glare and Traffic Guidance." *Hwy. Res. Rec. 53* (1963) pp. 17-25.
56. DOLLING, H. D., and LANDERS, R. Q., "Iowa: Conservation Aspects of Iowa Roadsides." *28th Short Course on Roadside Development,* Ohio State University (1969) pp. 139-145.
57. DOUCET, G. J., SARRAZIN, P. R., and BIDER, J. R., "Use of Highway Overpass Embankments by Woodchuck *Marmota monax." Canadian Field Naturalist,* Vol. 88, No. 2, pp. 187-190 (1974).
58. DOUGLAS, C. L., and JOHNSON, R. R., "Highways and Their Impact on the Wildlife of the Pinyon-Juniper-Oak Woodland and Grassland in North-Central Arizona." *Prescott College Ecological Survey* (1972) 111 pp. and appendixes.
59. DOUGLAS, D. S., "Services of the S.C.S. and Soil and Water Conservation Districts Can Assist the Highway Program." *28th Short Course on Roadside Development,* Ohio State University (1969) pp. 79-81.
60. DUCKWORTH, F. S., and SANDBERG, J., "The Effect of Cities Upon Horizontal and Vertical Temperature Gradients." *Bull. Am. Meteorol. Soc.,* Vol. 35, No. 5, pp. 198-207 (1954).
61. EARLEY, W. O., "Warrants, Criteria, and Standards for Acquiring Land and Interests in Land for Scenic and Other Highway Environmental Purposes." *Hwy. Res. Rec. 206* (1967) pp. 1-35.
62. EARLEY, W. O., "Roadside Development—Evaluation of Research." *NCHRP Rep. 137* (1972) 78 pp.
63. EGLER, F. E., "Fifty Million More Acres for Hunting?" *Sports Afield,* Vol. 132, No. 6, pp. 48-51 (1954).
64. EGLER, F. E., "Vegetation Management for Rights-of-Way and Roadsides." In *Annual Report of the Board of Regents of the Smithsonian Institution* (1953) pp. 299-322; *Publication No. 4149,* 418 pp.
65. EGLER, F. E., "Right-of-ways and Wildlife Habitat: A Progress Report." *North American Wildlife and Natural Resources Conference Transactions,* Vol. 22, pp. 133-142 (1957).
66. EISELE, C. R., "Salvaging Fossils in Nebraska." *Museum Notes, University of Nebraska State Museum,* No. 24, pp. 1-6 (1964).
67. EVERETT, H. W., "Direct Establishment of Shrubs and Other Woody Vegetation." *29th Short Course on Roadside Development,* Ohio State University (1970) pp. 76-81.
68. EVERETT, H. W., DICKERSON, J. A., and KIMMONS, J. H., "Woody Plants for Maryland Highways." *Soil Conservation,* Vol. 39, No. 7, pp. 18-19 (1974).
69. FABOS, J. G., "Putting Numbers on Qualities: The Rising Landscape Assessors." *Landscape Architecture,* Vol. 64, No. 3, pp. 164-165 (1974).
70. FABOS, J. G., CAREAGA, R., GREENE, C., and WILLISTON, S., "Model for Landscape Resource Assessment Part I." Metropolitan Landscape Planning Model (METLAND), Univ. of Massachusetts, College of Food and Natural Resources, Agricultural Experiment Station (1973) 141 pp.
71. FEDERICK, J. C., "The Highway Roadsides as an Element in Urban Design." *Hwy. Res. Rec. 280* (1969) pp. 15-24.
72. FEDERICK, J. C., "The Highway Roadside as an Urban Land Reserve." *28th Short Course on Roadside Development,* Ohio State University (1969) pp. 54-64.
73. FRANKLAND, B., "California's Scenic Highway Program." *Hwy. Res. Rec. 161* (1967) pp. 50-53.
74. FRANKS, K. N., "Kentucky." *29th Short Course on Roadside Development,* Ohio State University (1970) pp 152-153.
75. "Freeways in the Urban Setting." *Landscape Architecture,* Vol. 53, No. 1, pp. 73-80 (Oct. 1962).
76. GABIOU, A., "The Blooming of the Roadsides." Dept. of Natural Resources, *Minnesota Volunteer* Vol. 37, No. 214, pp. 12-17 (1974).
77. GALLOWAY, W. J., CLARK, W. E., and KERRICK, J. S., "Highway Noise—Measurement, Simulation and Mixed Reactions." *NCHRP Rep. 78* (1969) 78 pp.
78. GARMHAUSEN, W. J., "Roadside Parks on Limited-Access Highway." *Roadside Development 1956,* Hwy. Res. Board (1956) pp. 57-60.
79. GILL, D., and BONNETT, P., *Nature in the Urban Landscape: A Study in City Ecosystems.* York Press, Baltimore (1973) 209 pp.
80. GODSCHALK, D. R., "Achieving Environmental Quality and the Highway Beautification Act of 1965." *Hwy. Res. Rec. 182* (1967) pp. 22-24.
81. GORDON, C. G., GALLOWAY, W. J., KUGLER, B. A., and NELSON, D. L., "Highway Noise—A Design Guide For Highway Engineers." *NCHRP Rep. 117* (1971) 79 pp.
82. GRAHAM, E. H., *The Land and Wildlife.* Oxford University Press (1947) 232 pp.

83. HALPRIN, L., *Freeways.* Reinhold Publishing Corp. (1966) 160 pp.
84. HANES, J. C., and CONNORS, C. H. (eds.), *Spencer Miller Jr. Lecture Series: Landscape Design and Its Relation to the Modern Highway.* Rutgers University, (1953) 63 pp.
85. HANES, R. E., ZELAZNY, L. W., and BLASER, R. E., "Effects of Deicing Salts on Water Quality and Biota—Literature Review and Recommended Research." *NCHRP Rep. 91* (1970) 70 pp.
86. HANSON, L. E., and PROGULSKE, D. R., "Movements and Cover Preferences of Pheasants in South Dakota." *J. Wildlife Management,* Vol. 37, No. 4, pp. 454-461 (1973).
87. HERNDON, T. W., "The First Wave of the Offensive for Highway Beauty and Safety." *26th Short Course in Roadside Development, Ohio State University* (1967) pp. 42-47.
88. HEUSMANN, H. W., "Analysis of the Potential Creation of Productive Wetlands by Interstate Highway Construction with Emphasis on Waterfowl Management." M.S. thesis, Univ. of Massachusetts (1969) 97 pp.
89. HEUSMANN, H. W., "How to Create Wildlife Habitat from Highway Construction." *Catalyst for Environmental Quality,* Vol. 3, No. 4, pp. 17-19 (1973).
90. Highway Research Board, "Information Systems for Land Use and Transportation Planning." *Hwy. Res. Rec. 194* (1967) 102 pp.
91. Highway Research Board, "Land Acquisition and Freeway Land Development." *Hwy. Res. Rec. 217* (1968) 41 pp.
92. HIGHWAY RESEARCH BOARD, "Planning and Management of Roadside Vegetation: An Analysis of Principles." *Sp. Rep. 23* (1956) 48 pp.
93. HIGHWAY RESEARCH BOARD, "The Art and Science of Roadside Development." *Sp. Rep. 88* (1966) 81 pp.
94. HIGHWAY RESEARCH BOARD, "Joint Development and Multiple Use of Transportation Rights-of-Way." *Sp. Rep. 104* (1969) 198 pp.
95. HIGHWAY RESEARCH BOARD, "Environmental Considerations in Planning, Design, and Construction." *Sp. Rep. 138* (1973) 161 pp.
96. HIGHWAY RESEARCH BOARD, "Highway and Air Quality." *Sp. Rep. 141* (1973) 90 pp.
97. HINE, R. L., and RUSCH, A. J., "New Look for Roadsides." *Wisconsin Conservation Bull.,* Vol. 30, No. 1, pp. 12-13 (1965).
98. HOFFMAN, D. M., "Nesting Cover for Pheasants." *Colorado Outdoors,* Vol. 22, No. 3, pp. 36-38 (1973).
99. HORNBECK, P. L., FORSTER, R. R., and DILLINGHAM, M. R., "Highway Aesthetics—Functional Criteria for Planning and Design." *Hwy. Res. Rec. 280* (1969) pp. 25-38.
100. HORNBECK, P., ET AL., *Visual Values for Highway,* Vol. 1, Harvard University (1970). (Abstract in Bagley, M.D., Kroll, C., and Clark, K., *Asthetics in Environmental Planning,* U.S. Environmental Protection Agency, pp. 78-81, 1973.)
101. HOROWITZ, J. L., and PERNELA, L. M., "Analysis of Urban Area Automobile Emissions According to Trip Type." *Transp. Res. Rec. 492* (1974) pp. 1-8.
102. HOTTENSTEIN, W. C., "Common Sense Turf Management on Today's Highways." *Hwy. Res. Rec. 23* (1963) pp. 66-69.
103. HOWARD, NEEDLES, TAMMEN and BERGENDOFF, *I-66 Corridor Transportation Alternates Study; Draft Environmental/Section 4(F) Statement.* (1973) 247 pp. and appendixes.
104. HUEY, L. M., "Mammalian Invasion Via the Highway." *J. Mammalogy,* Vol. 22, No. 4, pp. 383-385 (1941).
105. HUFF, E., "Road Ranch '69." *Nebraskaland* (May 1969) pp. 30-33.
106. HUNTER, W. C., "Role of Roadway Planting Design in Control of Drifting Snow." *Roadside Development 1962,* Hwy. Res. Board (1962) pp. 23-31.
107. IURKA, H. H., TOTH, J. F., and TUTTLE, W. S., "Design of Urban Highway Landscaping." *Roadside Development 1959,* Hwy. Res. Board (1959) pp. 3-14.
108. JACOBS, P., and WAY, D., *Visual Analyses of Landscape Development.* Harvard University, Department of Landscape Architecture (1968) 54 pp.
109. JACOBS, P., and WAY, D. "How Much Development Can the Landscape Absorb?" *Landscape Architecture,* Vol. 59, No. 4, pp. 296-298 (July 1969).
110. JONES, I. D. "Noise: A Further Highway Design Consideration." *J. Inst. Hwy. Eng.,* Vol. 19, No. 8, pp. 3-8 (Aug. 1972).
111. JOSELYN, G. B., "Wildlife—An Essential Consideration Determining Future Roadside Maintenance Policy." *Hwy. Res. Rec. 280* (1969) pp. 1-14.
112. JOSELYN, G. B., WARNOCK, J. E., and ETTER, S. L., "Manipulation of Roadside Cover for Nesting Pheasant—A Preliminary Report." *J. Wildlife Management,* Vol. 32, no. 2, pp. 217-233 (1968).
113. JOSELYN, G. B., and TATE, G. I., "Practical Aspects of Managing Roadside Cover for Nesting Pheasants." *J. Wildlife Management,* Vol. 36, No. 1, pp. 1-11 (1973).
114. JUMIKIS, A. R., *Introduction to Soil Mechanics.* D. Van Nostrand Company, Inc. (1967) 436 pp.
115. KLEIN, G. E., CURRY, D. A., ELLIS, H. B., FRATESSA, C. C., MCGILLIVARY, R. G., MOON, A. E., THOMPSON, G. I., and TILTAN, P. D., *Methods of Evaluation of the Effects of Transportation Systems on Community Values.* Stanford Research Institute (1971) 290 pp. and appendix.
116. KROECK, L. G., SMITH, B. L., and FOGO, R. D., "Highway Aesthetics." *Civ. Engineering* (May 1967) pp. 54-56.
117. KUGLER, B. A., and ANDERSON, G. S. "Automotive Noise: Environmental Impact and Control." *Hwy. Res. Rec. 390* (1972) pp. 45-55.
118. KUGLER, B. A., and PIERSOL, A. G., "Highway Noise—A Field Evaluation of Traffic Noise Reduction Measures." *NCHRP Rep. 144* (1973) 80 pp.
119. LANGERWERFF, J. V., and SPECHT, A. N., "Contamination of Roadside Soil and Vegetation With Cadmium, Nickel, Lead and Zinc." *Environmental Sci. and Tech.,* Vol. 4, pp. 583-586 (1970).

120. LARSON, T. D., and MCKELVEY, F. X., "Environmental Impacts of Transportation Facility Design Decisions." Course notes, The Pennsylvania Transportation Institute, The Pennsylvania State University (1973).
121. LEEMING, J. J., "A Highway Engineer and the Environment." *Hwy. Eng.*, Vol. 20, No. 9, pp. 22-26 (1973).
122. LEOPOLD, L. B., "Quantitative Comparison of Some Aesthetic Factors Among Rivers." *Geological Survey Circular 620* (1969) 16 pp.
123. LEOPOLD, L. B., CLARK, F. E., HANSHAW, B. B., and BALSLEY, J. R., "A Procedure for Evaluating Environmental Impact." *Geological Survey Circular 645,* (1971).
124. LEVIN, D. R., "Scenic Roads and Parkways." *Hwy. Res. Rec. 161* (1967) pp. 30-33.
125. LEVIN, D. R., "Scenic Corridors." *Hwy. Res. Rec. 166* (1967) pp. 14-21.
126. LEWIS, P. H., JR., "Quality Corridors for Wisconsin." *Landscape Architecture,* Vol. 54, No. 2, pp. 100-107 (Jan. 1964).
127. LEWIS, P. H., JR., "Environmental Values in Regional Highway Design." *Hwy. Res. Rec. 161* (1967) pp. 1-16.
128. LEWIS, P. H., JR., "The Highway Corridor as a Concept of Design and Planning." *Hwy. Res. Rec. 166* (1967) pp. 1-8.
129. LINSDALE, J. M., "Roadways as They Affect Bird Life." *Condor,* Vol. 31, pp. 143-145 (1929).
130. LITTON, R. B., ET AL., "An Aesthetic Overview of the Role of Water in the Landscape." University of California, Department of Landscape Architecture (July 1971). (Abstract in Bagley, M. D., Kroll, C., and Clark, K., *Aesthetics in Environmental Planning,* Environmental Protection Agency. pp. 69-74, 1973).
131. LORENS, E. R., "Valuation of Scenic Area Easements." *Hwy. Res. Rec. 166* (1967) pp. 44-53.
132. LYNCH, K., *Image of the City.* The Technology Press and Harvard University Press (1960) 194 pp.
133. MCHARG, I., "Where Should Highways Go?" *Landscape Architecture,* Vol. 57, No. 3, pp. 179-181 (Apr. 1967).
134. MCHARG, I., "A Comprehensive Highway Route Selection Method." *Hwy. Res. Rec. 246* (1968) pp. 1-15.
135. MCHARG, I., *Design with Nature.* Natural History Press (1969).
136. MACLAUCHLAN, R. S., "The Role of the Soil Conservation Service's Work With Plant Materials." *3rd Midwest Prarie Conference Proceedings* (1973) pp. 9-12.
137. MAEKAWA, Z., "Noise Reduction by Screens." *Appl. Acoustics,* Vol. I, pp. 157-173 (1968).
138. MANVILLE, R. H., "Roadside Abundance of Woodchucks (*Marmota monax rufescens*)." *American Midland Naturalist,* Vol. 75, pp. 537-538 (1966).
139. MARTIN, R. F., "Syntopic Culvert Nesting of Cave and Barn Swallows in Texas." *Auk.,* Vol. 91. pp. 776-782 (1974).
140. MATHENY, J. B., "Acquisition of Scenic Easements." *Hwy. Res. Rec. 166* (1967) pp. 36-43.
141. MAUBART, J. K., "Engineering Guidelines for Highway Noise Shield Design." *J. Transp. Engineering,* Vol. 100, No. TE 4 (Nov. 1974).
142. MAYHEW, W. W., "The Biology of the Cliff Swallow in California." *Condor.,* Vol. 60. pp. 7-37 (1958).
143. MICHAEL, E. D., FERRIS, C. R., and HAVERLACK, E. G., "Effects of High-speed Highways on Small Mammals." *Trans. First International Theriological Congress,* Moscow, June 6-12 (1974) 403 pp.
144. MONTAG, D., "Roadsides for Wildlife." Dept. of Natural Resources, *Minnesota Volunteer,* Vol. 38, No. 219, pp. 26-32 (1975).
145. MOORE, C. T., MAYER, M. L., LIPSON, H. A., and JOYCE, G., "A Study of the Expected Economic and Social Impact of Interstate Highways in the Industrial and Commercial Trading Area of Birmingham, Alabama—The First Phase." *Hwy. Res. Rec. 38* (Sept. 1964) 132 pp.
146. MORGAN, R. D., Director of Highway Planning, Federal Highway Administration, personal correspondence (July 1975).
147. MOULTON, J. C., "The Fishery Potential of Four Aquatic Environments Created by Interstate 71 Construction in Massachusetts." M.S. thesis, Univ. of Massachusetts (1970) 86 pp.
148. MUMFORD, L., *The Highway and the City.* Harcourt, Brace and World, Inc. (1963) 246 pp.
149. MURPHY, L. M., "Landscape Planting Species Survival." *29th Short Course on Roadside Development,* Ohio State University (1970) pp. 132-138.
150. MYRUP, L. O., "Impact of Highways on Air Quality." *Hwy. Res. Rec. 465* (1973) pp. 75-95.
151. NABHAM, G., "Prairie Revival Bringing Native Grasses Back to Pastures, Backyards." *High Country News,* Vol. 6, No. 22, pp. 6-7 (Nov. 1974).
152. National Cooperative Highway Research Program, "Rest Areas." *NCHRP Synthesis of Highway Practice 20* (1973) 38 pp.
153. "The New Urban Highway." Paper presented at the Annual Meeting of the Southeastern Association of State Highway Officials (Nov. 20, 1967).
154. NIERING, W. A., and GOODWIN, R. H., "Creation of Relatively Stable Shrublands With Herbicides: Arresting 'Succession' on Rights-of-Way and Pastureland." *Ecology,* Vol. 55, No. 4, pp. 784-795 (1974).
155. NORTON, T. J., "Decision-Making Techniques for Identifying Aesthetically Superior Highway Environments." *Hwy. Res. Rec. 182* (1967) pp. 5-8.
156. OETTING, R. B., "Rights-of-Way Resources of the Prairie Provinces." *Blue Jay,* Vol. 29, No. 4, pp. 179-183 (1971).
157. OETTING, R. B., and CASSEL, J. F., "Effects of Interstate Right-of-Way Mowing on Wildlife, Snow Buildup, and Motorist Opinion in North Dakota: A Preliminary Report." *Hwy. Res. Rec. 335* (1970) pp. 52-59.
158. OETTING, R. B., and CASSEL, J. F., "Waterfowl Nesting on Interstate Highway Right-of-Way in North Dakota." *J. Wildlife Management,* Vol. 35, No. 4, pp. 774-781 (1971).
159. OGLESBY, C. H., *Highway Engineering.* John Wiley & Sons (1975) 783 pp.

160. OWENS, H. B., "Landscape Design and the Modern Highway." *Roadside Development 1960,* Hwy. Res. Board (1960) pp. 16-18.
161. PAGE, R. D., and CASSEL, J. F., "Waterfowl Nesting on a Railroad Right-of-Way in North Dakota." *J. Wildlife Management,* Vol. 35, No. 3, pp. 544-549 (1971).
162. PARIZEK, R. R., "Impact of Highways on the Hydrogeologic Environment." *Environmental Geomorphology.* Proceedings of First Annual Geomorphology Symposia Series, Binghamton, N.Y. (1970) pp. 151-199.
163. PEEK, F. W., and BELLIS, E. D., "Deer Movement and Behavior Along An Interstate Highway." *Hwy. Res. News 36* (1969) pp. 36-42.
164. PETERS, J. C., "Montana Highway and Wildlife Professions Cooperate." *Civ. Engineering,* Vol. 40, No. 11, pp. 58-59 (1970).
165. PETERSON, G. L., "Complete Value Analysis: Highway Beautification and Environmental Quality." *Hwy. Res. Rec. 182* (1967) pp. 9-17.
166. PIENAAR, U. DE V., "The Ecological Significance of Roads in a National Park." *Koedoe.,* Vol. 11, pp. 169-175 (1968).
167. POUGH, R. H., "Roadsides as Living Museums of Natural History." *Roadside Development 1956,* Hwy. Res. Board (1956) pp. 18-21.
168. POWELL, H. H., and BURROWES, F. G. A., "Multiple Use of City Transportation Corridors." *J. Transp. Engineering,* Vol. 98, No. TE 3 (Aug. 1972).
169. PRIEDE, T., "Origins of Automotive Vehicle Noise." *J. Sound and Vibration,* Vol. 15, No. 1, pp. 61-73 (Mar. 1971).
170. PUGLISI, M. J., LINDZEY, J. S., and BELLIS, E. D., "Factors Associated with Highway Mortality of White-tailed Deer." *J. Wildlife Management,* Vol. 38, No. 4, pp. 799-807 (1974).
171. PUSHKAREV, B., "Esthetic Criteria in Freeway Design." *Proc. 41* (1962) pp. 89-108. Abstract in *Roadside Development 1962,* Hwy. Res. Board (1962) p. 47.
172. PUSHKAREV, B., "Highway Location as a Problem of Urban and Landscape Design." *Hwy. Res. Rec. 23* (1963) pp. 7-18.
173. QUARLES, H. D., III, HANAWALT, R. B., and ODUM, W. E., "Lead in Small Mammals, Plants and Soil at Varying Distances From a Highway." *J. Appl. Ecology, Paper* 78 (1974) 13 pp.
174. RABINOWITZ, C. B., and COUGHLIN, R. E., "Analysis of Landscape Characteristics Relevant to Preference." *RSRI Discussion Paper Series No. 38,* Philadelphia, Pa., Regional Science Research Institute (1970) 86 pp.
175. RABINOWITZ, C. B., and COUGHLIN, R. E., "Some Experiments in Quantitative Measurement of Landscape Quality." *RSRI Discussion Paper Series No. 43,* Philadelphia, Pa., Regional Science Research Institute (1971) 57 pp.
176. RAPUANO, M., "Scenic Roads—Do We Need Them?" Paper presented at The Pennsylvania State University (Apr. 1971) 22 pp.
177. RAPUANO, M., HALPRIN, L., KAVANAGH, T. C., POWELL, H. R., ROCHE, K., ROCKWELL, M. L., SIMONDS, J. O., and SPRINGER, M. R., *The Freeway in the City.* U.S. Government Printing Office (1968) 141 pp.
178. REVIS, J. S., "Short-term Transportation Control Strategies for Air Pollution Control." *Hwy. Res. Rec. 465.* (1973) pp. 21-45.
179. RICKER, E. R., and ROPER, V. J., "Effect of Planting in Median Strip on Night-Visibility Distances." *Hwy. Res. Board Bull. 89* (1954) pp. 16-20.
180. RIEDESEL, G. A., SCOTT, D. M., PATTON, R., MATTHEWS, H. C., ABBOT, H. T., VAN BLAADERN, A. N. M., WEAVER, N., and LOOK, J. C., "A Study of the Social, Economic, and Environmental Impact of Highway Transportation Facilities on Urban Communities." Washington State University, Hwy. Res. Sec. Engineering Res. Div. (1968) 208 pp.
181. RIGNANI ASSOCIATES, INC., *Draft Environmental/ Section 4(f) Statement for Department of Transportation, Federal Highway Administration and the Pennsylvania Department of Transportation for Legislative Route 1061, Sections 6, 7, 8, 9 and 10, Blair County, Pennsylvania.* Camphill, Pennsylvania (1973).
182. ROBINSON, J., *Highways and Our Environment.* McGraw Hill (1971) 340 pp.
183. RYAN, J. J., "Coordinating Landscape Development in Urban Areas With the Right-of-Way." *Roadside Development 1961,* Hwy. Res. Board (1961) pp. 77-79.
184. SARGENT, F. O., "Scenery Classification." *Vermont Resources Res. Center Rep. 18.* Burlington, Agricultural Experiment Station (1967) 28 pp.
185. SAUNDERS, J. A., "A Helping Hand for Mother Nature." *27th Short Course on Roadside Development,* Ohio State University (1968) pp. 58-61.
186. SCHEELE, W. E., HYDE, J. E., and HLAVIN, W., "Fossil Dig." *Explorer, Cleveland Museum of Natural History,* Vol. 7, No. 3, pp. 5-8; No. 4, pp. 28-31; No. 5, pp. 4-11 (1965).
187. SCHMITZ, W. A., "Wisconsin." *27th Short Course on Roadside Development,* Ohio State University (1968) pp. 153-154.
188. SCHMITZ, W. A., "Wisconsin." *29th Short Course on Roadside Development.* Ohio State University (1970) pp. 177-178.
189. SCHOLES, W. E., and SARGENT, J. W., "Designing Against Noise From Road Traffic." *Appl. Acoustics,* Vol. 4, No. 3, pp. 203-234 (1971).
190. SCHRAMM, P., "A Practical Restoration Method for Tall-Grass Prairie." Proceedings of a Symposium on Prairie and Prairie Restoration, Sept. 14-15, 1968. Knox. Coll. Biol. Field Station, *Sp. Pub. No. 3* (1970) pp. 63-65.
191. SEARS, B. G., "Lanscape Design Principles and Their Application to the Modern Highway." *Roadside Development 1960,* Hwy. Res. Board (1960) pp. 19-20.
192. SEARS, B. G., "Highways as Environmental Elements." *Hwy. Res. Rec. 93* (1965) pp. 49-54.

193. SHAFER, E. L., JR., and MIETZ, J., "It Seems Possible to Quantify Scenic Beauty in Photographs." *U.S.D.A. Forest Service Res. Paper NE-162,* Northeastern Forest Experimental Station (1970) 12 pp.
194. SHEEHAN, J., "Tortoises Relocated in Desert." *Outdoor California,* Vol. 32, No. 6, pp. 1 (1971).
195. SIMONSON, W. H., "Abatement of Highway Noise With Special Reference to Roadside Design." *Roadside Development 1954,* Hwy. Res. Board (1954) pp. 55-78.
196. SIMONSON, W. H., "Roadside Design to Reduce Traffic Noise." *Roadside Development 1956,* Hwy. Res. Board (1956) pp. 41-44.
197. SIMONSON, W. H., "Roadside Design to Reduce Traffic Noise." *Roadside Development 1959,* Hwy. Res. Board (1959) pp. 25-26.
198. SIMONSON, W. H., "Roadside Design to Reduce Traffic Noise: 1958-60." *Roadside Development 1960,* Hwy. Res. Board (1960) pp. 9-10.
199. SIMONSON, W. H., "Progress Report on Noise Abatement: 1961." *Roadside Development 1961,* Hwy. Res. Board (1961) pp. 2-4.
200. SIMONSON, W. H., "Progress Report on Noise Abatement." *Hwy. Res. Rec. 23* (1963) pp. 47-49.
201. SKOG, J., SHIRLEY, E., and RANZIERI, A., "The Quantitative Air Quality Report." *Hwy. Res. Rec. 465,* (1973) pp. 55-66.
202. SMITH, L. B., and ROCCO, V. A., *Air Pollution Impact Analysis, Interstate Route 240 and U-101 Connector Rank, Memphis, Shelby County, Tennessee.* Technical Environmental Section, Tennessee Department of Transportation (Feb. 1973).
203. SNOW, W. B. (ed), *The Highway and the Landscape.* Rutgers University Press (1959) 230 pp.
204. SOLOMON, D., "Environmental Research and Highways." *Pub. Roads,* Vol. 37, No. 8, pp. 297-305 (Mar. 1974).
205. SPEARING, G. D., and PORTER, M. R., "Motorways and the Rural Environment." *Proc. Inst. Civ. Eng.,* Vol. 47, pp. 107-120 (1970).
206. SPENCER, S. J., "A Study of the Physical Characteristics of Nesting Sites Used by Bank Swallows." Thesis, Doctor of Education, The Pennsylvania State University (1962) 105 pp.
207. SPOONER, P., *Highway Landscape Design.* Australian Road Res. Board, Sydney (1969) 255 pp.
208. STEEN, M. O., "The Nebraska Chain-of-Lakes." Nebraska Game and Parks Commission (1973) 6 pp.
209. STEINER, W. M., "Control of Soil Subject to Wind Erosion." *Hwy. Res. Rec. 23* (1963) pp. 60-65.
210. STEINITZ, C., "Meaning and the Congruence of Urban Form and Activity." *J. Am. Inst. Planners,* Vol. 34, No. 3, pp. 233-248 (1968).
211. STEINITZ, C., "Lanscape Resource Analysis." *Landscape Architecture,* Vol. 60, No. 2, pp. 101-105 (Jan. 1970).
212. STEINITZ, C., and ROGERS, P., "Visual Quality." *Interstate Highway 84 in Rhode Island,* Vol. 2, Ch. 6, Department of Transportation, State of Rhode Island and Providence Plantations (May 1972). (Abstract in Bagley, M.D., Kroll, C., and Clark, K., *Aesthetics in Environmental Planning,* Environmental Protection Agency, pp. 76-78, 1973).
213. STOECKELER, J. H., "Drainage Along Swamp Forest Roads: Lessons From Europe." *J. Forestry,* Vol. 63, No. 10, pp. 772-776 (1965).
214. SULLIVAN, C., "Highway Dams: Water for the Future." *West Virginia Conservation,* Vol. 22, No. 6, pp. 1-5 (1958).
215. SUTTE, D. T., JR., and CUNNINGHAM, R. A., "Scenic Easements—Legal, Administrative, and Valuation Problems and Procedures." *NCHRP Rep. 56* (1968) 174 pp.
216. THIEL, F. I., "Social Effects of Modern Highway Transportation." *Hwy. Res. Board Bull. 327.*
217. THIEL, F., and YASNOWSKY, J., "Some Effects of Highway Beautification." *Hwy. Res. Rec. 233* (1968) pp. 1-15.
218. THOMPSON, D. Q., "Food Preferences of the Meadow Vole (*Microtus pennsylvanicus*) in Relation to Habitat Affinities." *American Midland Naturalist,* Vol. 74, pp. 76-86 (1965).
219. TOBEY, G. B., JR., "Leave Those Roadsides Alone!" *Landscape Architecture,* Vol. 55, No. 3, pp. 182-183 (Apr. 1965).
220. TORDOFF, H. B., *A Systematic Study of the Avian Family Fringillidae.* Miscellaneous Publications, Museum of Zoology, Univ. of Michigan, *No. 81* (1954) 41 pp.
221. TUNNARD, C., "Highway Scenic Potentials." *Hwy. Res. Rec. 182* (1967) pp. 1-4.
222. TUNNARD, C., and PUSHKAREV, B., *Man-Made America Chaos or Control?* Connecticut Printers, Inc. (1963) 479 pp.
223. UHLER, F. M., "Bonus from Waste Places." *Waterfowl Tomorrow,* U.S. Dept. of the Interior, Fish and Wildlife Service (1964) pp. 643-653.
224. U.S. CONGRESS, *Highway Beautification Act of 1965.* P.L. 89-285, Statutes at Large, Vol. 79 (1965).
225. U.S. CONGRESS, HOUSE OF REPRESENTATIVES, Committee on Public Works, *Benefits of Interstate Highways.* No. 91-41, 91st Cong., 2d. Sess. (1970).
226. U.S. CONGRESS, SENATE. Public Law 93-291, 93rd. Congress, 2d. Sess., S. 514, 24 May 1974. Amendment to *An Act to Provide For the Preservation of Historical and Archaeological Data (Including Relics and Specimens) Which Might Otherwise be Lost as the Result of the Construction of a Dam,* Statutes at Large, Vol. 74 (1960).
227. U.S. DEPT. OF COMMERCE, BUREAU OF PUBLIC ROADS, *Policy and Procedure Memorandum 20-7* (Aug. 24, 1959).
228. U.S. DEPT. OF COMMERCE, *A Proposed Program for Scenic Roads and Parkways* (June 1966) 254 pp.
229. U.S. DEPT. COMMERCE, *The Automobile and Air Pollution: A Program for Progress* (1967).
230. U.S. DEPT. OF TRANSPORTATION, FEDERAL HIGHWAY ADMINISTRATION, Environmental Development Division, Office of Environmental Policy, *Highway Environment Reference Book* (1970) 92 pp.
231. U.S. DEPT. OF TRANSPORTATION, FEDERAL HIGHWAY ADMINISTRATION, Environmental Development Division, Office of Right-of-Way and Location, *Highway Joint Development and Multiple Use* (1970) 126 pp.

232. U.S. DEPT. OF TRANSPORTATION, *Fatal and Injury Accident Rates on Federal-Aid and Other Highway Systems* (1970).
233. U.S. DEPT. OF TRANSPORTATION, FEDERAL HIGHWAY ADMINISTRATION, "Road May Aid Creation of a New Park." *Highway Transportation* (Nov. 1970) pp. 16-17.
234. U.S. DEPT. OF TRANSPORTATION, FEDERAL HIGHWAY ADMINISTRATION, "Highway Helps Improve Game Management Area." *Highway Transportation* (Spring 1971) p. 14.
235. U.S. DEPT. OF TRANSPORTATION, FEDERAL HIGHWAY ADMINISTRATION, *Final Draft Impact Statement: Project I-80-1(10), Potter-Brownson, Cheyenne County, Nebraska, and Project S-921(3), Potter South to I-80, Cheyenne County, Nebraska* (1971). NTIS Abstract, U.S. Department of Commerce 1974.
236. U.S. DEPT. OF TRANSPORTATION, FEDERAL HIGHWAY ADMINISTRATION, "California Plans Highways to Meet Community and Environmental Objectives." *Highway Transportation* (Winter 1972) pp. 4-7.
237. U.S. DEPT. OF TRANSPORTATION, *Summary of National Transportation Statistics* (June 1974) 149 pp.
238. UPGREN, T., "Winter Energy Problems of North Dakota Huns." *North Dakota Outdoors,* Vol. 37, No. 5, pp. 8-13 (1974).
239. UPHAM, C. M., "Twenty Years of Roadside Development." *Roadside Development 1951,* Hwy. Res. Board (1951) pp. 4-11.
240. USHER, J. M., "Roadside Problems on the Interstate System: Forest and Conservation Aspects." *Roadside Development 1957,* Hwy. Res. Board (1957) pp. 20-22.
241. VENTRE, G. G., and CASE, K. E., "Control and Abatement of Transportation Noise." *Transp. J.,* Vol. 10, No. 4, pp. 54-59 (Summer 1971).
242. VIRGINIA DEPARTMENT OF HIGHWAYS, Special Task Committee on Planning and Management of Roadside Vegetation, "Planning and Management of Roadside Vegetation." 71 pp.
243. WALKER, R. T., "Preliminary Report on Landscape Design Factors and Their Influence on Highway Safety." *Roadside Development 1961,* Hwy. Res. Board (1961) pp. 49-53.
244. WARBURTON, R., "The Jackson Park-Highway Controversy; A Major Turning Point in Public Policy." *Landscape Architecture,* Vol. 58, No. 4, pp. 288-291 (July 1968).
245. WAY, J. M., "Roadside Verges and the Conservation of Wildlife." *J. of the Devon Trust,* No. 12, pp. 483-486 (1967).
246. WAY, J. M., "Management of Roadsides for the Conservation of Wildlife in Britain." *28th Short Course on Roadside Development,* Ohio State University (1969).
247. WAY, J. M., "Further Observations on the Management of Road Verges for Amenity and Wildlife." *Road Verges—Their Function and Management,* symposium held in Edinburgh (Apr. 4, 1970) 13 pp.
248. WAY, J. M., "Wildlife on the Motorway." *New Scientist,* Vol. 47, No. 718, pp. 536-537 (1970).
249. WAY, J. M., "Road Verges on Rural Roads: Management and Other Factors." Monks Wood Experimental Station, Natural Environment Research Council, *Occ. Reports No. 1* (1973) 67 pp.
250. WAY, J. M., Co-operation for Conservation of Rural Road Verges: Co-operation Between County Highway Departments and Conservation Organizations On the Management of Rural Road Verges and Conservation of Sites of Special Interest." Monks Wood Experimental Station, Natural Environmental Research Council, *Occ. Reports No. 2* (1974) 179 pp.
251. WAY, J. M., "The Management of Grass." *Municipal Engineering* (Sept. 6, 1974).
252. WESTERSKOV, K., "Winter Food and Feeding Habits of the Partridge (*Perdix perdix*) in the Canadian Prairie." *Canadian J. of Zoology,* Vol. 44, No. 1, pp. 303-322 (1966).
253. WETMORE, L. B., "Visual Approach to Highway Planning and Design." *Hwy. Res. Board Bull. 190* (1958) pp. 29-40.
254. WHITAKER, G. A., "Phoebe and Barn Swallow Nesting Structures." *Atlantic Naturalist,* Vol. 29, No. 3, pp. 106-109 (1974).
255. WHITELEY, D. M., "Development of Interstate 80, Platte Valley-Nebraska." Nebraska Game and Parks Commission (1970) 4 pp.
256. WIEDEMANN, G. K., "Borrow Pits Can be Assets." *Landscape Architecture,* Vol. 52, No. 2, pp. 92-93 (Jan. 1962).
257. WILDLIFE MANAGEMENT INSTITUTE, "Highway Construction Causes Wetland Drainage." *Outdoor News Bull.,* Vol. 29, No. 7, p. 1 (Apr. 1975).
258. WILLEY, W. E., "Priority Programming and Effect of Highways on Wildlife—The Sycamore Wilderness Area." *Traffic Quarterly,* Vol. 27, No. 3, pp. 365-375 (1973).
259. WILLIAMS, T. E. H., "Highway Engineering and the Influence of Geometric Design Characteristics on Noise." *J. Sound and Vibration,* Vol. 15, No. 1, pp. 17-22 (Mar. 1971).
260. WINKEL, G. H., "Community Response to the Design Features of Roads, A Technique for Measurement." *Hwy. Res. Rec. 305* (1970). (Abstract in Bagley, M. D., Kroll, C., and Clark, K., *Aesthetics in Environmental Planning,* p. 89-90, 1973.)
261. YALE UNIVERSITY, Department of City Planning, *Highway as Environment* (1971) 99 pp.
262. YOUNG, H. E., "Woody Fiber Farming: An Ecologically Sound and Productive Use of Rights-of-Way." *Hwy. Res. Rec. 411* (1972) pp. 15-23.
263. YOUNG, H. E., "Management of Forest Stands on Highway Right-of-Ways." *Res. in the Life Sciences,* Vol. 20, No. 12, 9 pp. (1973).
264. ZUBE, E. H., "Study of Visual and Cultural Environment; North Atlantic Regional Water Resources Study." Research Planning and Design Assoc. Inc. Amherst, Mass. (1970).
265. ZUBE, E. H., "Scenery as a Natural Resource." *Landscape Architecture,* Vol. 63, No. 2, pp. 126-132 (Jan. 1973).
266. ZUBE, E. H., "Rating Everyday Rural Landscapes of the Northeastern U.S." *Landscape Architecture,* Vol. 63, No. 4, pp. 371-375 (July 1973).

APPENDIX B

SOCIAL BENEFITS

Because of the changes that highway improvements bring to regions, communities, and neighborhoods, residents of affected areas experience direct and indirect social benefits and costs. They encounter changes in the amounts and kinds of desirable social interaction in which they engage. Families with children, for example, may be able to visit grandparents in a distant place more easily and more frequently once a nearby limited-access highway is completed. Rural and urban residents may experience an expanded range of employment and recreational opportunities once it becomes easier and safer to travel longer distances. The purpose of this appendix is to examine these and other social effects emanating from highway improvements.

CLASSIFICATION

With the intent to obtain an exhaustive and easily understood classification, the social benefits have been categorized according to the various scales of social organization. The major categories of beneficial effects in the classification system are: A. Individual Effects, B. Population Effects, C. Community Effects, and D. Regional and National Effects.

Individual effects are divided into user and nonuser effects. An important group of effects for the freeway users is the accessibility benefits that include accessibility and freedom of choice in employment, residence, public services, and commercial facilities. Generally, this group of benefits is of long duration, occurs in both urban and rural areas, and may be direct or indirect. Both users and nonusers may enjoy the benefits of reduced congestion and benefits to health and safety, such as accident reduction. These are direct benefits for the users of the freeway; but indirect for the nonusers.

Population effects deal with population distribution and population change as affected by freeways. The population benefits primarily occur in urban and suburban areas; they are indirect and of long-run duration. As the term population is applicable to large and small groups of individuals, population effects do not reflect exactly a level of scale fitting between individual effects and community effects. The population discussions in this report generally relate to (1) the effect of freeways on the distribution of individuals in the community by age, race, and socioeconomic status; and (2) changes in population at the community level. Thus, inclusion of the population section at this scale seems justified.

Community effects include the influence of freeways on: (1) the amount and quality of community services, (2) settlement patterns, (3) social interaction and communication, and (4) the effectiveness of the relationship between transportation planning and comprehensive planning. Although comprehensive/land use planning and transportation planning are closely related to environmental and economic effects of highways in addition to social effects, the research team felt that comprehensive planning is basically a social process most relevant at the community level.

The regional and national effects of freeways are large-scale benefits that influence (1) movement of goods and people, (2) regional and national welfare, (3) national defense, and (4) national unity and pride. Usually, these benefits are of long duration.

A. Individual Effects

1. *Users*

a. *Accessibility and Freedom of Choice.*—Urban and rural residents who use limited-access highways, both as drivers and as passengers, stand to gain direct and immediate benefits because they can reduce the time, cost, and effort of highway travel (*8, 16, 116, 134, 138, 164, 189, 191*). Through reduction of travel time, there is an increase in the amount of time users may devote to other activities (*189*). The net effect is an expansion of available opportunities and a reduction in travel time and cost, leading to greater freedom for the highway user to pursue alternative activities.

a.1. Employment. By providing access to more jobs, highways increase the variety and number of employment opportunities for workers (*138, 172, 189, 191, 205, 215*). Two studies have documented the effects of highway improvements on employment opportunities (*68, 124*), showing that highways can boost employment opportunities not only by providing better access to existing jobs, but also by stimulating the economic growth of an area thereby generating more jobs. It has been demonstrated that distances from which employees were recruited increased for a large industry after a highway was constructed, compared to distances before the highway was present (*208*). Unfortunately, all three of these studies were of specifically selected cases in which the increases in employment were particularly dramatic after the opening of a new highway. Comparative studies involving a number of randomly selected areas would go farther towards indicating the conditions under which highway construction will bolster employment in an area.

To the extent that a highway opens up job opportunities for the unemployed, it helps to equalize opportunities among users (*153*). Greater access to jobs may eliminate the need for workers and their families to relocate in the event that a wage earner changes jobs. This means that families can avoid the economic costs of moving as well as the social costs of breaking neighborhood ties and changing school districts. Even in cases where a move is necessitated, high-speed roads may lessen moving costs and make it easier. Thus, highways make it less difficult for

workers to take advantage of regional fluctuations in employment opportunties (*191*).

The degree to which employment opportunities increase depends on factors other than the highway itself. In rural areas, where employment opportunities are more restricted, a new limited-access highway will probably benefit workers more than a similar road in or around an urban area with a diversified economic structure. This is why the employment-inducing effect of limited-access highways has been particularly highlighted for rural parts of the nation (*182*).

a.2. Shopping. The literature suggests that limited-access highways expand peoples' opportunities for the purchase of goods and services, especially in the short run. These roads provide the highway user with access to more retail and service outlets. As a result, the shopper has more choice in terms of variety, price, and quality (*138, 182, 189, 205*). Highways also allow commodities from distant markets to become more available and to cost less, thus widening the choices of consumers (*138, 189*).

Since the expansion of large retailing centers has most often occurred in suburbs, the retail function of central business districts of most metropolitan communities has declined in importance (*76, 80, 89*). This is not to say, however, that all functions of the "downtown" area of central cities have declined in importance; the decentralization and loss of retailing has been one factor that has resulted in a loss of activity and revenue for central city businesses and government. Hence, the beneficial effect of highways for suburban retailing has been at the expense of residents in central cities.

a.3. Recreation and Travel. Better access to a particular resource for recreation is a direct effect of highway development. The long-range prospect in this regard is to provide opportunities for various outdoor recreational activities by creating access to areas having potential for these pursuits. There are many areas that hold vast potential for such activities, but they are of little value if the recreator cannot get to them. Accessibility, especially to the city dweller, is extremely important and for this reason is seen as urban in thrust.

There are preservationist groups who hold that certain areas must be maintained as limited-access areas. The wild, virgin, and pristine nature of such areas must be retained for posterity. Improved access may be looked on as a detriment with regard to these areas and certainly merits some consideration as true wilderness is all but gone from our great landscape.

Access to seaside resorts by lower income segments could be viewed as a controversial issue, but the philosophy of public recreation has been to serve all the people; if recreation professionals strive to accommodate this doctrine, at least for the public sector, this must be construed as a benefit. Recreation by the sea can be achieved through skillful manipulation of a natural resource base by combining it with a high degree of accessibility. Stansfield (*174*, p. 17) states the following:

> Given the demand for recreation facilities, a demand which was intimately and profoundly interrelated with both the industrial and democratic revolutions, the focusing of the demand on the portions of seashore readily accessible from the metropolises was effected by changes in transit technology. Each decrease in time distance to the seashore associated with the introduction or improvement of coachroad, railroad, steamboat or highway connections enabled successively lower income segments of society to play by the sea, though for correspondingly shorter periods of time.

The Gateway National Seashore in New York and New Jersey is an excellent example of the demand for greater access to seaside resorts by the population of a large metropolis.

Freeways provide access to existing systems of secondary roads that might encompass or lie beyond the urban landscape and thus provide greater living space to the urban dweller. Long-range consideration of secondary road systems, combined with freeway planning, can successfully channel heavy flows of recreational traffic emanating from urban centers into secondary road systems that lie outside the city. According to Cracknell (*39*, p. 148), "Accessibility to the countryside round towns and cities is already an important aspect of planning for leisure. . . ." The freeway reflects a human use of the natural landscape for numerous and varied activities that in combination are outdoor recreation (*203*). The properly planned freeway should integrate elements of design that reflect the nature of man at play, his natural surroundings, and the need to provide for efficient mobility. The proposed system may have a beneficial impact on the urban community, but may adversely affect the rural area through which it passes.

Americans know our nation through the windows of its automobiles. This is, indeed, a nation on wheels. Scenic roads, properly designed, can provide meaningful recreation and educational experiences to our nation's travelers. The scenic highway favors urban needs in that it brings people to specific resource areas, and it is capable of handling large numbers of people.

a.4. Residential. One of the most important effects of highways is that they permit a wider choice of residence for individuals and families, because they increase the number of existing or potential residential areas that are within commuting distance of jobs, shopping, visiting friends, and other nonwork activities (*172, 181, 189*). The importance of residential mobility for families can be inferred, to a certain extent, by the degree to which people actually do migrate. Much data have been gathered on the growth of suburbs (*65, 74, 75, 80*). This growth is one manifestation of residents taking advantage of the freedom of residential choice made possible by highways. Studies have shown that people move from central cities to suburbs for privacy, cleanliness, safety, and increased space in the house and yard (*81*). The desire for these particular amenities is especially strong during the child-rearing stage of the family's life cycle (*162*). The smaller numbers of people who move from outlying areas into the central city are typically in search for lower housing and travel costs and closer proximity to the amenities of the central city (*81*).

Studies have shown that residential development in outlying areas frequently follows the construction of a new highway serving these areas (*28, 38, 61, 107, 185, 217*). In addition, other studies have shown an increase in property values in residential areas served by new highways (*117*). Thus, the increase in residential choice provided by highways is a well-documented direct effect which takes

hold in the long run, especially around densely settled urban places.

The adverse effects of highways on nearby residential areas arising from the noise, vibration, dust, and odors from passing cars and trucks must also be considered. These effects have been examined in several studies (*26, 32, 93*) and constitute a constraint on expanded housing opportunities. The problem of noise, especially for communities located near highways with high average daily traffic flow and on the same grade as the highway without any barriers between the road and residences, is a major environmental problem that has significance because of social implications. High decibel levels caused by freeway traffic have been associated with a reduction in the usage of yards and playground equipment by families and less neighborliness outdoors among homeowners (*93*).

a.5. Educational and Cultural Activities. Along with dramatic changes in the school age population of the United States, an increased need for educated employees, and a decline in the demand for unskilled workers, as well as a rise in per family auto ownership, another factor in the expansion of educational opportunities has been highways (*103, 131, 134, 182, 189, 216*). For example, by permitting college and university students to commute to classes while living at home, savings in room and board costs are realized. This allows students who might not otherwise be able to afford higher education the opportunity to pursue this goal. In a 1960 study, Wilbur Smith and Associates (*216*) show the increasing distances from which students at the University of Kansas commuted to classes as the surrounding highway system developed between 1939 and 1959. This illustrates, for one area at least, the expansion of higher education opportunities generated by highway improvements. This illustration is probably typical for most institutions of higher learning in the United States.

Highways have undoubtedly contributed in a similar way to people's opportunities to pursue training in vocational and technical schools. Moreover, the increases in percentages of school age population enrolled in the public schools and the improved attendance rates of enrolled pupils since the turn of the century may be partially attributable to improved highways (*182*). Partial support for this thesis is evidenced in the increased number of students transported in school buses and the decrease in the cost per pupil of bus transportation (*182*). Of course, many factors other than highways account for increased school attendance. The age structure of the U.S. population has been conducive to the expansion of enrollments until very recently. Further, greater demand for skilled workers has been a very important factor.

Another way in which highways contribute to freedom of choice in education is by making libraries, lectures, museums, historical sites, and other educational facilities and activities more accessible to more people (*216*). In addition, cultural activities, such as religious services, concerts, and plays, are made available to some people who were formerly unable to reach them because of poor highway transportation (*103, 131, 138, 166, 188, 206*). Studies have shown that church membership has been growing in suburban areas. Some of these studies, which are summarized by Thiel (*182*), also show that the size of suburban churches is increasing. This fact, coupled with the relatively low population densities of suburban areas, strongly suggests that more people are using automobiles to get to church (*182*). This is reinforced by the finding that church membership, as a percentage of the population, increased from 41 percent of the population in 1910 to 63 percent in 1961 (*182*). Apparently, people are more selective about the churches to which they belong, and they use highways to implement this selectivity.

a.6. Public Services. Although there are some public services toward which one does not normally exercise choice (such as fire and police protection), there are others (such as bus terminals, airports, train stations, hospitals) among which highway users may be selective. No research was found examining selectivity of users with regard to these types of facilities. However, one can speculate that highways contribute to freedom of choice among these public services by making more alternatives available to the user.

Mass transit is one public service that has definitely been expanded recently in conjunction with past highway improvements. This has been done in at least three ways: (1) "transportation corridors" or separate lanes for buses have been opened (the Shirley Busway, for example, has been running for 9 mi from Washington, D.C., to I-495 in Virginia; the 11-mi San Bernardino Busway uses the freeway median and parts of an adjacent rail right-of-way); (2) "wrong-way bus lanes" that use part of the highway servicing "light opposing traffic flow" have been opened in New Jersey, Long Island, Boston, Harrisburg, and San Francisco; and (3) the reservation of a lane for buses, trucks, high occupancy cars, and emergency vehicles has been implemented for portions of highways. On the San Francisco-Oakland Bay Bridge, for example, transportation planners have routed buses around the toll barrier. Buses, trucks, and high occupancy cars have access to the right-hand lane of the Benjamin Franklin Bridge in Philadelphia on a preferential rather than an exclusive basis (*113*).

Many benefits can be gained by stimulating mass transit as a public service. Transportation corridors and other means of using highways for buses reduce a family's need for more than one automobile, thereby giving individuals opportunities to pursue activities normally precluded by their expenditures on cars. The use of buses also increases the carrying capacity of freeway lanes. According to Levinson et al. (*113*), "A freeway lane can carry about 2,000 to 3,000 persons per hour in cars. This lane can carry 35,000 to 40,000 people per hour in buses using off-lane stations and adequate downtown distribution."

The expansion of mass transit on freeways has also encountered public criticism. In Milwaukee, Wisconsin, and New Haven, Conn., minority groups have criticized proposals for busways on highways because they will serve residents of suburbs rather than residents of the central city (*113*). The critical views of minority groups including low income white, black, and Puerto Rican families, as well as the aged, is understandable, even though there are real benefits to be gained from busways. A study in Buffalo, N. Y., for example, concluded that trends in the location of working places for black workers and changes in travel time resulting from expressway construction

showed that low income families with interest in skilled and semiskilled jobs have remained in the central city, and the jobs that they could perform have moved closer to freeways. Since large proportions of low-income families do not own automobiles, they need public transportation to obtain work (*48, 137*). In this context, it is not difficult to see why residents of the inner city are critical of plans to expand public transportation from suburbs to the central city. It is apparent that the full benefits of freeways and mass transportation are not being exploited.

b. *User Health and Safety.*—The improved design of highways, especially median strips, multiple lanes, control over vehicle access, and more gradual curves, provide users with more safety than they had on older roads. This expanded margin of safety reduces accidents among highway users. Not only is the physical health of users improved, but also their mental health, because driving fatigue and stress are reduced.

b.1. Reduced Accidents, Injuries, and Fatalities. The increase in safety and, therefore, the reduction of accidents, injuries, and fatalities are a result of utilization of the design features detailed in the "Red Book" (*5*). The accident data for California (*29*), which are typical for freeways in general, indicate that the average fatality rate for 1971, 1972, and 1973 throughout the State was 1.9 fatalities per 100,000,000 veh mi for freeways and 6.0 fatalities per 100,000,000 mi for nonfreeways. When urban and rural highways were examined separately, the rates were: 1.5 for urban freeways, and 3.7 for urban nonfreeways with 3.1 for rural freeways and 7.6 for rural nonfreeways.

The fatality rate experience in California duplicates that found for the nation as a whole. Using 1970 as a typical year (*194*), the fatality rate was 1.95 for urban areas and 3.51 for rural areas. For other than freeways, it was 3.61 for urban roads and 6.90 for rural roads.

The injury rates, expressed in injuries per 100,000,000 veh mi were as follows:

Rural: Interstate—66
Other Federal Aid Primary Systems—149
All Non-State Systems—265
Urban: Interstate—107
Other Federal Aid Primary Systems—231
All Non-State Systems—406

The relative magnitude of these rates has held fairly consistently over many years. It is apparent that the freeway provides distinct advantages over uncontrolled access roads where injury and loss of life as a result of accidents are concerned.

The reduction in accidents is a result of many aspects of design—one of the more important being the reduction of head-on, at-angle, or side-swipe collisions because opposing traffic is separated (*20, 131, 138, 145, 164, 188, 192, 197, 198, 200, 201*). This separation of traffic, not only the opposing traffic but also the crossing traffic at grade, reduces the number of conflict points where the potential for an accident can occur. Other factors contributing to the reduction of accidents are the elimination of parking, except well off the traveled way; flatter slopes minimizing the chance of overturning; and the presence of guard rails and energy attenuating devices to entrap a colliding vehicle or reduce its deceleration rate to tolerable limits without producing serious injury.

It has often been said that "speed kills" and slogans such as "slow down and live" promoted improvement in highway accident statistics. Although it is true that the severity of an accident is greater at higher speed, Beatty (*17*) found that fatalities per accident and speed were independent for speeds below 55 mph on Interstate highways, Above 55 mph, however, he found that fatalities increased sharply. Since that study was completed (Dec. 1972), a limit of 55 mph has been established throughout the nation. There has been a marked reduction in the number of fatalities and total accidents since the recent fuel shortage and lowering of the speed limit, more than might be expected from change in the amount of travel. The reasons for such a change are presently being investigated by a number of researchers.

All of the benefits of accident reduction discussed accrue directly to the users—the drivers and their passengers —of the highway. Not only is life prolonged, but the traumatic effects of an accident are avoided. The lower accident and fatality rates of freeways give the driver a sense of security and well being, which for the majority of time is justified but occasionally can lead the motorist into hazardous situations. The continuously uniform speed, with its constant level of noise and vibration and little challenge in the driving task, has led to a condition called highway hypnosis and, along with weather and other factors, has resulted in spectacular crashes involving several hundred vehicles as has happened in Southern California and on the New Jersey Turnpike.

b.2. Greater Comfort, More Pleasure, Less Stress and Fatigue. Modern, limited-access highways have contributed to the ease and comfort of travel by automobile by reducing intersections, sharp curves, stops and starts (*116, 131, 140, 167, 172, 187, 192, 196*); and by providing wide, smooth lanes (*140*).

The care taken to maintain a pleasant view from the road on many new highways also makes travel more pleasant (*184, 187, 192, 205*). This, in turn, is thought to reduce stress and fatigue and, thereby, contribute to highway safety (*69, 123, 130, 191, 192, 205*). Some writers have speculated that scenic highways augment the mental health of users (*192*). Billboard controls, for example, presumably reduce stress through the reduction of visual clutter (*69*). Planting of trees and bushes along the right-of-way can buffer the effects of highway nuisances, such as wind, headlight glare, or unsightly and distracting visual features (*77, 8, 44, 192*). The provision of roadside rests also enhances beauty, provides recreation, and gives the driver a means by which to combat fatigue, thereby enhancing safety (*161*).

Highways also reduce stress by giving users knowledge that they have easy access to desired destinations (*103*). Limited-access highways provide greater access to recreation facilities; this may promote relaxation and improve mental health (*131, 189*). Finally, highways may serve to provide a transition period for commuters travelling from work to home and vice-versa, so that they have time to adjust to their different roles (*126*).

b.3. Noise Reduction. Noise to the user (driver and passengers) of the freeway comes from engines, gear train, tire-pavement interaction, and wind passing the vehicle. At normal operaing speed on a freeway the largest contributor of noise is the tire-pavement interaction and the wind. Grades influence the amount of truck engine noise, so that the flatter grades of freeways result in lower engine noise (*37*). Larson and McKelvey show the effect of tire type and vehicle speed on the noise measured 50 ft from the vehicle path. They also show the noise levels measured inside of public transportation vehicles and indicate that noise levels within vehicles is of importance because it is a measure of the quality of service available to the traveler. The expanded right of way also becomes an absorption area for noise, vibration, and exhaust fumes (*160*).

b.4. Air Pollutants. It has been indicated in an earlier section of this report that freeways result in less air pollution because of higher speeds, fewer speed changes, and drastically reduced stop-and-start driving (*40, 195, 201*). The smaller production of pollutants is ameliorated further by the draft action created by the moving stream of vehicles. Unless the vehicles are confined to an area where little air circulation is possible, the vehicle occupants will be subjected to less air pollutants on a freeway than on a roadway of lower standards. Vehicle emissions are lower in free flowing traffic, but the amount of reduction depends on the base line speed (*105*).

c. *Reduced Congestion.*—Because new highways usually have a greater capacity than the roads they replace, and because some of the existing traffic continues to use the old roads, users typically experience a reduction of traffic congestion after a new highway opens. In essence, this reduced congestion is a component of accessibility, discussed earlier.

The investigators consider reduced congestion to be both a short-range and long-range benefit. However, benefits may decrease in the long run as freeways get congested. This has happened mostly in major metropolitan areas. This phenomenon has been documented in numerous studies (*60, 71, 121, 122*). To what extent this problem is a function of the road itself is unclear. The additional traffic may reflect an increase in the driver-age population, greater affluence, increased leisure time, continued urban growth, or other factors. However, some of the increase in congestion may be a result of the limited-access highway itself as a stimulus for commercial and residential development and as an inducement to private automobile ownership and use. Nonetheless, the relative importance of the road itself in comparison to other factors influencing the possible long-term congestion is unknown. In view of the complexities involved in this issue, reduced congestion is viewed as a beneficial effect in both the short and the long run. Reducing congestion leads to savings in travel time and costs and improves user comfort and pleasure by reducing stress and fatigue.

c.1. Travel Time Savings. The measure of travel "costs" is not always in dollars. In many cases, particularly for trips in an urban area, the "cost" of a trip is measured in terms of minutes of travel time rather than in dollars, because where no tolls or parking charges are present, the actual dollar cost of the trip is not determined or even recognized. Therefore, the traveler attempts to minimize travel time. The amount of time savings will depend on the difference in the average speeds and the difference in the trip lengths via the various routes. Higher average speeds permit longer trips in no greater and often less travel time.

The development of recreational areas, historic centers and athletic arenas is often governed according to the accessibility potential of such areas. The freeway system provides this type of accessibility and is a crucial determinant before investment decisions in such facilities are made. The aforementioned facilities are vital to spectator-oriented recreational involvement. This type of involvement becomes even more important in the large urban complex. Major athletic team franchises are highly sought by municipalities, but such franchises cannot be attracted unless access to their stadium can be provided. The availability of existing recreational attractions is enhanced by the development of freeways (*9, 192*). In addition, scenic roads, because of the pleasant driving surroundings they afford, can help to alleviate traffic congestion on arteries that are used more frequently. The reduction of congestion on these highways will help people reach destinations expediently, without the traffic jam so well known to many urban residents. Scenic highways must be viewed as a benefit in that they help facilitate the flow of traffic to recreation areas and help to abate heavy traffic flow to other roadways.

c.2. Less Irritability and Stress. Since traffic congestion is a source of stress and irritability, it is reasonable to suggest that a reduced incidence of this problem would be a beneficial effect for drivers and passengers alike (*123, 128, 130, 191, 195, 196, 199, 201*). Such a reduction in stress and fatigue undoubtedly improves user safety (*205*) by reducing driver fatigue and hostility and by cutting down on the number of occasions on which drivers may be tempted to speed to make up for time lost in traffic tie-ups. This beneficial effect applies not only to users of limited-access highways, but also to other nearby roads that may be less congested because of the traffic diverted from them by the limited-access road.

d. *Pleasure Driving.*—The findings of the Outdoor Recreation Resources Review Commission (ORRRC) indicate, "Driving for pleasure is America's most popular single outdoor recreation activity—this accounts for 42 percent of his total outdoor activity" (*192*, p. 15). Statistics such as these further substantiate the need for facilities to accommodate those driving for pleasure. Such facilities include more than just a highway but, of necessity, must also contain the accessories that will allow opportunities for roadside recreation.

An aimless drive over aesthetically pleasing highways can provide meaningful recreational experiences for users (*147*). A road that provides a good vantage of an area's agricultural activities or connects a number of historic sites or sites of cultural interest can provide picturesque and instructive trips for the family that is interested (*171*).

Driving for pleasure, simply for taking a ride through picturesque country, or for the intent of reaching a particular destination in the interest of recreation is an integral part of the total recreational experience. O'Rourke (*147*, p. 141) states the following:

> Aside from being a form of recreation itself, travel is a fundamental component in most outdoor recreation and indications are that in many cases the pleasure of the car ride is as important as the destination.

Under special conditions it is possible that driving for pleasure is representative of the total recreation experience. This has been viewed as a direct, short-range effect that allows the urban family temporary escape from the urban surroundings.

Toffler (*186*) has proclaimed the automobile as "the reincarnation of spatial freedom." Families cramped into small urban dwellings, located in dense complexes of such dwellings, can well appreciate the added mobility and freedom afforded by a leisurely automobile trip neither of which would be possible without the automobile or roadways to take them there. According to Cracknell (*39*, p. 148), "The emphasis is upon the short distance day or afternoon trip into the countryside."

The manner in which a roadway displays the country through which it passes is a critical design factor and of importance to the traveler. Smith (*171*, pp. 13-14) states:

> A road can expose the landscape in its best qualities. It can show off the country and help interpret its natural, cultural and historic attributes; or it can show the most depressing commonplace aspects of the area; a calamity of signs and tacky roadside development, or long monotonous tunnels of greenery which tell us nothing about the country but a good deal about the state of the art of highway landscaping.

"The automobile has allowed more extensive use of the recreational belt but has not noticeably expanded its radius" (*39*, p. 150). This further substantiates the need for parkway systems developed with recreational amenities in mind.

The countryside surrounding urban centers has actually become an extension of the city's living space. Cracknell (*39*, p. 153) discusses the benefit of pleasure driving to urban residents:

> It is for some people a temporary return to the countryside they left not so long ago in the search for better employment, educational or entertainment opportunities. For every city dweller it has become, through the motor car an integral part of his environment—it is part of the subconscious contract he makes with city living, namely that whenever he wants to, he can get out and enjoy the country.

2. *Effects of Highway Improvements on Nonusers*

People who do not drive on limited-access highways also benefit from numerous effects of the highway. A new, limited-access highway may alter the living environment of local citizens in beneficial ways. For example, by removing traffic from neighborhood streets, a new highway may contribute to quiet and safety for local residents.

a. *Health and Safety.*—Because of vastly improved design features, modern limited-access highways benefit the health and safety of nonusers, as well as users, by providing additional lighting for adjacent residential areas, thus reducing the incidence of crime (*182*). The absorption of local traffic by limited-access highways can reduce the number of vehicles on neighborhood streets. This reduction in traffic flow results in fewer accidents on local streets and greater safety for pedestrians, in general, and school children, in particular. These benefits are regarded as both short run and long run, although their long-run efficacy is tempered in some cases by the fact that the reduction of traffic on local streets, which is a major aspect of nonuser health and safety, may not last.

a.1. Reduced Accidents, Injuries, and Fatalities. The nonusers of freeways are beneficiaries of highway construction in a number of ways. One important way is that the freeway takes traffic off the local streets, resulting in fewer vehicles, fewer vehicle conflicts, and, therefore, fewer accidents (*10, 103, 138, 191, 205*). This benefit accrues not only to the occupants utilizing the local streets, but also to the pedestrians crossing these streets. After traffic is diverted from the local streets to a freeway, the remaining traffic is usually destined for locations within the area and drivers generally will be familiar with the street system and any particular aspects of the system that may exist that could be a source of difficulty to a transient in the area.

Freeways have been instrumental in helping to lower the death rate of accident victims and seriously ill patients by making medical services more available (*138*). The freeway has shortened the time an individual requires to receive emergency medical attention.

Freeways, while acting as an artery for transportation, also act as a buffer to hazards of fire, explosion, or other calamities that may occur either on the roadway or beside the roadway (*191*). The greater width of freeways provides a measure of protection to adjacent and nearby neighborhoods not provided by older routes.

a.2. Noise Reduction. The factors that cause highway noise for users are the same ones that cause highway noise for nonusers; that is, the engine, gear train, tire-pavement interaction, and wind. However, the nonuser experiences the combined effect of all of the highway, whereas the user experiences the noise generated by his own vehicle and those that are nearby. The difference can also be described for the highway nonuser as that occurring at a point location over time by many vehicles rather than that occurring over both space and time by fewer vehicles.

A freeway reduces noise to nonusers primarily for two reasons: (1) vehicles generate less noise on freeways (*37, 189, 195, 198, 201*), and (2) freeways remove much of the through traffic from local streets (*106, 197*). Flatter grades, fewer speed changes, and less stop-and-go driving reduce noise. Some of this reduced noise level because of smoother flowing traffic may be offset by the higher average speeds attained on the freeway.

Sound is attenuated by the atmosphere and by sound absorbing materials. Because freeways have wider right-of-way as compared with local streets, the noise source is located at a greater distance from the nearby neighborhood residents. With freeways, there is also a greater opportunity to use sound absorbing materials and devices, such as plants, acoustical screens, and depressed roadways that can channel sound away from adjacent development.

a.3. Reduced Air Pollutants. Freeways reduce air pollutants for nonusers in a manner similar to the way they reduce noise; that is, by more efficient operations than is possible on the older routes and by shifting of through

traffic away from congested areas (*106, 195, 198, 201*). Smoothing traffic flow on both the freeways and the less congested local streets can reduce traffic up to 20 percent during the peak period with corresponding reductions in air pollutants (*105*). Freeways also permit more efficient and competitive mass transportation that could reduce air pollution by up to 5 percent.

Wider rights-of-way of freeways also contribute to better natural ventilation with more diffusion capability because of increased wind velocities, fewer ground-level obstacles, and increased vertical mixing. The freeway, with a steady average speed of 30 mph, can result in a reduction of harmful carbon monoxide (CO). For a flow rate of 400 vph on each type of roadway, the freeway would produce only 77 percent of the CO produced on local streets under city traffic conditions. When the flow rate increases to 1000 vph, the freeway would produce only 38 percent of that produced on the local streets. The amount of CO produced on each street type increases as the vehicle flow rate increases, but the percentage increase is much less on a freeway (*105*). As the figures indicate, the difference becomes more significant as the volumes of flow increase.

Pollutants can be absorbed at or near the roadway by the use of special materials where adequate space in the right-of-way is available for installing these materials. These materials consist of various types of plants as well as materials used in construction, which can absorb and neutralize the pollutants. These absorbent materials are particularly effective when used in the construction of tunnels and covered roadways that confine pollutants. The pollutants can then be at least partially neutralized before they are exhausted into the surrounding atmosphere. The extra space in the right-of-way can also provide clean air reservoirs and filter out some of the gaseous and particulate pollutants.

b. *Reduced Congestion on Local Streets.*—By providing an alternative route that is often faster and more convenient than an older route, limited-access roads attract motorists away from their old travel patterns. The result is a reduction in traffic on local streets and highways (*9, 77, 106, 138, 154, 195, 197*). This is considered an indirect benefit of the road, because the limited-access highway was designed primarily with the user in mind. This benefit is especially evident in the case of bypass routes (*152, 191, 205*). The Federal Highway Administration (*205*) has summarized the results of 33 studies of bypassed areas, showing the average percentage decrease in traffic for towns of various population ranges. The decline in local traffic resulting from construction of bypass routes has been well established. Data on reduction of local traffic for roads not of a bypass nature are much less evident.

Reduction of congestion is typically accompanied by a segregation of through traffic from local traffic (*154*). The reduction in traffic facilitates parking and the conduct of many social activities unhampered by large volumes of autos.

Although reduction of traffic congestion on local streets could occur anywhere, it is more noteworthy in urban communities where population density and automobile travel make congestion a significant problem.

c. *Less Irritability and Stress.*—By removing traffic from local streets, limited-access highways benefit people who use streets in communities, even if they do not drive at all. For the nonuser who lives, works, walks, studies, or relaxes near streets with reduced traffic, a lower level of noise from motors, horns, and tires is undoubtedly welcome (*197*). Dust and fumes may be similarly reduced. In many cases, particularly with the opening of a new bypass route, the truck traffic is reduced (*165*). This helps reduce noise, fumes, and congestion.

For the driver using local streets, the reduction of traffic increases the chance that he or she will reach a destination on time, and reduces the number of driving-related stimuli to which the driver must respond on the journey. Thus, travel is quicker and local accessibility is improved. This, in turn, reduces the stresses on the driver.

The effect of reducing irritability and stress has been classified as primary in rural as well as urban areas because it improves the environment for residents of communities. This effect has also been classified as a long-run effect, because it is not likely to go away unless people stop using limited-access highways. Reduced irritability and stress for people not using limited-access highways is an indirect effect, of course, because it relates to people who are not driving on the highway.

While those who live and work near these local streets may enjoy these benefits, those people who happen to be situated near the new highway suffer an increase in noise, dirt, and odors. The high speeds and high volumes of cars and trucks on modern limited-access highways sometimes cause significant deterioration in the livability of nearby residential areas, despite the wider absorptive area for noise, vibrations, and exhaust provided by these roads (*26, 32, 35, 93, 160*).

B. Population Effetcs

1. *Population Distribution*

A considerable amount of information is available on the impact of limited-access highways on population distribution and change. Whether or not people regard these impacts as benefits or disbenefits probably is a function of their geographical isolation, the rate of unemployment in their community, and their concern over environmental quality. Noteworthy anti-growth sentiment exists in some communities today. A circumstance that could be instrumental in the development of such an attitude would be, for example, an area that thrives on tourist trade because of its natural beauty. Population growth in such an area could threaten the natural resource base of the community. In areas of high unemployment and/or low income, highway improvements can provide incentives for industrial location. Under these circumstances, communities might see population growth differently. The effects of limited-access highways are discussed here with the realization that communities will differ in their views about the desirability of population change.

a. *Socioeconomic Status.*—There are numerous ways in which highways influence the socioeconomic status of people in a community. It is known that highways aid economic development. This process enables residents of a community to obtain jobs that can enhance their socioeco-

nomic status. Thus, highways contribute to upward social mobility (*118, 159, 182, 191*). The positive impact of highways on social mobility has been particularly noticeable in communities located near interchanges (*42*).

The same process that contributes to social mobility among people living in a highway community also contributes to the in-migration of families. These in-migrants tend to be more educated. Thus, the over-all level of socioeconomic status for the community residents may rise (*42*). There is an adverse side to this benefit, however. In the process of economic development, some workers may be displaced if their skills are not suited to the new employment opportunities introduced into the community. This occupational displacement effect is discussed by Frey et al. (*61*), who found that blue-collar workers were displaced by white-collar workers in the vicinity of a major turnpike interchange. This study used a before-and-after research design. Other communities within the same metropolitan region were selected for their similarity to the interchange community before the highway was built. These communities served as a basis for comparison to the interchange community in the "after" condition. Since they did not have a limited-access highway interchange, differences between these control communities and the interchange community could be attributed to the presence of the interchange.

The expansion of educational opportunities provided by highways also helps contribute to upward social mobility. Universities, vocational training schools, and primary and secondary schools are important avenues to increased socioeconomic status in the United States. As highways make these institutions more accessible, they increase peoples' opportunities for educational attainment (*182, 216*).

The benefits of upward social mobility accrue also to members of the community not directly involved in the pursuit of better jobs or higher educational attainment. Those who do attain higher socioeconomic status provide a tax base that supports and enhances public services in the community, from which nearly everyone benefits. Moreover, the purchasing power wielded by high socioeconomic residents helps to maintain the local economy, thereby bolstering employment on all levels. Finally, it has been argued that those of high socioeconomic status are more likely to participate in community affairs (*182*), thereby lending vitality to civic activities.

The positive effect of freeways on the mobility and status of people is an indirect result of the road. Not the road, but the opportunities created by the road, such as new job opportunities, supply the mechanisms for mobility. This effect is evident only in the long run because any kind of social mobility will take a considerable amount of time to be apparent, and the effect will not stop unless economic growth ceases. Mobility induced by highways is classified as primarily an urban phenomenon because the kinds of jobs and educational opportunities created by freeways are more often in industry or other employment sectors that are not oriented toward farming or extractive industries.

To the extent that increased socioeconomic levels in the vicinity of a highway are due to in-migration rather than upgrading of the indigent population, the communities that have lost these higher socioeconomic residents experience a disbenefit.

b. *Racial Distribution.*—By increasing the amount of residential land accessible to employment opportunities, highways have encouraged rapid population decentralization in communities throughout the United States. Limited-access highways in conjunction with the Federal Housing Acts and rising birth rates after World War II interacted to produce unprecedented suburban development (*65, 74, 76, 79, 85*). As families moved into new suburban homes, more roads were built to service the suburban population. Beltway roads that were part of the 1956 Federal Highway Act accelerated the process of urban decentralization (*38*). Suburban growth, in turn, opened up vacanices in middle as well as lower income housing in places left behind by people moving to the suburbs. The Fair Housing Act of 1968 helped insure that suburban as well as urban housing could be purchased by any racial group. This chain of events suggested that limited-access highways might now play a role in expanding housing opportunities for minority groups, although there are still many barriers in society that discourage the full achievement of this beneficial effect.

In fact, there is evidence that the expansion of housing, which limited-access highways have encouraged, has resulted in greater racial segregation in American cities (*82*). Although black families have been moving into suburban housing in unprecedented numbers (*49*), most black families have annual incomes that are below average and so they remain in the least desirable housing in cities. Data from the 1970 census indicate that whites continue to migrate from central cities, while suburban rings still contain relatively few blacks (*50, 190*). At the same time, the proportion of blacks living in central cities increased between 1960 and 1970 (*82*).

Students of urban politics may argue that this segregation is in the interests of black families because they become better represented in city government (*65*). This observation is a matter of speculation, however. The fact remains that many low-income racial groups do not benefit from the housing effects of limited-access highways, even though they have the legal right to do so.

Stepped-up construction of limited-access highways since 1956 has frequently displaced the residences of many families with average or less than average incomes. Again, because of unequal distribution of wealth among racial or ethnic groups, black, Mexican-American, Puerto Rican, Chinese-American, and American Indian families are more likely to be affected by right-of-way acquisitions. This too has been a reason for the changing distribution of minority families living in urban communities. While highway construction has removed truly dilapidated housing in some instances, and a need exists for more research on low-income families who experience increased satisfaction from housing after they have been displaced by a highway project, it has also contributed to increased costs of housing and transportation for these people (*2, 146*). Thus, it should be noted that limited-access highway construction is not the only cause of residential displacement for low-income urban families.

Highways do, indeed, serve to expand housing opportunities, but the chances of enjoying this benefit are not shared equally and highway construction in the past has reduced the amount of available housing for low-income

racial and ethnic groups within downtown city areas. Whether this is a long-term or short-term effect remains to be seen.

c. *Age Distribution.*—Limited-access highways also affect the age structure of areas in the long run. The age structure of populations living near highways, especially close to interchanges, is likely to undergo an increase in the proportion of residents in the 18 to 30 age category, because in-migration to such areas is usually relatively heavy and young adults are more likely to migrate than other age groups (*42*). This change in age structure can be a benefit to a community, because the young population will increase the demand for consumer goods and add to the productive potential of the labor force. However, this benefit is at the expense of the communities from which this younger population migrated, and it can also place disproportionately heavy demands on public services, such as education, without the benefit of a tax base characteristic of a more balanced population.

2. *Population Change*

Two factors affect population change in an area. The difference between births and deaths results in a natural population change. A local population can also change as a result of differences between the numbers of in-migrants and out-migrants over a period of time. It is possible that highway improvements have an indirect effect on population numbers through natural increase. Limited-access highways are safer than uncontrolled-access highways, thus reducing the rate of death from accidents. This may be partially offset if the highway improvement induces more highway travel than would have otherwise occurred.

Also, by affecting the age structure of the population near the highway, causing a higher proportion of young adults to move into areas near interchanges, the birth rate of these areas is augmented.

These effects on the natural population change are rather small. Economic, religious, and health factors undoubtedly have a greater influence on the natural rate of population increase than do highways.

Far more important is the effect of limited-access highways on net migration, but few studies have restricted their focus to this component of population change. For example, the influence of highways has been examined in suburban Pittsburgh, Pa. (*42*). By matching areas intersected by a controlled access highway with comparable areas away from highway intersections, and by using a "before-after" research design, the researchers found that places intersected by the road experienced more in-migration than areas not intersected by the road. Similar studies can be found for areas in Virginia (*209*), Missouri (*87*), and Georgia (*107*).

Considerable attention has been given to the impact of limited-access highways on nonmetropolitan growth by the combined effects of migration and natural increase. A study of the Connecticut toll road, for example, showed the benefits of one controlled access highway for economically depressed counties in southeastern New England (*117*). Rates of population growth, retail sales, tourism, and manufacturing were higher in counties in Connecticut intersected by or closer to a turnpike than in counties away from the influence of such a roadway. In this discussion, it is important to note that the term "nonmetropolitan area" does not correspond exactly to "rural area." Nonmetropolitan areas are those counties outside the boundaries of metropolitan areas as defined by the U.S. Bureau of the Census. Some of the places in these nonmetropolitan areas would actually be considered urban areas. Thus, the findings of the research on nonmetropolitan areas do not necessarily apply to the descriptor "rural" as it is used in this report. However, there is some indication that rural areas may gain in population as a result of a new highway if they are within 25 mi of a metropolitan area (*94*) and, particularly, if accessibility has been a real deterrent to growth because of adverse geographical features and/or lack of good highways (*1*).

A study completed by the U.S. Bureau of the Census examined the impact of limited-access Interstate highways on population change for all nonmetropolitan counties in the United States from 1960 to 1970 (*95*). Using regression analysis, counties were coded by the presence or absence of a limited-access highway, the size of cities in each county, the presence of such institutions as colleges or military bases, and the population growth in the decade. The findings were that colleges were the most important of the identified sources of nonmetropolitan population growth. The second most important source of positive nonmetropolitan population growth was the presence of an Interstate highway. Although the variables used in this research jointly explained only 9.5 percent of the variation in the growth of nonmetropolitan counties in the decade of the sixties, the study suggests that the positive demographic impact of highways is a nationwide phenomenon.

Another study finds that controlled access highways have more positive impact on regions of the United States that have not had efficient road networks previously, such as some southern states, Montana, and the Dakotas (*1*). This work suggests that the positive demographic impact of highways is a general one that is independent of other sources of growth, but the magnitude of the impact varies inversely with the previous levels of highway development in a given section of the country.

A recent study examined the impact of controlled access highways on nonmetropolitan areas in one U.S. region for each decade since 1940 (*94*). Minor civil divisions corrected for boundary changes were the units of analysis. Data were examined by regression analysis, cross tabulation, and a matching procedure. Findings suggested that there has been a positive relationship between proximity to a controlled access highway and population growth, especially since 1950. The demographic impact of the highway did not diminish as the road system developed, but the effect of proximity to a highway interchange was less important for growth than distance to a metropolitan area, population density, or (for 1960-1970) change in the college or military population in an area. When the areas were stratified by distance from a metropolitan community, controlled access highways had no statistically significant impact on population growth in places more than 25 mi from a metropolitan area. This suggests that highways influence population growth in rural as well as urban areas, but only within about 25 mi of major population centers.

Moreover, the impact of highways on population change is relatively small outside the boundaries of metropolitan areas.

C. Community Effects

1. *Community Services (Amount, Quality)*

Highways are instrumental in making services financed by governmental organizations (*138, 188*) as well as private companies available to people. Because of increased accessibility, highways encourage more centralized control of services, and they permit the operation of many services to diffuse throughout the community and specialize their functions (*159*). For example, schools, parks, police, and fire protection can be located according to the needs of various sections of urban or rural areas, but still be effectively administered and maintained from central locations (*131*). The construction and maintenance of utilities, such as water and sewage treatment, are directly and indirectly enhanced by an efficient highway system (*182, 191*). Freeways also facilitate the construction, maintenance, and repair of such utilities as electricity and telephone (*191*). The development of an efficient network of highways can also increase metropolitan specialization. Pittsburgh, for example, has based its growth on steel manufacturing. Before the development of highways and railroads, it was necessary for small foundries to be scattered throughout the nation to serve the iron and steel needs of localities.

a. *Health Services.*—There is considerable literature that emphasizes the role of highways in providing more and better health services (*67, 138, 189, 191, 216*). The mobility provided by highways has undoubtedly been an indirect factor in the consolidation of small hospitals into large regional hospitals that are better equipped and have a wider range of specially trained personnel (*191, 216*). Highway improvements in urban and rural areas can also directly improve the efficiency and promote the use of mobile health testing facilities, such as tuberculosis x-ray units (*182, 189, 191, 216*), and emergency health vehicles, such as ambulances, fire fighting vehicles and emergency vans (*216*).

Freeways are particularly valuable direct benefits during large-scale community or regional emergencies. They permit large numbers of physicians and other medical personnel as well as needed supplies and equipment, to converge on areas experiencing floods (*138, 188*), fires (*138, 188*), or epidemics (*188, 216*). In cases of floods or other natural disasters, the high standards of construction for many limited-access highways help ensure their survival, even when other forms of transportation or communication fail.

Historically, highways have enabled physicians to serve more patients by changing the practice of doctors making house calls. Now, because the vast majority of patients come to the physician's office, a single doctor is able to take care of a much larger number of patients because less time is spent in transit (*111, 183, 189, 191, 216*).

Highways also permit consolidation of educational facilities for nurses and other medical personnel, as well as facilitating meetings among nurses and other health-related occupational groups to exchange ideas and possibly improve methods of practicing health care (*216*).

b. *Education.*—Probably the most evident indirect benefit of highways for education is that they enable educational institutions at all levels to consolidate; this, in turn, permits the acquisition of superior educational facilities and equipment, as well as more specialized teachers (*182, 189, 191, 216*). This benefit is particularly felt in rural areas, where it has contributed to the decline in the number of one-room school houses (*182, 191*).

It has been argued that improved highways are also a factor in the improved rates of enrollment and attendance in schools (*182*).

It seems plausible that highways have contributed to the development of small state colleges and "branch campuses," thus making higher education available to a larger segment of the population (*189*). By providing college opportunities within commuting distance for a greater proportion of the population, these institutions have enabled some students to get a college education by taking advantage of the savings of living at home rather than in a dormitory (*189*). This is also true in the case of vocational training centers (*189*).

Highways additionally permit the consolidation of libraries and museums (*216*). As a result, administrative duplication of services and overhead costs of running more than a single physical plant in an area can be reduced. The consolidation of services thereby permits the use of more public revenues for the provision of the service itself. Highways have also encouraged the development of mobile libraries to reach remote areas (*216*).

c. *Fire and Police Protection.*—The most obvious way in which highways directly benefit the amount and quality of fire and police protection is by providing greater mobility for the vehicles involved in rural and urban areas (*53, 188, 191*). This effect can take hold as soon as a highway opens, and it will continue as long as the road is operating. This increased mobility becomes particularly important when there are long distances involved, such as when outlying fire departments are called in a mutual aid agreement to help with a major fire (*182, 191*). Improved highways facilitate cooperation between state and local police (*182*). Finally, a well-developed highway system permits flexibility in the location of fire and police facilities and may allow more centralized headquarters (*182, 216*).

d. *Recreation.*—For certain segments of the population who cannot get to recreation areas, programs have been developed to reach the ill, poor, and handicapped. These are mobilized leisure service delivery systems that would not be feasible without highways (*97*). Bookmobiles, play wagons, and swimming pools are examples of mobile leisure service systems that are direct benefits to all kinds of communities. A play street, coupled with a mobilized recreational system, can afford opportunities to those who cannot reach them otherwise.

The use of mobilized leisure service delivery systems might also be a direct benefit to the conservation of energy (*97*). If a gasoline shortage or energy crisis reached proportions that would not allow the public much latitude for travel, it would be desirable for recreation departments to bring some programs to the people. Through the use of mass transit to take people to the recreation resource or bring recreational opportunities to them, individual travel would be discouraged.

Recreational services must be as aware of market forces and locational advantages as most other forms of enterprises. This includes, in part, choosing locations that are as accessible as possible to potential customers. There are several kinds of commercial recreational activities that are strongly oriented to highway users. Campgrounds that serve the touring public mainly for overnight stops rather than longer term vacation visits must locate near major highway routes, or near major tourist attractions, such as national parks or historic sites. To this extent, they are serving the same function as many motels. At the other extreme are private campgrounds that take advantage of outstanding natural resource amenities, such as lakes, and become destinations for campers spending longer times at one place. To the former type of campground, a location close to a major highway is preferred (some even locate right alongside the highway to take advantage of visibility benefits). To the second type, it is fortuitous if a major highway is near, but not essential. For both types of campgrounds, highway developments have not only improved their accessibility to potential customers, but through stimulating automobile travel have greatly expanded their markets.

The researchers have observed that some types of commercial resorts appear to compromise between natural resource advantages and highway locations. For example, many of the newer resort hotels and motels in areas like the Pocono Mountains in Pennsylvania and Catskill Mountains in New York seek locations with a moderate degree of accessibility to major highways. Other kinds of commercial recreational establishments such as night clubs, bowling alleys, and drive-in theatres may seek major highway locations for both visibility effects as well as accessibility benefits. Major highway interchanges in suburban locations attract many such types of recreational businesses. The benefits of locational advantage and high accessibility that highways confer on many other types of public and private activities are also conferred on recreational activities.

e. *Transit.*—The reader is referred to the previous section (A1.a.6) dealing with accessibility and freedom of choice of public services, in which public transit is discussed in considerable detail.

f. *Other Services.*—A frequently cited direct benefit of highways is that they improve the efficiency of postal services (*24, 138, 182, 191*). In particular, the consolidation of post offices is facilitated, longer rural delivery routes are instituted, and rural carriers are enabled to reach areas not formerly served because of low population density (*182*).

Highways may help to increase the membership of churches particularly those located near interchanges, those visible from the highway, and those located in the suburbs (*182, 188, 189, 205*). In some cases, good highways enable a clergyman to reach more people by having a dual or multiple worship service assignment. A well-developed highway system facilitates the clergyman's task of making calls on his parishoners. Finally, by making the church available to more members, consolidation of churches takes place. This means that a single clergyman can reach a larger congregation.

Drive-in businesses, such as restaurants, hotels, motels, banks (especially those with drive-in banking windows), and many other privately-owned drive-in businesses, benefit from highway development (*191*). Community services are enhanced when the profits of these businesses are reinvested to improve the service.

Private community services of a mobile nature, such as taxis, buses, and delivery services, benefit from improved highways (*188*). Nearly all private community services depend on highway transportation in some way. For example, newspaper deliveries, especially to outlying areas, may be speeded by new highways (*138*). In this way, highways enhance the distribution of information in the community.

2. *Settlement Patterns*

a. *Spatial Array of Land Use Activities.*—It is common knowledge that only a minority of the American population lived in urban places with at least 2,500 people when the first census was taken in 1790; that 75 percent of the U.S. population lives in urban places today; that the majority of American urban residents (68.6 percent in 1970) now live in metropolitan areas; and that the major place of residence today for metropolitan dwellers is the "suburban ring" around the central city (*80, 180*). Industralization, the development of automotive technology, and modern agricultural production helped bring about these changes in the spatial distribution of the American population.

A modern transportation system is essential for regional specialization in production to take place. Highways increase the likelihood that an area will specialize in certain activities. Food cannot be grown in sufficient quantities even within a small urban area to support its population. The density and size of an urban area are a function of the ability to transport needed goods into that area. Thus, highways have been instrumental in fostering urbanization (*10, 138, 165*). Because highways have helped promote the use of motor vehicles, they have also promoted urbanization by providing a significant proportion of urban jobs, both in the manufacture of automobiles and automobile accessories, and in related businesses, such as insurance, service stations, etc. Finally, trucks and other highway-using vehicles have been instrumental in revolutionizing farming techniques, contributing to an oversupply of farm labor, thereby "pushing" workers into the city in search of jobs (*191*).

Highways have also promoted the development of suburban areas (*131, 138, 159, 165, 188, 191*). Increased affluence has given more and more city dwellers the opportunity to move from the central city into more spacious suburbs. The automobile and the highway provide the mobility required by the suburbanite to get to his job and to shopping, recreation, and other activities in the city. Frequently, these desirable activities have followed the inner city population to the suburbs. This has even been true for jobs; the development of industrial parks is but one example. Thus, over the long run, highways have helped to radically alter settlement patterns of urban areas, resulting in residential and industrial decentralization.

a.1. Residential. The ability of highways to concentrate residential areas in communities, while permitting more

affluent urban residents—especially those in the child-rearing stage of the family life cycle—to move into less dense housing on the expanding community fringe, has been well explored. Highways stimulate housing development in a number of ways (*186, 218*). First, highways make land, which previously was too far out from the urban center, more suitable for residential development by bringing this land within commuting distance of shopping, work, and other activities (*164, 191*). This directly expands locational choices for residents (*205*). Second, by stimulating the economic well-being of an area, highways indirectly increase the capability of the residents to afford better housing. Frequently, this entails a move from the central city to a suburb (*80*), but the process can work in rural towns as well. Third, the highway, both by opening up new areas for residential development and by stimulating the economy and creating employment opportunities, encourages in-migration. Since in-migrants tend to be of relatively high socioeconomic status, they tend to occupy primarily low-density housing, such as is found in suburbs or suburban apartments. The rapid expansion of multifamily dwellings in the vicinity of a beltway, for example, has been noted (*38*).

A fourth way in which highways indirectly influence the spatial array of residential land use is by facilitating mechanization and consolidation of farms, thereby fostering rural to urban migration because of the decrease in the need for farm labor (*205*). Fifth, relocation of families displaced by highway construction, by definition, causes some residential shifting. Often the quality of housing moved into by those displaced is improved (*2, 146*) and, therefore, more costly.

a.2. Industrial. Freeways affect the location of industrial sites because of the importance of highway transportation in shipping finished products and receiving raw materials, and by providing a wider area from which labor may be recruited (*23, 38, 42, 101*). Several studies have shown highways to be an important factor in plant site selection (*23, 66, 107*). This is reflected also in the increase in value of industrial property that occurs after a freeway is built (*66, 107*).

A well-developed highway network in an area directly provides freedom of choice in plant site location (*191, 205*). Because of this freedom of choice, many industries have elected to move away from central city areas, rebuilding in suburban or rural areas. In this way, highways have contributed to the decentralization of industry (*33, 138, 191*). Undoubtedly, this has played a part in the growth of industrial parks over the long run (*188, 191*).

Decentralization, and particularly the development of industrial parks, has served to provide more adequate parking space and a different kind of working environment for industrial employees (*182, 191*). However, there is the risk that some kinds of industries may be accompanied by increased air and water pollution, traffic, and noise. Good zoning can prevent the juxtaposition of industries near residential areas or incompatible land uses.

a.3. Commercial. Limited-access roads directly provide preferred locations for many types of businesses—especially drive-in businesses, such as banks, restaurants, department stores, etc. (*27, 174, 182, 191*). The highway provides a wide market for these businesses, and proximity to the highway often means visibility to passing motorists, a form of advertising (*23, 191*). A survey of 134 business firms investigated the importance of highways as a location determinant. Nearly 18 percent of these businesses reported that highway exposure was a dominant factor for the location of the business. Other highway-related factors reported as dominant location criteria were highway access, adequate transportation of materials, highway network in relation to market, and highway network in relation to labor force (*157*).

Probably the most prominent feature demonstrating the impact of highways in the location of retail outlets is the decentralization of commercial establishments, and in particular the development of suburban shopping centers. Hawley (*80*) notes that the central business district in urban areas, which formerly contained the bulk of retail businesses, is changing functions. Often, it becomes the location for offices as the shopping centers take over much of the retail trade. Since the most affluent population lives primarily in the suburban ring, shopping centers tend to congregate nearer to these markets.

A highway passing through a particular area is apt to trigger development of recreational activities if the natural resource base has the suitable prerequisites. Greater accessibility to land-resource-based recreation can be viewed as a long-range benefit. While the influx of people into an area may be viewed as having negative effects by some people, it can also contribute economically to the area. Greatly improved accessibility to some public outdoor recreational facilities, such as our national parks, has resulted in problems of overcrowding that threaten to destroy the very amenities the people seek to enjoy.

a.4. Public Use. As the highway network in an area develops, such public facilities as fire and police protection; court houses; terminals for air, bus, and train transportation; and many other public facilities can have a wider range of locations to perform their functions (*27, 182*). For example, many of our parks appear to be underutilized, in part, because of the poor accessibility to these areas. Improvement of the accessibility to such parks may reduce the conditions of overcrowding that exist at other parks and recreation areas (*27*). From the recreationists' perspective, the elimination of overcrowding is an indirect benefit of highway development that enhances and encourages a quality experience.

A typical way in which the increasing accessibility provided by highway development is manifested is in the consolidation of public services. An excellent example of this is the consolidation of public schools. Although the school-age population has been on the increase until recently, the number of school districts has shown a nationwide decrease from 108,579 in 1942 to 50,446 in 1957 (*191*). This decrease in the number of districts has, of course, been accompanied by an increase in the size of schools and the districts and numbers of people they serve. In turn, this has permitted the employment of specialists in such fields as music, art, and vocational training, as well as the acquisition of more and better specialized equipment, such as audiovisual aids and physics and chemistry laboratories (*191*).

b. *Density.*—Highways have affected population density in at least two different ways in various localities. If one considers the indirect contribution of highways to mechanized, large-scale farming, the resultant displacement of farm workers and their families from rural areas to urban areas represents a concentration of population into urban areas (*80, 159*). At the same time, however, highways have contributed to the movement of populations out of the central city into the expanding suburban rings—in other words, to a deconcentration of urban populations (*80, 172*).

c. *Relocation.*—The displacement of people in urban and less often rural areas by freeway construction has received much attention in the literature, primarily in the form of case studies. Usually, these studies conclude that most displaced residents find improved housing when they relocate (*36, 84, 86, 90, 99, 103, 182, 189, 191*). Moreover, some studies have indicated that housing satisfaction is increased for the majority of relocated families after they have had time to adapt to their new neighborhoods (*36*). The provisions of the Federal Aid Highway Act of 1968 have probably mitigated many of the disbenefits of relocation (*103*). However, certain disbenefits remain. Some of these arise from the shortage of housing in many areas. The demolition of existing housing aggravates such a shortage (*103*). Also, the poor, the elderly, and the disabled frequently have special difficulties finding housing because of their low income (*90, 146, 182, 205*), and a forced move into new housing may place additional strain on their already inadequate budgets.

The housing of the poor tends to be relocated by highway construction in a disproportionate amount compared to their numbers in the population. A 1971 report by the Federal Highway Administration (*205*) indicates that one fourth of the occupied residences taken for highway construction were valued at less than $6,000 or rented for less than $60 per month. Two reasons for this are that highway planners seek the least expensive right-of-way acquisitions in urban areas, and that highway construction is seen by many planners as a means for reducing urban "blight" (*53, 189*). However, some studies have shown that neighborhoods that may be regarded by planners as blighted areas or slums sometimes serve as sources of pride and security for their residents (*59, 155*).

Closely related to this is the effect of the severance of neighborhoods by freeways and the separation of relocated families from their neighbors. The closeness of neighborhood ties is known to vary considerably in different neighborhoods and among different families located within a neighborhood. These differences have been attributed to many factors, such as family life cycle, social class, ethnicity, regional affiliation, etc. (*98, 173*). Several studies have indicated that the breakup of closely knit neighborhoods by highway construction can be a serious disbenefit (*58, 59, 164, 169*). The problems involved where children must change schools are another important facet of relocation disbenefits.

Businesses, churches, and schools are also affected by relocation when highways are constructed. Small businesses, particularly those run by part-time owners or managers to supplement retirement income, seldom are able to survive relocation (*182*). No studies were found that dealt with schools or churches relocated by highway construction.

3. *Interaction-Communication*

a. *Implement Community Values.*—Many writers have emphasized the need to design highways in such a way as to optimize community goals and objectives (*4, 57, 99, 103, 136, 142, 151, 159, 166, 205*). The literature suggests that this can be done through community participation in highway planning (*3, 102, 151, 156, 211*) and by integrating highway planning with comprehensive planning (*4, 151*). If there is a public demand for highway construction or improvements, then a new highway enhances community values in a very direct way (*158*). It has been suggested that a good highway network bolsters civic pride, both regarding the highway itself (*166*) and by promoting identification and recognition of historic sites within a community (*168*). Highways can also promote civic pride and implement community values by removing slums and blighted areas from the community (*131, 135, 153, 182, 189, 191*) and by providing scenic landscaping along the right-of-way (*189*). By drawing members of the public into the planning process, new highways can help to establish the habit and the ability of people to participate in governmental affairs on all levels (*3, 114, 131, 151, 159, 182, 205*). Under certain conditions, it is possible that highways can contribute to social equality. For example, if inexpensive public transportation is available and if the orientation of a highway is favorable to low-income neighborhoods, the highway may help equalize access to employment (*163*) and to educational opportunities (*138*). It has been claimed that highways can decrease residential segregation in a community, though the means by which this could be accomplished neither was clear, nor was the claim substantiated by evidence (*159*). Finally, highways may act to reinforce neighborhoods under certain conditions if they serve as boundaries to such neighborhoods rather than dividing them (*4, 53*).

Most of these benefits remain unsubstantiated. There have been a few studies regarding the adverse effects of highways when they divide a neighborhood (*118, 164*). These studies have supported the loss of contact among neighbors (*164*) and a decline in neighborhood quality (*118*) when freeways are built through, rather than around neighborhoods.

b. *Participation.*—The ultimate purpose of any freeway is to serve the needs of people. Participation by the members of a community in the freeway development process is not merely a courtesy. Full and active participation early in the planning process can make a great deal of difference as to how the freeway will serve the community. A direct relationship can be established between participation and the benefits derived from the freeway.

Growing public sophistication and potential militancy must also be considered. A small group of people can obstruct the construction or completion of a freeway. People tend to act in their own personal interest. When their homes and neighborhoods are threatened, they will go to considerable lengths to protect them. If used effectively, participation can ameliorate potentially conflicting

situations and make the public aware of the over-all beneficial effect of the freeway.

Comprehensive planning can provide the means necessary for achieving a full measure of public participation in the highway planning process. This can be accomplished by creating a forum through which citizen views can be heard and made part of the highway planning process.

Another means of achieving a form of citizen participation is through the formulation and application of the local comprehensive plan. Most local comprehensive plans give major attention to transportation considerations. This process and product substantially augment efforts to take local goals and aspirations into account for highway planning purposes.

In California, State law requires that local expression of community values be taken into consideration before freeway construction can take place (*57*). Community values are seen as the means by which many adverse effects can be controlled. These values also serve to ensure the preservation of certain benefits to the community. Comprehensive planning and the local planning process are mentioned as means by which community values can be added to the freeway development process. This is a benefit to both urban and rural areas.

In Pennsylvania, a structure has been developed through which highway planning goals and community goals can be defined and identified (*151*). Goals can be seen as abstract expressions that guide the planning process. Coordination and integration of goals can ensure that freeways be built with maximum benefit to both user and the community. The participation process considers future community, regional, and State goals. This enhances the development of both natural and human resources.

The Pennsylvania Department of Transportation recognizes the importance of citizen participation in meeting community needs and increasing cooperation (*151*). Participation can ensure that plans, programs, and policies of PennDOT are aimed at the goal of fulfilling citizen needs. This is especially important in the freeway planning process. Participation on this level serves to directly and indirectly benefit citizens in both urban and rural areas.

Another facet of the highway planning process in Pennsylvania is the corridor location study, which attempts to select the most practical, economical, and justifiable corridor available for highway or freeway construction (*151*). An important aspect of this study is that it attempts to achieve effective community agreement on the location of the corridor. Public participation in this effort can ensure actions that are feasible, equitable, and desirable.

There are other applications of public participation which, while not a part of actual practice, have influenced its use. It is stated in (*211*) that, in a democracy, peoples' needs find expression through the political process. Public participation in the freeway planning process improves the likelihood that the net result of planning will be what people want. In this way, participation serves to legitimize the planning process for freeways. The means suggested for participation vary; public meetings, rating panels, and attitude surveys are suggested. Participation serves as an indirect benefit to both the user and the freeway planner.

Public participation is a means of establishing good relations between those who plan the freeway and the ultimate users (*156*). Inputs from citizens and local officials serve many purposes in the planning process. Primary among these purposes is the prevention of neighborhood mutilation.

Public hearings are some of the best means available for receiving input from citizens in the highway planning process (*3*). In order for hearings to be successful, they should include engineering studies, alternative routes, all benefits and costs, and the participation of those officials responsible for the planning itself. This process has the benefit of allowing the public some means of expressing their desires in the planning of a proposed freeway facility.

The comprehensive planning process itself can provide the means for public participation (*4*). Comprehensive planning attempts to be a vehicle for the implementation of community goals and values. Used in conjunction with freeway planning, comprehensive planning provides the means for these values to be expressed.

Citizens must be willing to make sacrifices in order to achieve effective participation (*102*). The primary function of citizen participation in the highway planning process is to reflect the values, needs, and priorities of those affected by the proposed highway or freeway development. Citizens must be willing to devote time and energy when becoming involved in planning issues. Public officials, on the other hand, must remain open to citizen ideas concerning freeway development. This serves the over-all benefit of meeting public needs in the most effective way possible.

In some ways, citizen participation in the freeway planning process can be as important as the plan itself (*25*). Participation can aid in reducing adverse effects, such as displacement. It can contribute to land use considerations and aesthetic design; this is an indirect benefit which can affect many diverse elements in the rural and urban social sphere.

It should be noted that no single means of participation has been established that is effective in every instance (*102*). The growing sophistication of citizen groups has in some instances made freeway planning more difficult. When some means of participation is used, it opens the way for understanding and compromise between divergent groups.

Several writers have claimed that the participation in governmental activities stimulated by proposed highway construction, particularly in cases where public participation is encouraged by highway planners, generalizes to other areas of government. In other words, those who participate in highway planning are thought to benefit from the experience by becoming more active in other political affairs (*114, 159*). Moreover, the greater access provided by highways may encourage more people to participate in civic activities (*131, 182, 205*). No studies were found that substantiate or reject these claims.

c. *Social Contacts.*—There are numerous ways in which highways affect the amount and the kinds of social interaction that take place in a community. Social interaction can be characterized in terms of its intimacy, the variety of life styles with which one comes in contact, the numbers of people with whom an individual typically interacts over

a period of time, the selectivity an individual may exercise over those with whom he interacts, and in other ways. Since highways have directly and indirectly contributed to urbanization, they have increased the frequency of contact among individuals by creating better accessibility and higher population densities (*80*). Urban areas, and especially metropolitan areas, are characterized by diverse life styles. Thus, as highways have promoted urbanization, they have brought these diverse life styles into close proximity, providing at least the potential for interaction among residents of these places (*159*). Such interaction is thought to reduce provincialism (*182*) and increase the rate of cultural change (*88*) through the diffusion of customs and life styles (*159*). Residential mobility, which tends to be a part of the urban way of life, is directly facilitated by highways, and is undoubtedly a part of the process which people of differing life styles are brought together (*182*). Another feature of urban life that brings people together to interact concerns voluntary organizations. Membership in such organizations is probably augmented because of the accessibility provided by highways, so that members can more easily attend meetings, social events, and other associational activities (*188*). This is reflected in the increasing size of many voluntary associations (*182*). Because of the additional accessibility provided by a well-developed highway system, individuals can have a wider range of social contacts (*182*). They can be more selective in their choice of friends or associates. In this way, highways may have an effect on courting and marriage, giving people a wider choice of partners (*138*). By making urban areas more accessible to rural communities, highways have undoubtedly contributed to a greater culture exchange between urban and rural areas, thereby spreading urban values and life styles into rural areas (*191*).

Although urbanization has brought people of diverse life styles together, highways have helped also to keep them from interacting significantly. Hawley (*80*) remarks that social differences take on spatial dimensions in cities, the upper and middle classes, with their associated life styles, move to the suburban rings, while the lower classes remain largely confined to the inner city.

These latter considerations cast some doubt on the speculations on highway benefits found in the literature, such as the claim that highways decrease the incidence of psychological problems by increasing social contacts (*12*), or that highways can help decrease residential segregation in a community (*159*), or that highways can cause an increase in the cultural integration of a metropolitan area (*159*). Because of a lack of substantive evidence on these matters, arguments either way are speculative. On the other hand, the claim that highways can promote neighborhood stability if they are constructed along a boundary of the neighborhood (*86*) has been substantiated in two case studies (*118, 164*).

Other speculative claims in regard to the effects of highways on social contacts are: (1) that highways reduce the loneliness of housewives by enabling them to get involved in civic and social activities (*126*); (2) that highways contribute to social intimacy in a community by getting people involved in the planning of the highway (*159*); (3) that highways contribute to social interaction by fostering carpools (*126*); (4) that highways reduce the necessity to break social ties by eliminating the need to move on many occasions because of access to other alternatives (*182*); (5) that highways provide advertising for nearby businesses that are visible to passing motorists (*23, 191*); and (6) that highways facilitate the distribution of public information by enhancing newspaper delivery (*138*).

For the occasional user seeking a specific address, the additional complexity introduced by limited-access highways and the blocking of some old roads by new highways cast doubt on the claim that they make it easier to direct friends and relatives to one's home (*182*). Although this may be true in some cases, it seems doubtful in others. The claim that highways enable more frequent visits among distant family members (*138*) is undoubtedly true; it is also probable that highways have contributed to the residential mobility of modern society (*182*) and, thus, were a factor in creating large distances between family members.

For the most part, the effects of highways on social interaction are long range and difficult to measure. This is one reason for the lack of substantiation of many of these effects.

4. *Comprehensive/Land Use—Transportation Planning Effectiveness*

Both benefits and disbenefits accompany freeway development. This section details the involvement of planning in the areas of interchange development, public participation, joint development and multiple use of freeway corridors, land use, and design. Its scope deals with both the maximization of benefits as well as the minimization of adverse effects. In a strict sense, planning involves both direct and indirect benefits.

Through numerous examples, the fact that planning benefits freeways has been established. It is also true, but not as obvious, that freeways have benefited planning.

In part, transportation planning evolved in response to the growth and complexity of freeways. Transportation planning becomes distinct from highway engineering in its consideration of external factors, such as environmental and social impacts and economic change. These factors are also usually considered by comprehensive planning. In this way, freeway development has provided a forum through which these distinct types of planning have grown and developed.

The literature search with respect to comprehensive/land use planning focused on an examination of transportation planning and its relationship with comprehensive planing both as an exploration of the subject matter and in terms of case studies. These provided further documentation for the considerations presented in the beneficial effects outline. A particular effort was made to look into these relationships from an evaluative as well as factual perspective for such insights as might be gained. In the final analysis, it was desired to gain a real world understanding of the extent and substance of these relationships and their results. From the research, one may judge that transportation planning has become a highly sophisticated technical science; that its relationship with comprehensive

planning can provide an increasingly well-grounded, technical framework for more specific functional planning (i.e., transportation); and that society is becoming increasingly artful in its use of comprehensive planning (whether so identified or under the rubric of technology assessment, environmental impact analyses, or overview examinations) as a way in which to gain the services and facilities it desires. The research reveals that benefits are more likely to come about, if transportation planning has been substantially coordinated with comprehensive planning, and that the questions raised in the respective instances examined may be dealt with in a fuller measure of beneficial result to the extent that planning—transportation planning, comprehensive planning, their relationship, their coordination, their integration—underpins the decisions made and the actions taken.

The planning process in its various elements has played a fundamental role in freeway development. To be able to understand this role, however, the planning process must be seen in its entirety.

Fundamental to the proper design of a freeway is the work of the highway planner. It is his responsibility to ensure that the structural elements of the freeway meet applicable design criteria. That element of planning that is most closely related to engineering has been part of freeway development virtually from the outset.

As freeways have become more significant in the life of the nation, it was realized that the effects associated with freeways extended into areas that had not been adequately considered earlier. These effects extended beyond the immediate horizons of the freeway user to physical development of cities and its economic, social, and environmental substance and structure. One means of understanding and dealing with those extended, external effects was hoped to be through regional and comprehensive planning.

Comprehensive planning when used as part of the highway planning process can further the provision of benefits that might not otherwise occur. There are many examples of benefits that have grown out of the interdisciplinary planning approach. These benefits represent both real and conceptual results emanating from freeway development.

Comprehensive planning provides an integrated process and forum in which the people of a community can participate and address highway planning. The expression and reception of citizen points-of-view can be gained in a number of ways. The comprehensive planning process can provide a mechanism through which citizen views and approval for highway plans are formulated and presented. Transportation is required frequently by law as a major consideration in most local comprehensive plans. The comprehensive plan can serve as a framework through which highway plans can be synthesized with local goals and aspirations.

Comprehensive planning when used as a framework for highway planning can lend coherence and a spirit of rationality to the concept of over-all development. The physical configuration of cities is affected by highways and transportation facilities in subtle as well as bold ways. Comprehensive urban planning can serve as a link between highways and the desired full scope of their effects. Integrating highway planning and development with comprehensive planning and development facilitates our cities becoming both functional and livable entities.

Specific highway problems may also be aided by comprehensive planning. Interchanges, for example, have represented particular problems for the functioning of freeways. Unplanned land uses growing up around an interchange can themselves become high volume traffic generators. Traffic generated in this fashion often places too high a demand on the physical capabilities of the interchange. Comprehensive planning when used as part of the advance planning of the freeway can attempt to resolve this problem. If used early in the freeway planning effort, comprehensive planning can attempt to prevent the inappropriate concentration of high volume traffic generators. Comprehensive planning can also, with greater validity, provide forecasts of traffic volumes from adjacent land uses to aid in the design of the interchange. This is not to say that interchange planning is an accomplished art. It is not. This does show some ways in which comprehensive planning aids in the resolution of specific freeway problems.

These are examples of how highway planning and comprehensive planning can work together to provide benefits for both users and nonusers of freeways. This does not mean that the relationship between these two disciplines has always been consistent and harmonious or that it works perfectly in practice. Experience in the real world has shown this relationship to have its stresses and strains. Comprehensive planning represents a means of strengthening the highway planning process. It adds the dimension through which highway development may become an effective instrument for community and regional development. Comprehensive planning can furnish forecasts and through its implementation help to guide future growth around freeways. In a very important way, comprehensive planning can provide insight into the goals and aspirations of a community when determining an over-all highway plan.

a. *Interchange Development and Bypasses.*—During the initial period of freeway development, interchanges were thought of only as access areas. As freeways grew in significance, however, it became apparent that freeways themselves were evolving into complex multiuse facilities.

Specific problems developed between interchanges and their surrounding land uses. Growing up around many interchanges have been commercial, industrial, and residential land uses that are themselves major generators of traffic. Without planning or regulation, these land uses have created traffic volumes well in advance of those that the interchange was designed to handle. This phenomenon has created a situation detrimental to both the freeway user and to those persons affected by the congestion created by conflicting land uses.

Comprehensive planning, when used in conjunction with the highway planning effort, attempts to address the interchange problem. Land-use plans and zoning regulations have been used in an attempt to control both the number and types of land uses at interchanges. Comprehensive planning also may provide forecasts of projected growth in areas serviced by the interchange. This information can aid the designer of an interchange in helping to determine the traffic capacity for the interchange.

Comprehensive planning has not been used in the development of all interchanges in the United States. In order to have any chance of success, it must be applied very early in the interchange formulation process. Comprehensive planning has made, to the greatest degree possible, a legitimate effort to deal with the problems of interchanges.

It must be recognized that the competition for land at interchanges is great. This is true because of the locational and access advantages an interchange presents. The power of land development ordinances and regulations in many instances is not strong enough to resist the pressures of this competition. This is true despite the very earnest efforts made by comprehensive planners and freeway designers.

The benefits mentioned in this section represent the efforts of comprehensive planning to address the interchange problem. These efforts are not the ultimate answer to the interchange problem. They do, however, represent directions in which planners have gone in search of answers.

By 1960, it had become apparent that freeways were developing into multiuse facilities (*149*), and legal controls began to be introduced at this time throughout the nation to try to contain the problems at interchange areas. These controls benefited freeway users by placing limits on interchange generating capacity. It also served to benefit nonusers living or working in the interchange area by controlling traffic congestion and incompatible land uses. As indicated earlier, the original experience saw interchanges solely as aiding the free flow of traffic on the major facility.

In California, laws have been established for the development of interchange districts (*57*), which were written mainly with agricultural areas in mind. Up to the early 1960's, large sections of irrigated farmland were being lost to freeway interchange development. The law specifies that the area encompassed by the interchange district be no smaller than 1 mi in diameter. In this district, local planning and zoning laws are to be enforced with the purpose of preventing the takeover or severing of farmland. This potentially serves as a *benefit to the farmer by retaining the utility of his land* while allowing him freeway access. It should be noted, however, that the enforcement power of this law has not been strong.

Studies made by the U.S. Department of Transportation, Federal Highway Administration, have yielded some basic conclusions about interchange development (*205*). In the main, the first land use to appear at an interchange may not always be the best in terms of future development. Therefore, some types of facilities that tend to locate early in the process may need to be discouraged. Planning and zoning for interchange areas are recommended as means of minimizing if not preventing adverse development.

The Capital Beltway System is the freeway system that serves the nation's capital, Washington, D.C. Development sectors consisting of circles up to 2 mi in diameter can make significant impacts on growth around interchanges (*38*). This concept has not been universally applied; however, where applied, it provides for control of industrial, commercial, and residential development. It also considers the freeway's ability to carry traffic in a particular area. The delineation, zoning, and capital improvement of the sectors are left to the local planning agency. The benefits derived from this idea are both direct and indirect. Freeway users are directly benefited by control of traffic volume; nonusers are benefited by proper development of interchange facilities.

Besides specific examples of what interchange planning and development have accomplished in actual usage, there have been studies dealing with what freeway development should involve. One study states that the primary function of interchange planning is to meet the needs of the freeway (*139*). Once these needs are met, the general land use configuration of the area can be determined. This factor can prove to be indirectly beneficial in that it establishes a system of priorities for interchange development.

It is important for interchange development control to begin at the earliest possible time (*139*). Designation of an interchange area usually takes place from 2 to 5 years before actual construction. It is at this time that land developers make decisions that influence growth in the area. Once these decisions have been made and private development begins, it is very difficult to undo mistakes. Interchange planning should begin at the earliest possible time in order to control undesired development. This benefits both freeway users and nonusers living in the area.

The actual design of the interchange (cloverleaf, diamond, or some other variation) has an effect on traffic volume and capacity. This design also affects land use patterns in the interchange area (*139*). The work of the transportation engineer and the comprehensive planner must be closely coordinated in order to ensure maximum benefit. These benefits include proper freeway access for users as well as proper land development in the freeway area.

Extension of land use controls near interchange districts can lead to poor land use selection and congestion in secondary areas. Therefore, it is beneficial to establish some boundary for the interchange district (*139*). The limits to these controls can be seen as an indirect benefit affecting persons living in secondary areas around the freeway.

Zoning can serve to regulate the density of development and organize traffic generators at interchanges (*139*). Zoning can also regulate competition for land in the area surrounding the interchange. This is a benefit to commercial enterprises heavily dependent on freeway access.

Levin (*110*) has suggested that comprehensive planning can have an effect in addressing the problem of interchange development; the problem is created by high volume traffic generators crowding the land areas around interchanges. A study made by Barton-Aschman Associates (*13*) states that if applied early in the interchange development process, comprehensive planning may be useful in preventing the overcrowding of traffic generators into inappropriately concentrated areas through land use and zoning regulations. Forecasts can also be provided as to the over-all projected growth of the interchange area.

It should be recognized that the forces with which interchange planning and zoning must contend are quite strong. The benefits created by interchange planning are proper stimulation and access for commercial, industrial, and residential areas. Benefits from this type of planning can also be realized by freeway users in terms of reduced congestion as well as reduced congestion on local streets (*30*).

b. *Joint Development.*—The joint or multiuse concept proposes that freeway right-of-way be used for purposes other than the movement of traffic. For example, mass transit and public utilities could share the use of right-of-way. Freeways need not exist as entities into themselves. They interact with commerce, industry, housing, public facilities, parks, schools, as well as other uses. The interaction between freeways and other uses gives rise to the idea of multiple-use freeway corridor.

Examples of joint use extend to many different areas, but in most instances this concept has been used in urban areas. Comprehensive planning is mentioned as one of the better means of bringing the idea of joint use into the freeway development process.

Mass transit facilities have been successfully developed within the freeway corridor (*178*). This efficiently uses urban land and prevents duplication of right-of-way. Exclusive bus or train lanes in the freeway corridor have enabled passenger traffic to increase in the corridor without a similar increase in traffic volume. The experience in Chicago, using this idea, has been particularly encouraging.

The use of air space rights over freeways has given planners and designers important new ideas in revitalizing urban Americ a. Specific examples of this can be found in almost every major city in the United States (*92*). The use of air space rights has allowed urban traffic to grow, while preserving commerce, industry, as well as the urban tax base. This is a long-term benefit.

Studies have shown that acquisition costs for a block area around the freeway right-of-way does not prohibitively raise over-all costs in many instances (*207*). This block area could provide valuable commercial property or housing, and it aids in preserving the urban tax base.

Residential housing is being developed using air space rights over freeways (*14*). Barton-Aschman Associates sees this type of development as most successful when the necessary support facilities are developed along with the housing. These facilities might include shops, schools, and playgrounds. Shivers and Hjelte (*170*, p. 217) state:

> In some instances air rights over thoroughfares have been used to construct residential buildings. There seems little reason to assume that the necessary support structures for recreation would be any more difficult. In some metropolitan centers, road systems or expressways cut across the urban community as depressed avenues.

Freeway corridors are used for the transmission of municipal services (*14*) that can include power and fuel lines, sewer, and water and waste disposal to make more efficient use of the right-of-way. Freeways not only serve traffic generated by existing land uses, in many cases, they also act as stimulants to growth themselves (*14*). This is especially true when considering land uses that are attracted by increased accessibility. When freeways are planned in conjunction with other facilities, such as regional traffic generators, mass transportation systems, and major land uses, congestion and conflict can be reduced—a benefit with both short- and long-run implications.

The joint development concept not only allows for good use of physical space, it can also represent a broad spectrum of community goals and values (*205*). Joint development can provide housing for those displaced by the freeway's construction, as well as providing parks, playgrounds, and other social facilities.

The multiple-use concept for highway corridors is well founded, but only through careful research can it be determined which activities are compatible with such multiple use. The placement of bike trails adjacent to highways helps avoid bike and automobile competition for the same road space, thus protecting the cyclist from the hazards associated with collision but not from the potential physiological hazards of pollution. Although multiple use of the right-of-way may be regarded as a direct, long-range benefit of highway planning and development, of value to the urban and rural community, traffic volume may be a constraining factor.

The National Park Service has built bike trails parallel to some of their parkways. Pressure currently exists to build trails along Interstate highways. More intensive development of picnic areas, campsites and other complementary facilities in scenic corridors will make available previously unused resources (*192*). The potential for recreational development afforded by using the highway corridor as an integral part of the recreation resource offers a resource base for recreation that, as yet, has remained greatly underutilized. The potential afforded by freeway development for recreational innovation must be viewed as a long-range benefit of highway development that is important to both the urban and rural communities.

Highway right-of-way is usually developed to a size just sufficient to accommodate the passage of the highway. Expansion of these easements is necessary to make optimum use of the land adjacent to highways. The potential for multiple use and expanded use of highway easements rests with some changes in planning emphasis; it is only then that this potential can be realized. This need is especially important to the urban sector where available land is minimal.

The identification of sites of historic significance in advance of actual highway construction, as part of the planning process, can help a community to maintain its cultural links to the past and help preserve irreplaceable assets. Using this approach as part of the planning process can enhance the relationship between transportation planning agencies, preservationists, and local communities. The highway corridor can be planned in such a manner as to provide opportunities for people to see many places of historic interest by linking these sites together. It must be realized that this is not a formula for absolute inclusion of historic sites within the corridor but an effort to afford the opportunity to preserve historically significant landmarks when this is possible.

Provision of ample open space, especially for recreation, is an important problem facing the urban sector. Freeways cutting across, through, under, and around the cities afford an excellent opportunity for new innovations in recreational planning and design. Competition for urban open space is very keen. Such space has the potential to provide long-range, indirect benefits for recreation services and amenities for the majority of our nation's citizens who reside in the large cities.

Coordination between Interstate highway development and major park development, involving both the multiple

use of highway right-of-way for park purposes and the provision of direct ramp access to recreational facilities, is highly desirable. Two hundred and fifty miles of controlled access parkway in the New York area have been well articulated as an interconnected network of some 21 routes. According to Seel (*168*), "Rights of ways for expressways commonly vary from 250-300 feet in width, or approximately 30-36 acres per route mile." Shivers and Hjelte (*170*, p. 220) state:

> The greatest single advantage of the linear recreational space within the metropolitan area will be found in maximizing the utilization of space by a large number of people at a considerably lessened economic expenditure.

Seel (*168*, p. 357) states:

> Freeways require large amounts of land, though less than half and often as little as ⅓ of the right of way is actually paved and used for moving traffic. Regional parks on the other hand, if they are to be available to as many potential users as possible, require a high degree of metropolitan accessibility. As a result, the coordination of freeway location with major park development, involving both the multiple use of highway right of ways for park purposes and division of direct ramp access to recreational facilities, represents a promising area for future public planning activities.

Large amounts of space are available at interchange sites and rampways and beneath elevated highway extensions. These spaces are often used for storage and parking, but with some creative design elements could be implemented for viable recreational space, sorely needed in the urban landscape.

Brodsky (*27*, p. 22) asserts:

> Despite the contribution made by highways toward outdoor recreation, highway planners have not always given explicit recognition to the unique problem of developing highways as a recreational resource. The several methods in use by highway engineers for road design and priority programming tend to gloss over the significance of recreational travel.

With the supply of open space diminishing, the development of lands adjacent to scenic corridors will be necessary to meet the recreational demands of a highly mobilized society. Open space abutting scenic highway rights-of-way can be developed in the interest of providing those social amenities so necessary for today's traveler or family seeking a simple recreative experience. "A scenic road program will tap the potential of presently unused areas. It will help make more effective use of existing acres" (*192*, p. 25). The development of picnic areas, campsites, and other facilities, complementary to the scenic corridor and planned for as an integral segment of the right-of-way, lends itself to maximizing the use of previously dormant resources.

The joint use concept can make freeways more adaptable to the over-all urban environment (*178*). Facilities appropriate for joint or multiple use of the freeway corridor should rank high in planning priorities. Major traffic generators, such as libraries, government centers, and major institutional buildings, are especially well suited for joint development. Development of such activities in conjunction with the freeway not only makes more efficient use of urban land, but it also reduces congestion on secondary roads supporting the freeway.

It should be noted that not all urban land uses are compatible with the joint use approach (*178*). Rivers, harbors, swamps, and some parks are examples of adjacent types of land that may not be successfully used for joint development.

c. *Land Use.*—The idea that a freeway and the land that it abuts have important effects on one another is not new. This idea has, however, grown in importance over time. Land use planning has not always been part of the freeway planning process. The growing complexity of land use issues has led to the realization that both freeways and the communities that they serve can be benefited by specific consideration of the use of land.

In areas adjacent to Massachusetts Route 128—a limited-access, 4- and 6-lane highway—zoning changes have encouraged industrial location (*22*). Locational advantages resulted from both increased accessibility due to the highway and better land-use control. The fostering of industry has created new jobs and strengthened the local tax base, all of which has been accomplished while partially maintaining the residential character of the affected area. This has benefited both urban and nonurban areas.

Although land use boundaries in urban areas are often blurred, freeways can be planned in a fashion such that they separate conflicting land uses (*91*). However, freeways can also cut off and separate neighborhoods. Any demarcation by freeways should involve community approval.

The control of land use, or zoning, does not imply that any type of land use can be forced on an area. Rather, by considering existing conditions, it influences how land will be used in the future. With regard to freeways, zoning can discourage industrial and residential development in the same freeway access area (*191*). In this way, the best use of land with regard to its relationship to the freeway can be established.

Land use packages should be thought of as whole units, such as commercial, residential, or industrial. Freeways should be developed to protect these areas (*156*). Comprehensive land use plans usually identify these units in advance.

Development of freeways in conjunction with adjacent land uses can help to ensure over-all land-use compatibility (*112*). Levin states that freeways should include scenic variety, proper access, and separation of conflicting land uses. Elimination of the crowding of uses can maintain viability and provide the maximum in user and nonuser benefit. Freeways that do not maintain this type of viability can become obsolete long before the road surface wears out.

d. *Design Characteristics.*—In many instances, there is a delicate relationship between a freeway and the community that it serves. A freeway that lacks certain creative inputs can in some ways be harmful to the community. Certain elements of design when implemented in the planning and development of a freeway can prove to be beneficial. These elements can include aesthetic, structural, and conceptual elements of the freeway.

Design and its implementation can be both physical and/or abstract. It can differ from the inclusion of a physical change in the freeways structure to the relationship between freeways and urban development. Although at times indirect, the benefits derived from the design of freeways

comprise a legitimate area of inquiry within the scope of this study.

Freeways play an important role in urban redevelopment. This can be accomplished by the establishment of a reciprocal relationship between the city and the freeway (*91*). Redevelopment often provides freeway right-of-way. Freeways, through the joint use concept, can provide housing for the displaced, commercial and industrial land use areas, as well as social facilities such as parks and playgrounds. It should be noted that old housing of low quality, occupied by poor people, often serves as the reason for the destruction of that housing for freeway right-of-way. The effort described here is one of designing the freeway facility in order to replace the housing of the displaced. This can be seen as a direct, long-range benefit.

The idea of designing freeways in conjunction with parks and recreation areas near urban centers has led to the development of parkways (*177*). A parkway provides for multiuse recreational facilities to be developed along with freeway right-of-way. Besides providing for the efficient use of urban land, the freeway serves as access to the recreation area. This process is brought about through the freeway planning process that considers both human need and freeway location.

Design elements can be used as an attempt to create harmony between a freeway and the city it serves. Although it is not always possible to separate freeways from segments of the urban environment with which it can conflict, ideas must be employed to allow for some type of integration. For example, buildings placed close to a freeway, but facing away from it, could avoid aesthetic and noise dislocations (costs) while making good use of space (*159*). The Park Presidio Boulevard in San Francisco uses trees to separate the freeway from residences surrounding it.

Potentially, freeways can do tremendous damage to social structures in cities. The growth of sophistication and militancy among many urban neighborhood groups has caused the termination or delay of many freeway projects. The second National Conference on Highways and Urban Development held at Williamsburg, Va., saw that freeways can employ certain elements of design that work toward the preservation of neighborhood patterns in urban areas (*4*). For example, freeway design must recognize that the shortest distance between two points in an urban area is not necessarily the best route.

Planning can aid the preservation of historical sites within the context of highway plans. A Massachusetts study identified communities and historical landmarks to be affected by 1975 highway plans (*168*). By combining the highway plans with the idea of historical preservation, both designs to integrate the highway with historical sites and alternative plans have been developed.

Freeway design must be consistent with the total urban environment. Studies have shown that the inclusion of shops, buildings, and garages within the freeway structure is of benefit to the city in which it is implemented (*4*). This idea allows the freeway to exist while preserving commerce and the urban tax base.

The freeway profile is also an important design consideration (*4*). Vertical stacking could in some instances be of greater value than horizontal design. In certain areas, a greater volume of traffic may be needed to move over a given space than in another area. This is an example of how freeways and the urban environment could be brought into greater harmony.

e. *Transportation/Comprehensive Planning Interface.*—The relationship between transportation planning and comprehensive planning is very important in a study of freeway benefits. Initially, freeways were planned and designed by engineers whose chief concern was the technical efficiency of the roadway. From the late 1940's to the early 1970's the freeway system in the United States has grown rapidly. During this same period, transportation planning has evolved.

Transportation planning seeks to establish objective engineering and design criteria on which to base transportation systems. It also attempts to recognize factors that are judgmental in substance as well as analytically quantifiable. Primary among these factors are potential economic changes, land use, social patterns, and community values. These considerations are also frequently taken into account within the concept of comprehensive planning.

Comprehensive planning represents a means of inputting community needs, desires, and values into the total freeway equation. Although this is desired by the transportation planner, it does not mean that the process has always worked in practice. As the complexity of the issues surrounding freeway development grows, the relationship between transportation and comprehensive planning becomes more important. Springing from this relationship is the realization that a functional, service-oriented freeway cannot be developed in a vacuum.

In detailing the elements of this relationship between comprehensive and transportation planning, the first statement that can be made is that it can provide an alternative to haphazard development (*57*). Experience in California has shown that freeway construction through or near a community forces it to make basic adjustments. Changes in social patterns, the need for new homes, and the development of utilities and municipal services to conform to the construction of the freeway are examples of various adjustments. Comprehensive planning used in conjunction with the planning of the freeway can lessen any effects on the community. This relationship can work to preserve the social structure, stimulate urban renewal, attract industry, and develop recreational facilities.

Montgomery County, Pa., has developed a system whereby local municipalities can plan for potential population growth and industrial development by combining highway and local comprehensive planning efforts (*73*). By combining outlooks, a new logical basis for planning and inquiry has been developed. Solutions to problems that are held jointly by small communities and that relate to their transportation systems have been found. Traffic circulation plans and a schedule for highway construction and maintenance have also grown out of this joint planning effort.

The experience in Pennsylvania has shown that the transformation of the highway planning effort into a multidisciplinary approach has benefited the entire transportation process (*151*). Whereas, previously, only economic benefits had been considered when planning for a highway or freeway, now, benefits are considered for the entire scope of society. To the greatest degree possible, an

overview of environmental, social, and economic benefits is considered. This outlook can do much to ensure the successful development of highways.

Orderly, rational plans for land use and development in areas subject to the freeways influence can be created by the coordination of comprehensive and transportation planning (*191*). The clustering of commercial establishments near interchanges, the development of residential housing too near the right-of-way, or the grouping together of incompatible land use parcels are of service neither to themselves nor to the freeway. When used as part of the freeway planning process, comprehensive planning can aid in preventing adverse development.

A transportation planner does much to shape the social and physical configuration of a community. The inclusion of comprehensive planners in the freeway planning process can do a great deal to encourage the formulation of urban goals (*214*). Development of the multidisciplinary approach helps to establish local and regional goals, along with including citizens and local officials in the planning process.

The relationship between transportation and comprehensive planners is also important in encouraging urban redevelopment (*191*). Urban comprehensive planning can act to clear slums and revitalize business areas. This redevelopment must not take place at the expense of displaced persons, but must work to replace any housing that is lost.

In some instances, transportation planning can aid in settling disputes among affected groups. This can be done by the establishment of standard, objectively oriented plans, which serve to adjudicate such issues as freeway access and location.

An externality can be defined as a cost or benefit affecting a person or group in society as a result of an action taken by others. Freeways are often seen as having an adverse effect on persons living in surrounding areas. Externalities, such as water or noise pollution, can be considered by comprehensive planning and their effects controlled (*149*).

The Washington State Planning and Community Affairs Agency saw that the use of multidisciplinary design teams, including not only transportation and comprehensive planners but also landscape architects and other designers, and representatives of the local community, can have a positive effect on freeway development (*102*). Such efforts may lead to better corridor selection and more likelihood that land use plans are implemented, community views respected, and design factors, such as multiuse facilities, taken into account (*102*).

The Sagamore Conference on Highways and Urban Development stated that transportation planners and comprehensive planners have a broad range of common goals, one of which is the expeditious movement of people in harmony with the local government (*3*). More specific goals might include preservation of certain land uses. These goals can be coordinated through the highway or freeway planning process.

D. Regional and National Effects

In this section, the large-scale effects of highways will be discussed. The Interstate Highway System, which is designed to interconnect every city of 50,000 or more population, serves as a communication link among major population centers (*161*). This is particularly evident in the functions of these highways in the distribution of mail and magazines and newspapers, and in the maintenance of telephone and telegraph lines. In these and other ways, limited-access highways help people to become informed of state and national affairs (*140*).

It has been speculated that limited-access highways help to enhance national unity (*138*). There are several ways in which this may occur. First, highways are a manifestation, and perhaps a symbol, of cooperation between state and federal government. Perhaps, they are also a source of national pride. Additionally, they contribute to functional interdependence among cities, between cities and rural areas, and among regions. For example, many states depend on oil produced in Texas and a few other states. Automobile production has come to be centered in Detroit and southeastern Michigan, which supply most of the automobiles for national markets. The steel used in these automobiles is mostly produced in centers specializing in steel production, such as Pittsburgh and Buffalo. The examples of such functional interdependence are, of course, too numerous to mention. The communications function of highways, mentioned earlier, serves to weld the nation into a unit. Finally, the access to national monuments, historical sites, and parks that tourists visit in great numbers each year, may serve to reinforce national pride.

Another important benefit of limited-access highways is their function in large-scale disasters. Although no studies were found that dealt specifically with the role of highways in disasters, such as tornados, earthquakes, and floods, the general literature on disasters contains numerous case studies that give indications of this role (*14, 46, 55*). Highways are an important means by which medical supplies and medical personnel, food, clothing, machinery for fire-fighting and debris clearance, and other needed items may be brought into a stricken area; they also help in getting the injured to hospitals. Form and Nosow (*55*), among others, have noted the importance of state police or state highway patrolmen in many emergencies—they are frequently among the first outside help on the scene of a disaster, and they generally serve the essential function of organizing and directing rescue activities.

There are some important limitations of highways in such disasters, however. First, tornados, floods, earthquakes, and many other disasters may leave highways blocked by water, debris, or highway damage. The high standards of construction of Interstate highways reduce the likelihood that this will occur, but certainly do not eliminate it. Secondly, in some types of disasters, highways permit the quick influx of large numbers of sightseers or looters, who serve to block the important functions of the highways and local streets and interfere with rescuers and supplies. Form and Nosow (*55*) note that, in a major tornado disaster, the state police who took charge of the rescue operation listed traffic control as the task first in importance and frequency during the emergency. These limitations suggest that helicopters, perhaps, might be better suited to disaster relief operations than motor vehicles. However, motor vehicles are generally more readily available in larger numbers.

Part of the rationale for the construction of the Interstate System of highways was their utility for national defense (*138, 161*). The overhead clearances and other design features of the Interstate System were to accommodate rocket carriers and other motor-vehicle-based weapons systems. However, the size of some of these units soon became so large that the construction of highways to accommodate them became prohibitive economically and practically. Moreover, despite the high standards of construction of the Interstate System, it remains extremely vulnerable to attack and of limited value in an attack by nuclear weapons. The highway undoubtedly serves a role in national defense by facilitating the preparations for nuclear attack, such as the construction and maintenance of defensive missile sites.

SOCIAL BENEFITS BIBLIOGRAPHY

1. ADKINS, W. G., *Economic Effects of Camp Creek Road Improvement.* Texas A&M University, Texas Transportation Institute (1958).
2. ADKINS, W. G., and EICHMAN, F. F., JR., "Consequences of Displacement by Right-of-Way to 100 Homeowners, Dallas, Texas." *Bulletin No. 16,* Texas A&M University, Texas Transportation Institute (1961).
3. AMERICAN ASSOCIATION OF STATE HIGHWAY OFFICIALS AND AMERICAN MUNICIPAL ASSOCIATION (Joint Committee on Highways), and the AUTOMOTIVE SAFETY FOUNDATION, *The Sagamore Conference on Highways and Urban Development (Guidelines For Action)* (1958) 29 pp.
4. AMERICAN ASSOCIATION OF STATE HIGHWAY OFFICIALS, *Highways and Urban Development: Report on the Second National Conference,* Williamsburg, Va. (1965).
5. AMERICAN ASSOCIATION OF STATE HIGHWAY OFFICIALS, *A Policy on Design of Urban Highways and Arterial Streets* (1973).
6. AMERICAN AUTOMOBILE ASSOCIATION, *Americans on the Highway* (1952).
7. ATKINSON, H. W., MENHINICK, H. K., *Land-Use Planning and Control Along the Interstate Highway System in Georgia,* State Highway Department of Georgia/Bureau of Public Roads (1963) 98 pp.
8. AUTOMOTIVE SAFETY FOUNDATION, *The Hershey Conference on Freeways in the Urban Setting.* Washington, D.C. (1962) 18 pp.
9. AUTOMOTIVE SAFETY FOUNDATION, *What Freeways Mean to Your City.* Washington, D.C. (1964) 56 pp.
10. BALKUS, K., "Transportation Issues in Consumer Motivation." *Hwy. Res. 439* (1973) pp. 1-9.
11. BARDWELL, G. E., and MERRY, P. R., "Measuring the Economic Impact of a Limited-Access Highway on Communities, Land Use, and Land Value." *Hwy. Res. Board Bull. 268* (1960) pp. 37-73.
12. BARKLEY, B. T., "Problem Solving in Urban Transportation." *Traffic Quarterly,* Vol. 27, No. 4, pp. 491-502 (Oct. 1973).
13. BARTON-ASCHMAN ASSOCIATES, *Highway and Land-Use Relationships In Interchange Areas* (1968) 61 pp.
14. BARTON-ASCHMAN ASSOCIATES, *Joint Project Concept, Integrated Transportation Corridors.* U.S. Department of Housing and Urban Development (1968) 129 pp.
15. BARTON, A. H., *Communities in Disaster.* Doubleday and Company (1969) 352 pp.
16. BAYLEY, J., "Transportation Plan-Melbourne 1985." *Traffic Quarterly,* Vol. 25, No. 1, pp. 73-85 (Jan. 1971).
17. BEATTY, R. L., "Speed Analysis of Accidents on Interstate Highways." *Public Roads,* Vol. 37, No. 3, pp. 89-102 (Dec. 1972).
18. BECKMAN, N., "Politics and Administration of Plan Supplementation." *Hwy. Res. Rec. 102* (1965) pp. 1-10.
19. BLACK, S., *Man and Motor Cars.* Secker and Warburg, London (1966).
20. BLAIR ASSOCIATES, *The Friendly Interchange.* Providence, R.I. (1960) 48 pp.
21. BOHM, R. A., and PATTERSON, D. A., "Interstate Highways and the Growth and Distribution of Population." Paper presented at the American Statistical Association, Fort Collins, Colo. (1971).
22. BONE, A. J., and WOHL, M., "Massachusetts Route 128 Impact Study." *Hwy. Res. Board Bull. 227* (1959) pp. 21-49.
23. BOWERSOX, D. J., "Influence of Highways on Selection of Six Industrial Locations." *Hwy. Res. Board Bull. 268* (1960) pp. 13-28.
24. BRANHAM, A. K., "Transportation Factors and National Transportation Policy." *Engineering Bull.,* Vol. 35, No. 2 (Mar. 1951).
25. BRIDWELL, L. K., "Freeways in the Urban Environment." *Hwy. Res. Board Sp. Rep. 104* (1969) pp. 103-118.
26. BRINTON, J. H., JR., and BLOOM, J. N., "Effect of Highway Landscape Development on Nearby Property." *NCHRP Rep. 75* (1969) 82 pp.
27. BRODSKY, H., "Highways and Outdoor Recreation." *Hwy. Res. Rec. 161* (1967) pp. 22-29.
28. BURTON, R. C., and KNAPP, F. D., "Socio-Economic Change in Vicinity of Capitol Beltway in Virginia." *Hwy. Res. Rec. 75* (1965) pp. 32-47.
29. CALTRANS, *1973 Accident Data on California State Highways* (1974).
30. CAMPBELL, E. W., "Transportation System Corridors." *Hwy. Res. Rec. 166* (1967) pp. 26-35.
31. CLARK, R. N., HENDEE, J. C., and CAMPBELL, F. L., "Values, Behavior, and Conflict in Modern Camping Culture." *J. Leisure Res.* (Sept. 1971) pp. 143-159.
32. CLARK, W. E., KERRICK, J. S., and GALLOWAY, W. J., "Highway Noise—Measurement, Simulation, and Mixed Reactions." *NCHRP Rep. 78* (1969) 78 pp.
33. CLAWSON, M., "Implications of Recreational Needs for Highway Improvements." *Hwy. Res. Board Bull. 311* (1962) pp. 31-37.
34. CODY, C., "It's Happening at the Interchange." *Hwy. User Quart.* (Spring 1974) pp. 13-20.

35. COLONY, D. C., *Expressway Traffic Noise and Residential Properties.* Univ. of Toledo, Research Foundation (1967).
36. COLONY, D. C., *Residential Relocation: The Impact of Allowances and Procedures in Effect Since July 1, 1970.* State of Ohio Department of Transportation and U.S. Federal Highway Administration (1974).
37. "Coming to Term With Traffic Noise." *Engineering,* Great Britain (Feb. 1966) pp. 374-375.
38. CONNALLY, J. A., and MEIBURG, C. O., "The Washington Capital Beltway and Its Impact on Industrial and Multi-Family Expansion in Virginia." *Hwy. Res. Rec. 217* (1968) pp. 9-27.
39. CRACKNELL, B., "Accessibility to the Countryside as a Factor in Planning for Leisure." *Regional Studies* (1967) pp. 147-161.
40. CURRY, D. A., and ANDERSON, D. G., "Procedures for Estimating Highway User Costs, Air Pollution, and Noise Effects." *NCHRP Rep. 133* (1972) 127 pp.
41. DANFORTH, H. L., and SHELDON, W. P., "Bantam Expressways—A New Urban Face-of-the Future." *Traffic Quarterly,* Vol. 20, No. 3, pp. 435-446 (July 1966).
42. DANSEREAU, H. K., "Five Years of Highway Research: A Sociological Perspective." *Hwy. Res. Rec. 75* (1965) pp. 76-82.
43. DENEUFVILLE, R., "The Demand for Airport Access Services." *Traffic Quarterly,* Vol. 27, No. 4, pp. 583-600 (Oct. 1973).
44. DEAKIN, O. A., "Planting for Screening Headlight Glare and Traffic Guidance." *Hwy. Res. Rec. 53* (1963) pp. 17-25.
45. DURKHEIM, E., *Suicide.* Translated by J. A. Spaulding and G. Simpson. The Free Press, N.Y. (1951).
46. DYNES, R. R., *Organized Behavior in Diaster.* Heath Lexington (1970) 237 pp.
47. EVERETT, M., "Warning! Bicycling May Be Hazardous to Your Health." *Parks and Recreation,* Vol. 7, No. 9, pp. 40-41, 77-79 (Sept. 1973).
48. FALCOCCHIO, J. C., PIGNATARO, L. J., and CANTILLI, E. J., "Modal Choices and Travel Attributes of Inner City Poor." *Hwy. Res. Rec. 403* (1972) pp. 6-17.
49. FARLEY, R., "The Changing Distribution of Negroes in Metropolitan Areas: The Emergence of Black Suburbs." *Am. J. Soc.,* Vol. 75, No. 4, pp. 512-259 (Jan. 1970).
50. FARLEY, R., and HERMALIN, A I., "The 1960's: A Decade of Progress for Blacks?" *Demography,* Vol. 9, No. 3, pp. 353-370 (Aug. 1972).
51. FREDERICK, J. C., "The New Trichotomy—The Highway, The Roadside and Recreation." *Hwy. Res. Rec. 206* (1967) pp. 36-46.
52. FEE, J. C., "Accident Experience on Speed-Change Lanes of the Interstate System." *Public Roads,* Vol. 37, No. 2, pp. 61-64 (Sept. 1972).
53. FIELDING, G. J., "Structuring Citizen Involvement in Freeway Planning." *Hwy. Res. Rec. 380* (1970) pp. 23-26.
54. FOLEY, D. L., "The Use of Local Facilities in a Metropolis." *Am. J. Soc.,* Vol. 56, pp. 238-246 (1950).
55. FORM, W. H., and NOSOW, S., *Community in Disaster.* Harper and Brothers (1958) 273 pp.
56. FORT, F. W., "Walk Time From Vehicle To Final Destination." *Hwy. Res. Rec. 439* (1973) pp. 28-31.
57. FRANKLAND, B., "Land Use Control at Freeway Interchanges in California." *Traffic Quarterly,* Vol. 19, No. 4, pp. 541-556 (Oct. 1965).
58. FREID, M., "Grieving for a Lost Home-Psychological Costs of Relocation." *The Urban Condition.* Basic Books (1963).
59. FREID, M., and GLEICHER, P., "Some Sources of Residential Satisfaction in an Urban Slum." *J. Am. Inst. Planners,* Vol. 27, pp. 305-315 (1961).
60. FREY, J. C., "Planned vs. Unregulated Development in a Suburban Community." *Agricultural Economics and Rural Sociology Report No. 23,* The Pennsylvania State University (1960).
61. FREY, J. C., DANSEREAU, H. K., PASHEK, R. D., and MARKHAM, J. W., "The Economic and Social Impact of Highways: A Progress Summary of the Monroeville Case Study." The Pennsylvania State University, Agriculture Experiment Station (1960) 38 pp.
62. FROMM, E., *Escape From Freedom.* Holt, Rinehart, and Winston (1941).
63. FUGATE, D. B., "Changing Highway Concepts." *Traffic Quarterly,* Vol. 24, No. 2, pp. 165-173 (Apr. 1970).
64. GALLAWAY, B. M., LEDBETTER, W. B., and EPPS, J. A., *Feasibility of Using Highway Litter in Highway Construction and Maintenance.* Texas A&M University, Texas Transportation Institute (1971).
65. GANS, H. J., "The White Exodus to Suburbia Steps Up." *The New York Times Magazine* (Jan. 7, 1968).
66. GARRISON, W. L., and MARKS, M. E., *Influence of Highway Improvements on Urban Land: A Graphic Summary.* Univ. of Washington, Seattle (1958) 70 pp.
67. GARRISON, W. L., BERRY, B. J. L., MARBLE, D. F., NYSTUEN, J. D., and MORRILL, R. L., *Studies of Highway Development and Geographic Change.* Univ. of Washington Press (1959).
68. GEORGIA INSTITUTE OF TECHNOLOGY, Engineering Experiment Station, *Analysis of Intercounty Commuting of Workers in Georgia* (1958).
69. GODSCHALK, D. R., "Achieving Environmental Quality and the Highway Beautification Act of 1965." *Hwy. Res. Rec. 182* (1967) pp. 22-24.
70. GOODWIN, A., "Attitudes and Shopper Mobility in a Small City." *Hwy. Res. Rec. 233* (1968) pp. 16-26.
71. GRATTO, C. P., "Social and Economic Factors Affecting Highway Use." *Research Publication No. 60,* The Pennsylvania State University, Institute for Research on Land and Water Resources (Oct. 1969) 23 pp.
72. GREENWOOD, N., and EDWARDS, J. M. B., "Outdoor Recreation." *Human Environments and Natural Systems,* Duxbury Press, Mass. (1973) pp. 298-308.

73. GROSSMAN, H. J., "Highway Planning in a Small Community." *Traffic Quarterly,* Vol. 19, No. 2, pp. 229-239 (Apr. 1965).
74. GUEST, A. M., "Retesting the Burgess Zonal Hypothesis: The Location of White-Collar Workers." *Am. J. Soc.,* Vol. 76, No. 6, pp. 1094-1108 (May 1971).
75. GUEST, A. M., "Urban Growth and Population Densities." *Demography,* Vol. 10, No. 1, pp. 53-69 (Feb. 1973).
76. GUEST, A. M., and CLUETT, C., "Metropolitan Retail Nucleation." *Demography,* Vol. 11, No. 3, pp. 493-507 (Aug. 1974).
77. HALPRIN, L., *Freeways.* Reinhold Publishing Corporation (1966) 160 pp.
78. HANNON, J. B., and FORSYTH, R. A., *Highway Research Report: Fill Stabilization Using Non-Biodegradable Waste Products. Phase I.* Sacramento, California State Division of Highways (1973).
79. HAWLEY, A. H., *The Changing Shape of Metropolitan America.* The Free Press, Glencoe, Ill. (1956).
80. HAWLEY, A. H., *Urban Society: An Ecological Approach.* Ronald Press, N.Y. (1971).
81. HAWLEY, A. H., and ZIMMER, B., *The Metropolitan Community Its People and Government.* Sage, Beverly Hills, Calif. (1970).
82. HERMALIN, A. I., and FARLEY, R., "The Potential For Residential Integration in Cities and Suburbs: Implications for the Busing Controversy." *Am. Soc. Rev.,* Vol. 38, No. 5, pp. 595-610 (Oct. 1973).
83. HIGHWAY RESEARCH BOARD, "Highway Capacity Manual 1965." *Sp. Rep. 87* (1965) 418 pp.
84. HIGHWAY RESEARCH BOARD, "Relocation: Social and Economic Aspects." *Sp. Rep. 110* (1970) 56 pp.
85. HIGHWAY RESEARCH BOARD, "Environmental Considerations in Planning, Design, and Construction." *Sp. Rep. 138* (1973) 161 pp.
86. HILL, S. L., and FRANKLAND, B., "Mobility as a Measure of Neighborhood." *Hwy. Res. Rec. 187* (1967) pp. 33-42.
87. HOBBS, D. J., and CAMPBELL, R. R., "Traffic Flow and Population Change—Missouri Towns and Cities." *Bus. and Gov. Rev.* (May-June 1967).
88. HOFFMAN, G. A., "Minimizing Land Used by Automobiles and Buses in Urban Central Core: Underground Highways and Parking Facilities." *Hwy. Res. Rec. 102* (1965) pp. 98-114.
89. HOOVER, E. M., and VERNON, R., *Anatomy of a Metropolis.* Harvard University Press (1959)
90. HOUSE, P. A., "Relocation of Families Displaced by Expressway Development: Milwaukee Case Study." *Land Economics,* Vol. 46, No. 1, pp. 75-78 (Feb. 1970).
91. HOWARD, J. T., "Community Growth—Impact of the Federal Highway Program." Paper prepared for the Nation Conference on Government of the National Municipal League (1957) 17 pp.
92. HUMMEL, D., "Housing and Urban Development Consideraions." *Hwy. Res. Board Sp. Rep. 104* (1969) pp. 161-169.
93. HUMPHREY, C. R., and KROUT, J., "Traffic and the Suburban Highway Neighbor." Paper presented at the Meeting of the American Sociological Association, San Francisco, Calif. (1975).
94. HUMPHREY, C. R., and SELL, R. R., "The Demographic Impact of Controlled Access Highways on Nonmetropolitan Areas, 1940-1970." *Population Redistribution and Depopulation in Non-Metropolitan Pennsylvania: Social and Economic Correlates and Policy Implications,* The Pennsylvania State University, The Population Issues Research Office (1974).
95. IRWIN, R., "Nonmetropolitan Population Change: 1960-1970." Paper presented at the Meeting of the Population Association of America, Washington, D.C. (1971).
96. JAMESON, G. D., and WYATT, W. V., "The Location and Potential Highway Use of By-Products in Arkansas." Final Report, Arkansas State University, Department of Physical Science (1973).
97. KELLER, B. K., "Recreation on the Move." *Parks and Recreation,* Vol. 9, No. 5, pp. 29-30, 63-64 (May 1974).
98. KELLER, S., *The Urban Neighborhood: A Sociological Perspective.* Random House (1961).
99. KEMP, B. H., "Social Impact of a Highway on an Urban Community." *Hwy. Res. Rec. 75* (1965) pp. 92-102.
100. KEYFITZ, N., "Numbers and Distribution of Mankind." *Environment: Resources, Pollution and Society.* Sinauer Associates, Inc., Stanford, Conn. (1971).
101. KILEY, E. V., "Highways As a Factor in Industrial Location." *Hwy. Res. Rec. 75* (1965) pp. 48-52.
102. KINSTLINGER, J., and KEEFER, L. E., "Citizen Participation in The Urban State." *Hwy. Res. Board Sp. Rep. 142* (1973) pp. 71-89.
103. KLEIN, G. E., CURRY, D. A., ELLIS, H. B., FRATESSA, C. L., MCGILLIVRAY, R. G., MOON, A. E., THOMPSON, G. I., and TILTON, P. D., *Methods of Evaluation of the Effects of Transportation Systems on Community Values.* Stanford Research Institute (1971) 290 pp. and appendix.
104. KUGLER, B. A., and PIERSOL, A. G., "Highway Noise: A Field Evaluation of Traffic Noise Reduction Measures." *NCHRP Rep. 144* (1973) 80 pp.
105. LARSON, T. D., and MCKELVEY, —., "Environmental Impacts of Transportation Facility Design Decisions." Course notes, The Pennsylvania Transportation Institute, The Pennsylvania State University (1973).
106. LEEMING, J. J., "A Highway Engineer and the Environment." *Hwy. Eng.,* Vol. 20, No. 9, pp. 22-26 (1973).
107. LEMLY, J. H., "Expressway Influence on Land Use and Value-Atlanta 1941-56." *Research Paper No. 10,* Georgia State College of Business Administration (1958) 137 pp.
108. LEMLY, J. H., "Changes in Land Use and Value Along Atlanta's Expressways." *Hwy. Res. Board Bull. 227* (1959) p. 19.

109. LEOPOLD, L. B., CLARKE, F. E., HANSHAW, B. B., and BALSLEY, J. R. A., "Procedure for Evaluating Environmental Impact." *U.S. Geological Survey Circular 645* (1971).
110. LEVIN, D. R., "The Highway Interchange Land-Use Problem." *Hwy. Res. Board Bull. 288* (1961) pp. 1-24.
111. LEVIN, D. R., "Informal Notes on Sociological Effects of Highways." *Hwy. Res. Rec. 75* (1965) pp. 82-84.
112. LEVIN, D. R., "Scenic Corridors." *Hwy. Res. Rec. 166* (1967) pp. 14-21.
113. LEVINSON, H. S., HOEY, W. F., SANDERS, D. B., and WYNN, F. H., "Bus Use of Highways—State of the Art." *NCHRP Rep. 143* (1973) 406 pp.
114. LEWIS, P. H., JR., "Environmental Values in Regional Highway Design." *Hwy. Res. Rec. 161* (1967) pp. 1-16.
115. LEWIS, P. H., JR., "The Highway Corridor as a Concept of Design and Planning." *Hwy. Res. Rec. 166* (1961) pp. 1-8.
116. MCHARG, I. L., "A Comprehensive Highway Route Selection Method." *Hwy. Res. Rec. 246* (1968) pp. 1-15.
117. MCKAIN, W. C., *The Connecticut Turnpike: Ribbon of Hope.* Univ. of Connecticut, Storrs Ag. Exp. Station (1964) 120 pp.
118. MCLEAN, E. L., and ADKINS, W. G., "Freeway Effects on Residential Mobility in Urban Neighborhoods." *Hwy. Res. Rec. 356* (1971) pp. 95-104.
119. MCMILLAN, R. K., and ASSAEL, H., "National Survey of Transportation Attitudes and Behavior—Phase One Summary Report." *NCHRP Rep. 49* (1968) 71 pp.
120. MCMILLAN, R. K., and ASSAEL, H., "National Survey of Transportation Attitudes and Behavior—Phase II Analysis Report. *NCHRP Rep. 82* (1969) 89 pp.
121. MAIOLO, J. R. (ed.), *Highways and Communities.* The Pennsylvania State University, Institute for Research on Land and Water Resources (1966) 109 pp.
122. MAIOLO, J. R., and DANSEREAU, H. K., "Planning, Zoning, and Interchange Protection: A Report of Leadership Attitudes." *Res. Pub. No. 45,* The Pennsylvania State University, Institute for Research on Land and Water Resources (1967) 22 pp.
123. MALONEY, M. F., LINDBERG, H. A. L., CLEVEN, G. W., "A Solution to Intercity Traffic Corridor Problems?" *Public Roads,* Vol. 37, No. 5, pp. 173-183 (June 1973).
124. MASSACHUSETTS INSTITUTE OF TECHNOLOGY, *Economic Impact Study of Massachusetts Route 128.* Cambridge (1958).
125. MAUBART, J. K., "Engineering Guidelines for Highway Noise Shield Design." *J. Transp. Engineering,* Vol. 100, No. TE 4 (Nov. 1974).
126. MEYERSON, M., "Implications of Sociological Research For Urban Passenger Transportation Policy." *Hwy. Res. Board Proc.,* Vol. 34, pp. 1-7 (1955).
127. MILLER, D. R. (ed.), *Urban Transportation Factbook.* Barton-Aschman Associates (1974) Part I. 94 pp., Part II. 203 pp.
128. MILLER, G. K., and GOODMAN, K. M., *The Shirley Highway Express-Bus-on-Freeway Demonstration Project/First Year Results.* National Bureau of Standards, Technical Analysis Division (1972).
129. MILLS, C. W., *The Power Elite.* Oxford University Press (1959).
130. MOHRING, H., and HARWITZ, M., *Highway Benefits: An Analytical Framework.* Northwestern University Press, Evanston, Ill. (1962) 209 pp.
131. MOORE, C. T., MAYER, M. L., LIPSON, H. A. and JOYCE, G., "A Study of the Expected Economic and Social Impact of Interstate Highways in The Industrial and Commercial Trading Area of Birmingham, Alabama." *H.P.R. Rep. No. 38,* Alabama Highway Department (1964) 132 pp.
132. MOORE, C. T., MAYER, M. L., MASON, J. B., and DAWSON, L. E., JR., "Land Use Analysis and Consumer Household Shopping Travel Behavior in a Highway Corridor Area: Theoretical Framework, Summary, Findings, and Conclusions." *H.P.R. Rep. No. 31-A,* Alabama Highway Research Group (1968).
133. MORRIS, S. S., "Housing, Transportation, and Urban Planning—An Assessment of Some Major Metropolitan Problems." *Traffic Quarterly,* Vol. 25, No. 2, pp. 189-207 (Apr. 1971).
134. MORRIS, S. S., "Freeways and the Urban Traffic Problem." *Traffic Quarterly,* Vol. 27, No. 4, pp. 517-528 (Oct. 1973).
135. MUMFORD, L., *The Highway and the City.* Harcourt Brace Jovanovich, N.Y. (1953) 246 pp.
136. NASH, W. W., and Voss, J. R., "Analyzing the Socio-Economic Impacts of Urban Highways." *Hwy. Res. Board Bull. 268* (1960) pp. 80-94.
137. NATESS, C. B., "Travel in the Black Ghetto." *Hwy. Res. Rec. 403* (1972) pp. 49-50.
138. National Highway Users Conference, *The Highway Transportation Story in Facts* (1969) 42 pp.
139. NETHERTON, R. D., *Control of Highway Access.* Univ. of Wisconsin Press (1963) 514 pp.
140. "The New Urban Highway." Paper presented at the Annual Meeting of the Southeastern Association of State Highway Officials (Nov. 20, 1967).
141. NEWMAN, O., *Defensible Space.* Collier (1973) 264 pp.
142. NILLEY, W. E., "Priority Programming for Arizona Highways." *Traffic Quarterly,* Vol. 26, No. 3, pp. 425-434 (July 1972).
143. North American Congress on Latin America, "Who Rules Columbia." *The Triple Revolution Emerging Social Problems in Depth* by Robert Perrucci and Marc Pilisuk. Little, Brown, and Company (1971) 631 pp.
144. NUSBAUM, R. F., "Engineering Considerations." *Hwy. Res. Board Sp. Rep. 104* (1969) pp. 119-128.
145. OGLESBY, C. H., *Highway Engineering.* John Wiley & Sons. (1975) 783 pp.
146. OREGON STATE HIGHWAY DEPARTMENT, *Property Replacement Study—Effects on Property Owners Displaced by Freeway Construction* (1964).
147. O'ROURKE, B., "Travel In The Recreational Experi-

ence—A Literature Review." *J. Leisure Res.*, Vol. 6, No. 2, pp. 140-156 (Spring 1974).

148. PACKARD, V., *The Waste Makers.* McKay, N.Y. (1960).
149. PAIGE, J. H., "Comprehensive Planning for Highways: A Political Perspective." *Traffic Quarterly,* Vol. 28, No. 2, p. 310 (Apr. 1974).
150. PARK, R. E., *Society.* The Free Press, Glencoe, Ill. (1955).
151. PENNSYLVANIA DEPARTMENT OF TRANSPORTATION, *The Penn DOT Action Plan.* (1973).
152. PENNSYLVANIA STATE UNIVERSITY, Highway Impact Research Staff, "Blairsville: A Bypass Study—The Economic and Social Impact of a Highway." *Agricultural Economics and Rural Sociology Rep. No. 35,* University Park (1962) 69 pp.
153. PIKARSKY, M., "Joint Development Concept; Chicago Cross-Town Expressway." *Hwy. Res. Rec. 68.* NTIS Abstract, U.S. Department of Commerce (1974).
154. PUSHKAREV, B., "Highway Location as a Problem of Urban and Landscape Design." *Hwy. Res. Rec. 23* (1963) pp. 7-18.
155. RAINWATER, L., "Fear and the House-as-Haven in the Lower Class." *J. Am. Inst. Planners,* Vol. 32, pp. 23-37 (Jan. 1966).
156. RAPUANO, M., HALPRIN, L., KAVANAUGH, T. C., POWELL, H. R., ROCHE, K., ROCKWELL, M. L., SIMONDS, J. O., and SPRINGER, M. B., *The Freeway in the City.* U.S. Government Printing Office (1968) 141 pp.
157. REAL ESTATE RESEARCH CORPORATION, *Highway Networks as a Factor in the Selection of Commercial and Industrial Locations* (1958).
158. "Report on the ENO Foundation Conference." *Traffic Quarterly,* Vol. 27, No. 3, pp. 475-486 (July 1973).
159. RIEDESEL, G. A., SCOTT, D. M., PATTON, R., MATTHEWS, H. C., ABBOTT, H. T., VAN BLAADREN, A. N. M., WEAVER, N., and LOOK, J. C., *A Study of the Social, Economic, and Environmental Impact of Highway Transportation Facilities on Urban Communities.* Washington State University, Highway Research Section (1968) 208 pp.
160. RIGNANI ASSOCIATES, INC., *Draft Environmental/Section 4(f) Statement for Department of Transportation, Federal Highway Administration and the Pennsylvania Department of Transportation for Legislative Route 1061. Section 6, 7, 8, 9 and 10. Blair County, Pennsylvania.* Camp Hill, Pennsylvania (1973).
161. ROBINSON, J., *Highways and Our Environment.* McGraw Hill (1971) 340 pp.
162. ROSSI, P., *Why Families Move: A Study of the Social Psychology of Urban Residential Mobility.* The Free Press, N.Y. (1955).
163. ROTHMAN, R., "Access Versus Environment?" *Traffic Quarterly.* Vol. 27, No. 1, pp. 111-132 (Jan. 1973).
164. SAWHILL, R. B., "Freeways and Residential Neighborhoods." *Hwy. Res. Rec. 149.* (1966) p. 57.
165. SCHENKER, E., VARGHA, L. A., FAVILLE, H., GOLDSCHMIDT, C., LARSON, R., and PHILBRICK, A., *Economic and Social Effects of Highway Improvements: A Summary.* Michigan State University, Highway Traffic Center (1961).
166. SCHIMPELER, C. C., and GRECCO, W. L., "The Community-Systems Evaluation: An Approach Based on Community Structure and Values." *Hwy. Res. Rec. 238* (1968) pp. 123-152.
167. SEARS, B. G., "Highways on Environmental Elements." *Hwy. Res. Rec. 93.* (1965) pp. 49-53.
168. SEEL, M. C., "Historic Sites Study." *Hwy. Res. Rec. 246* (1968) pp. 16-35.
169. SEEMAN, I., "Easing the Effect on People of the Construction of the North Leg of the Inner Loop." Report of the National Capital Planning Commission by the Health and Welfare Council of the National Capital Area, Washington, D.C. (1963).
170. SHIVERS, J., and HJELTE, G., *Planning Recreational Places.* Fairleigh Dickinson University Press, Rutherford, N.J. (1971) 381 pp.
171. SMITH, J., "Scenic Driving—The Roadway and Its Association to the Scenic, Cultural and Historic Qualities of America." *Parks and Recreation,* Vol. III, No. 8, pp. 13-14 (Aug. 1968).
172. SOLOMON, D., "Environmental Research and Highways. *Public Roads,* Vol. 37, No. 8, pp. 297-305 (Mar. 1974).
173. SPEARE, A., JR., "Home Ownership, Life Cycle, and Residential Mobility." *Demography,* Vol. 7, No. 4, pp. 449-458 (1970).
174. STANSFIELD, C. A., "The Development of Modern Seaside Resorts." *Parks and Recreation,* Vol. 5, No. 10, pp. 14-17, 43-46 (Oct. 1970).
175. STEIN, M. M., "Transportation and Metropolitan Growth: A Case Study of Circumferential Highways on Intraregional Population Shifts." Paper presented at Meeting of the Western Regional Science Association (Feb. 1973).
176. STUART, D. G., "Coordinated Freeway Park Development." *Traffic Quarterly,* Vol. 21, No. 3, pp. 355-378 (July 1967).
177. STUART, D. G., Freeways, Parks and Parkways." *Traffic Quarterly,* Vol. 22, No. 1, pp. 129 (Jan. 1968).
178. STUART, D. G., "Multiple-Purpose Freeway Land Development." *Hwy. Res. Rec. 217* (1968) pp. 1-8.
179. SYKES, G. M., "The Differential Distribution of Community Knowledge." *Social Forces,* Vol. 4, No. 29, pp. 218-224 (1951).
180. TAEUBER, I. B., "The Changing Distribution of the Population in the United States in the Twentieth Century." *Population Distribution and Policy,* U.S. Commission on Population Growth and the American Future. U.S. Government Printing Office (1972) pp. 31-108.
181. TESKA, R. B., "Social, Economic, and Environmental Impacts of a System of High Accessibility Corridors." *Hwy. Res. Rec. 356* (1971) pp. 119-129.
182. THIEL, F. I., "Social Effects of Modern Highway Transportation." *Hwy. Res. Board Bull. 327* (1962) pp. 1-20.

183. THIEL, F. I., "Seminar on Sociological Effects of Highway Transportation: Introductory Remarks." *Hwy. Res. Rec. 75* (1965) pp. 75-76.
184. THIEL, F., and YASNOWSKY, J., "Some Effects of Highway Beautification." *Hwy. Res. Rec. 233* (1968) pp. 1-15.
185. THOMPSON, R. H., and ADKINS, W. G., "Some Economic Effects of the Suburban Portion of the North Central Expressway." *Bulletin No. 15,* Texas A&M University, Texas Transportation Institute (1961).
186. TOFFLER, A., *Future Shock.* Random House Inc. (1970).
187. TUNNARD, C., "Highway Scenic Potentials." *Hwy. Res. Rec. 182* (1967) pp. 1-4.
188. TUNNARD, C., and PUSHKAREV, B., *Man-Made American Chaos or Control?* Connecticut Printers, Inc., Hartford (1963) 479 pp.
189. U.S. CONGRESS, HOUSE OF REPRESENTATIVES, *Benefits of Interstate Highways.* No. 91-42, 91st. Congress, 2d. Sess. (1970).
190. U.S. DEPT. OF COMMERCE, BUREAU OF THE CENSUS, *U.S. Census of Population : 1970.* PHC (2) (1971).
191. U.S. DEPT. OF COMMERCE, BUREAU OF PUBLIC ROADS, *Highways and Economic and Social Changes* (1964) 219 pp.
192. U.S. DEPT. OF COMMERCE, *A Proposed Program for Scenic Roads and Parkways* (1966) 254 pp.
193. U.S. DEPT. OF THE INTERIOR, NATIONAL PARK SYSTEM, *Public Use of the National Park System, Fiscal Year Report, 1973.*
194. U.S. DEPT. OF TRANSPORTATION, *Fatal and Injury Accident Rates on Federal-Aid and Other Highway Systems* (1970).
195. U.S. DEPT. OF TRANSPORTATION, FEDERAL HIGHWAY ADMINISTRATION, *U.S.—17 Edenton Bypass, Chowan County, North Carolina* (Apr. 1971). NTIS Abstract, U.S. Department of Commerce (1974).
196. U.S. DEPT. OF TRANSPORTATION, FEDERAL HIGHWAY ADMINISTRATION, *Draft Environmental Impact Statement U.S. (31),* Montgomery, Ala. (Apr. 1971). NTIS Abstract. U.S. Department of Commerce (1974).
197. U.S. DEPT. OF TRANSPORTATION, FEDERAL HIGHWAY ADMINISTRATION, *Project I-80-1(10, Potter-Brownson, Cheyenne County Nebraska, Project S-921(3), Potter-South to I-80, Cheyenne County, Nebraska* (May 1971). NTIS Abstract. U.S. Department of Commerce (1974).
198. U.S. DEPT. OF TRANSPORTATION, FEDERAL HIGHWAY ADMINISTRATION, *Route 40, Sussex County, (Draft of Environmental Impact Statement),* Richmond, Va. (May 1971). NTIS Abstract. U.S. Department of Commerce (1974).
199. U.S. DEPT. OF TRANSPORTATION, FEDERAL HIGHWAY ADMINISTRATION, *Route 4 Freeway in the City of Stockton, Stanislaus Street to Wilson Way, California.* Sacramento, Calif. (May 1971). NTIS Abstract, U.S. Department of Commerce (1974).
200. U.S. DEPT. OF TRANSPORTATION, FEDERAL HIGHWAY ADMINISTRATION, *FAB 411, Vermilion County, Illinois.* Springfield, Ill. (Aug. 1971). NTIS Abstract, U.S. Department of Commerce (1974).
201. U.S. DEPT. OF TRANSPORTATION, FEDERAL HIGHWAY ADMINISTRATION, *The Proposed Freeway Development of Route 101 in the City of Santa Barbra, Between Salines Street and Carrillo Street, California.* Sacramento, Calif. (Sept. 1971). NTIS Abstract, U.S. Department of Commerce (1974).
202. U.S. DEPT. OF TRANSPORTATION, FEDERAL HIGHWAY ADMINISTRATION, *East-West Freeway, U.S. Highway 67, In San Angelo, Texas,* Austin, Texas (Sept. 1971). NTIS Abstract, U.S. Department of Commerce (1974).
203. U.S. DEPT. OF TRANSPORTATION, FEDERAL HIGHWAY ADMINISTRATION, *U.S. 131 Freeway M-46 North. Mecosta and Osceola Counties. Proposed Construction of the U.S. 131 Etc. Northerly to the Vicinity of Ashton. Draft Environmental Impact Statement.* Lansing: Mich. (1971).
204. U.S. DEPT. OF TRANSPORTATION, FEDERAL HIGHWAY ADMINISTRATION, *Interstate 90, West Shore Mercer Island To East-Channel Bridge. Draft Environmental Impact Statement.* Olympia, Wash. (1971).
205. U.S. DEPT. OF TRANSPORTATION, FEDERAL HIGHWAY ADMINISTRATION, *Economic and Social Effects of Highways* (1972) 373 pp.
206. U.S. DEPT. OF TRANSPORTATION, FEDERAL HIGHWAY ADMINISTRATION, *Social and Economic Effects of Highways* (1974) 180 pp.
207. U.S. DEPT. OF TRANSPORTATION, FEDERAL HIGHWAY ADMINISTRATION, *Freeways to Urban Development: A New Concept for Joint Development,* 8 pp.
208. UNIVERSITY OF CONNECTICUT, *The Economic and Social Effects of the Turnpike on Eastern Connecticut.* Storrs (1958).
209. UNIVERSITY OF VIRGINIA, Bureau of Population and Economic Research, *The Socio-Economic Impact of the Capitol Beltway on Northern Virginia.* Charlottesville, Va. (1968).
210. VEBLEN, T., *The Theory of the Leisure Class.* B. W. Huebsch, N.Y. (1919).
211. VOORHEES, A. M., "Techniques for Determining Community Values." *Hwy. Res. Rec. 102* (1965) pp. 11-18.
212. WACKS, M., HUDSON, B. M., and SCHAFER, J. L., "Integrating Localized and Systemwide Objectives in Transportation Planning." *Traffic Quarterly,* Vol. 28, No. 2, p. 163 (Apr. 1974).
213. WALSH, S. P., "Some Effects of Limited Access Highways on Adjacent Land Use." *Hwy. Res. Board Bull. 227* (1959) pp. 78-82.
214. WASHINGTON STATE PLANNING AND COMMUNITY AFFAIRS AGENCY, *Multi-Discipline Design Teams for Transportation Facilities* (1972) 65 pp.
215. WICKSTROM, G., "Defining Balanced Transportation—A Question of Opportunity." *Traffic Quarterly,* Vol. 25, No. 3, pp. 337-349 (July 1971).
216. WILBUR SMITH AND ASSOCIATES, *The Impact of Highways on Selected Public Services* (1960).
217. WILBUR SMITH AND ASSOCIATES, *Future Highways and Urban Growth.* New Haven, Conn. (1961).

218. WILBUR SMITH AND ASSOCIATES, *A Socioeconomic Study of Highway Development I-287, I-95 Corridor, Middlesex and Somerset Counties, New Jersey—1967* (1968) pp. 172 and appendix.
219. WINFREY, R., and ZELLNER, C., "Summary and Evaluation of Economic Consequences of Highway Improvements." *NCHRP Rep. 122* (1971) 324 pp.
220. WITHEFORD, D. K., "Highway Impacts on Downtown and Suburban Shopping." *Hwy. Res. Rec. 187* (1967) pp. 15-20.
221. WRIGHT, R., *Techniques for Incorporating Historical Preservation Objectives into the Highway Planning Process.* National Trust for Historic Preservation, U.S. Department of Transportation, Washington, D.C.
222. ZADROZNY, J. T., *Dictionary of Social Science.* Public Affairs Press, Washington, D.C. (1959) 367 pp.
223. ZULFACAR, A., and CLARK, C. S., "Highway Noise and Acoustical Buffer Zones. *J. Transp. Engineering,* Vol. 101, No. TE 1 (Feb. 1975).

APPENDIX C

ECONOMIC BENEFITS

The two previous appendixes of this report dealt with environmental and social effects of freeways. This appendix describes and elaborates on the economic effects. As in the previous appendixes, the effects will be discussed in the order in which they appear in the beneficial effects (see Chap. Three). Prior to this discussion, however, a general but brief description of the concepts and theory associated with economic impact appears desirable. It is hoped that from such a discussion the users of this report might avoid some of the confusion that pervades much of the literature on economic impacts.

Highway improvements, in the form either of a new highway or of the upgrading of an existing one, unquestionably generate changes in the function of an economy. To some extent, the welfare and/or income position of some individuals and/or firms will be altered. Economic effects can be beneficial (positive), where travel time and costs are reduced or land values rise; or they can be adverse (negative), where land values decrease or congestion on feeder roads increase. Rarely is an economic impact clearly all beneficial or all harmful within a community. The more usual case is that some people or firms in the community gain, but other people or firms experience added costs. For this reason, it is important to identify, where possible, the incidence of a given economic impact; that is, who or what groups in society realize the gains and who or what groups bear the costs. For example, a new highway might generate a dramatic increase in land values near interchange sites, but at the same time values may be lowered for tracts abutting the highway but without ready access to it. A new urban expressway may reduce travel time and costs for higher income commuting suburbanites, but at the expense of more noise and air pollutants for central city residents, some of whom are very likely to be in lower income classes and not users of the highway.

In the portions of this section in which the specific economic benefits are discussed, attempts are made to identify the principal groups or classes of people who are apt to be the gainers or losers from highway improvements. This is done primarily for the most significant benefits. However, for the benefits of lesser relative importance, such identification is readily apparent from the discussion and is not done explicitly in the text. But even for the major benefits, identification of all gainers and all losers is not carried out in detail or in depth. To do this would make the report too cumbersome, since the effects from highway improvements indirectly spill over to most all segments of society in one form or another. The incidence of public investments is of utmost importance, but is an area of concern for which a treatment in depth would be far too lengthy to incorporate in this volume.

Economic impacts from highway improvements may or may not be measurable. Of those that are measurable, some are relatively easy to quantify; for example, the saving in vehicle operating costs as a result of reduced travel distance and/or time. Others are considerably more difficult to quantify, as, for example, the increase or decrease in land values near a highway. Because there are many interacting factors influencing the value of land in a community, it is extremely difficult in the real world to isolate the influence of only one variable, such as a new highway. Other beneficial highway effects cannot be objectively measured at all; for example, the value of a scenic vista that is opened to the motorist's view by a new highway.

There are still other effects, because of their pervasive and complicated relationship with many factors, that cannot be clearly defined and measured. For example, a highly productive economic system taking advantage of technological innovations and characterized by growing real per capita incomes cannot come about or maintain itself in the absence of an efficient transportation system that constantly expands to meet the needs of growth. The unique contribution of a new highway to such a system cannot be measured satisfactorily. The monetary value of the contribution of the highway system to economic development in this country has been immense, but it would be fruitless to attempt to measure it. An important point to be made, however, is that the inability to objectively measure certain highway benefits is not a reason to exclude them from consideration.

Measuring benefits from highway investments is not straightforward even where such measurement is theoretically possible. The process of measurement is one confronted with many difficulties. Excellent discussions of the theory of highway benefits and of the conceptual difficulties encountered in their measurement are provided by Garrison et al. (*44*), Lang and Wohl (*67*), and Mohring and Harwitz (*88*). Of utmost importance is a clear distinction between *gross* benefits and *net* benefits. Failure to distinguish clearly between such benefits has led in the past to erroneous statements as to the magnitudes of benefits that have been measured.

Much of the literature on the subject makes a distinction between highway user and nonuser benefits. Highway user benefits are largely in the form of travel time savings; reductions in operating costs; and reduced losses from accidents, injuries, and death. User benefits accrue to firms as well as to individuals. A transportation intensive firm may locate near a highway improvement in order to improve its accessibility to factor and/or product markets, and thus to reduce costs.

Highway nonuser benefits accrue to individuals and firms whose gains are a result of the highway, but not from a direct use of the highway. These benefits are indirect in nature, and generally come about because of a transfer of user benefits to others in the community. Residents in a community may benefit from commodity prices being lower than they would have been in the absence of the highway improvement, reflecting lower transportation costs to distributors and retailers. Travelers and pedestrians on downtown streets may benefit from less congestion following the construction of a bypass. Owners of land in close proximity to a new highway may realize significant increases in land values because of improved accessibility, even though they may not be users of the highway.

It is quite apparent that many individuals in a community receive at the same time both user and nonuser benefits. Most of the user (direct) benefits are easily identified and relatively simple to measure, although there is still considerable conceptual and empirical difficulty in measuring the value of travel time savings (see *88*). It is much more difficult to identify and measure the nonuser (indirect) benefits.

Very important problems arise when attempts are made to aggregate economic benefits. When aggregating benefits to estimate the net benefits of a highway improvement, the degree of exclusivity of the different benefits should be determined to avoid the double counting of benefits. The distinction between highway users and nonusers has frequently resulted in overstating the net benefits because many of the direct user benefits are transferred to nonusers. Thus, it is not correct to aggregate user and nonuser benefits because double counting will result. A more complete discussion of this important concept is warranted.

Highway investments result in improving the accessibility of certain tracts of land. The demand for these tracts by business firms and individuals increases because of lower transportation costs for either their customers or for themselves. In a competitive land market, this increased demand leads to higher prices because of a shift of the traditional downward sloped demand curve to the right. In this way, savings in travel costs (direct, or user benefits) get capitalized into higher land values. The user benefit of lower transportation costs is transferred to those individuals who owned the land before the highway improvement was made. Because initial ownership of property may not be connected in any way to highway use, it can be considered as a nonuser highway benefit. Thus, there has been a partial or complete transfer from the buyer to the seller of the benefits the buyer will receive from improved accessibility (lower costs). Land value changes and the highway benefits (reduced transportation costs) underlying them cannot be aggregated to determine net benefits; this would involve double counting. The benefit may be measured where it arises or after it is transferred, but such benefits cannot be combined.

User benefits can be transferred in ways other than through increases in land values. A transportation intensive firm may realize production cost savings either through lower costs for its inputs (reflecting lower delivery costs) or lower shipping costs for its product to markets. Such cost savings may be passed on to the consumer through lower retail prices. If not passed along to the consumer, the firm will realize an increase in its capital values or in its profits over what they would have been in the absence of the highway improvement. As in the previous example, double counting of highway benefits would result if both transportation cost savings to the firm and consumer expenditure savings were combined.

In a rigorous theoretical discussion of highway benefits, Mohring and Harwitz (*88*) distinguish between two kinds of user benefits. The first kind, representing "benefit of existing use," is the reduction in transportation costs that accrue to the highway transportation that takes place before and after the improvement of the highway network is made. The second kind of benefit is called substitution benefits, and arises from the "substitution of highway for other forms of transportation, the substitution of highway intensive for other types of consumer goods, or the substitution of transportation intensive for other means of production" (*88*, p. 53). Substitution benefits, for example, arise from a business firm responding to highway transportation cost reductions by reorganizing its production and distribution activities in a more economical fashion. Under purely competitive factor and product markets, and where only a relatively small proportion of the average consumer's income is spent for highway transportation, highway cost and use data would provide reasonable estimates of the two user benefits previously described.

Mohring and Harwitz also enumerate two kinds of nonuser, or indirect, benefits, which they broadly categorize as income generating benefits. The first includes benefits arising out of increases in the productive capacity of the economy associated with highway investment. Highway improvements, by a reduction of the resources required in moving goods and people and shortening travel time, release resources that in a fully employed economy would be used to increase economic output. This output can be in the form of additional consumer goods and services including transportation. The measure of these highway investment benefits becomes the same as the measure for any public or private investment. This measure is the

opportunity cost of the resources released in alternative forms of employment. Proper measurement of user benefits will have already accounted for benefits of this type.

The second type of income generating benefit deals with "investment triggering" or industrial development benefits. Many studies have documented the rapid growth that follows new highway developments in some regions through which they pass. There can be no doubt that highways have played a very significant role in the location decisions of many firms and individuals. But extreme caution must be observed in claiming development or growth benefits as a result of highway investments, especially in terms of full or nearly full employment. One must first ask the question: What would have been the location and extent of growth in the absence of the highway improvement? Considerations of such a question should quickly point to the likelihood that, for society as a whole, only a relatively small portion of the growth observed around new highways can be claimed as a net benefit from the highway.

When considering net highway benefits to society as a whole, interregional effects must be accounted for, not just local or community effects. Highways do play an important role in the location decisions of many firms, but this is not the same as saying that the highway investment was responsible for the *existence* of the firm. In most cases, the firm would have located in some other community or region in the absence of the highway under consideration. To this extent, the highway merely caused a transfer of activity from one location to another. For example, shopping centers are becoming a common sight at major highway interchanges in many suburban areas. But the growth of retailing activities at such locations has largely been at the expense of retailing in the center city locations—again a transfer from one region or community to another.

In cases where a new industrial plant or new commercial business establishment does locate near a highway, and clearly there is no shift or transfer involved from another region, the net highway benefit is still not necessarily the increase in assets represented by the new firm. The capital, labor, and land resources employed by the firm, in most cases, would be employed in some alternative fashion. For example, the land probably would have remained in its prehighway use, such as agriculture, and the labor employed in the way it was previously, although returns in both cases would probably have been less, especially for the land. The net benefits of industrial development that can be attributable to highway improvements, then, become the difference in returns to resources employed in the absence of the highway improvement. Mohring and Harwitz (*88* p. 55) are somewhat more explicit on this point and list three conditions that must be fulfilled in order for net industrial development benefits to arise as a result of highway improvements: "(1) the specific investment would have been made in the absence of the highway improvement; (2) it utilizes resources that otherwise would have remained unemployed; and (3) it does not displace economic activity that otherwise would have taken place."

The criteria set forth by these authors for the determination of net highway benefits from industrial development are more restrictive than the "opportunity earnings" approach suggested by this report. In most cases, the Mohring and Harwitz approach will underestimate the actual net benefits, since rarely would all unemployed resources remain unemployed in the absence of highway development.

Both Mohring and Harwitz (*88*) and Land and Wohl (*67*) reach the conclusion that net economic benefits of highway improvement are the aggregate of all user benefits. In other words, there are no net nonuser benefits over and above the user benefits. This in no way implies that nonusers receive no benefits from highway improvements. On the contrary, their benefits are very large, but occur primarily as a result of transfer from the highway users. The precautionary point to emphasize again is that when tallying highway benefits a clear distinction must be made between user and nonuser benefits in order to avoid double counting. Mohring and Harwitz (*88*, p. 56) address this point succinctly: "where one draws the line between the user and the non-user benefits of highway investments is largely a matter of definition. If the origin of benefits is the basis of differentiation decided upon, most if not all of highway benefits must necessarily be placed in the user category. If, on the other hand, the differentiation is made on the basis of ultimate recipient, many if not all highway benefits are in the 'non-user' category."

No attempt can be made in this report to determine the net economic benefits from highway improvements. The purpose of this section of the report is to identify for highway planners and other highway personnel all possible highway economic benefits, both user and nonuser. Since many user and nonuser benefits accrue to the same individuals in a community (that is, there is a great deal of overlap when viewing benefits from the standpoint of the recipient), this categorization of benefits was deemed too confusing for purposes of the matrix or outline. Stated another way, most of the direct economic benefits are in the form of savings from reduced travel time and costs, but these get transferred and subsequently translated into many different kinds of indirect benefits. It is very important that these indirect benefits get explicitly identified and discussed. Consequently, the information provided hereafter is in no way to be construed as implying *net* economic benefits. This report identifies and discusses *all* benefits, with no attempt at aggregation. Users of the report are urged to keep this point continually in mind.

EXPLANATION OF TERMS

As with the environmental and the social benefits, the economic benefits are described in the matrix as being direct or indirect, urban or rural, and short run or long run. A brief explanation of how these descriptions apply to economic benefits is necessary.

A user and nonuser classification approach is used in portions of the environmental and social sections, but is not used as a principal classification system in the economics section, despite its wide application in the economic effects literature. The researchers felt that the system used in this document was better able to accommodate all the possible economic benefits and with a minimum of confusion.

The direct-indirect classification is determined primarily in terms of the recipient of the effect. Direct effects are viewed as those falling primarily on highway users, whether they be individual motorists, highway-oriented business establishments (such as gas stations and motels), or highway transportation intensive firms. The principal forms of direct benefits are increased sales; savings in travel costs and time; reduced losses from accidents, injuries and deaths; and greater comfort and pleasure.

Indirect economic benefits are largely those associated with highway nonusers, and arise as a result of the transfer of user benefits to others in society. With indirect benefits, there is a disassociation between highway use and the receiving of a benefit. In other words, the recipient of an indirect benefit would have received it whether or not he used the highway. Most people in society benefit both directly and indirectly from highways; that is, they are both highway users and nonusers when considered as benefit recipients. Lower prices for consumer goods, higher land values, and less congestion on local streets are a few examples of indirect highway benefits.

No objective criteria can be set forth for delineating effects as being urban or rural. There exists a great amount of inconsistency in the literature on highway effects when it comes to delineating urban and rural areas. Therefore, when referring to specific studies, the interpretation of urban and rural as used by the different authors will be followed. Within the context of economic benefits from highways, the urban-rural dichotomy probably has less relevance and meaning than when considering the environmental or social benefits. Most of the economic benefits that accrue from highway development will be applicable in both urban and rural areas, although not necessarily to the same extent. Because of the more complicated economic structure of urban regions (greater agglomerations and linkages, as well as more economic units), the highway benefits will tend to be more widely distributed in these areas as compared to rural areas, and there may be some income distributional differences also.

The distinction between short-run and long-run economic benefits is made on the basis of the duration of the effect, rather than on the more traditional economic criteria, which view time in terms of technological innovations resulting in change to the production function. Thus, time is the determinant rather than change in capital inputs. An economic benefit from highway improvements that is only transitory in nature is considered short run—for example, travel time savings for a motorist and his family visiting relatives or friends or taking a vacation trip. Short-run benefits remain with the recipient (improve his income or welfare) for only a short duration, perhaps hours, days, or a few weeks. Long-run benefits, on the other hand, persist with the recipient for much longer periods, even years or decades.

It is not useful to think of the short-run and long-run dichotomy in terms of *when* the effect is felt as a result of highway use. Some effects could be felt immediately on highway use, or there could be a considerable time delay between generation of the effect and when a particular recipient felt its impact. Both short- and long-run effects could be conveyed immediately or could be considerably delayed. Moreover, there is no particular relationship between the direct and indirect and the short- and long-run categorizations.

The same effect can be both short run and long run, depending on the recipient. The owner of a residential tract near a highway interchange enjoys a long-run benefit from the increase in land values, even though he should later sell the land and move from the community. The new owner of the house, who commutes daily on the highway, has, through his purchase, transferred his future time- and cost-reduction benefits to the seller, and consequently receives only immediate short-run benefits for each occasion of highway use.

CLASSIFICATION

A detailed and exhaustive literature search yielded a wide variety of economic benefits originating from highway improvements. The outline of benefits used in this report, therefore, was structured to reflect this great diversity. Because of the manner in which the effects are outlined, they cannot be considered as additive, otherwise, as pointed out earlier, double counting or overestimation of benefits would result. All the benefits outlined and discussed may not occur within any specific highway community, even over time.

The economic benefits are divided into six major groupings, each group representing distinct kinds of benefits. Within each major group, the benefits are further subdivided into subgroups.

The first major classification of highway-generated economic benefits is concerned with economic growth and development. Within this group, improved accessibility arising from locational advantages with respect to other economic activities or land uses results in reduced travel time and costs for both the movement of goods and people (first subgroup). These are the primary direct user benefits, which, in part, get transferred to others in the region.

Within a regional context, a highway improvement is likely to attract new business firms to a communty. These firms may have merely shifted location to take advantage of highway benefits, or they may represent new investments of capital; but, for the region, they provide income, employment, and expanded output (second subgroup). As the community grows, economies of scale and agglomeration economies are likely to arise, further stimulating economic growth (third subgroup).

A great deal of literature in the highway economics field deals with the special cases of interchange development and joint development, and for this reason these categories of development are treated as subgroups under economic growth and development.

The second major classification of benefits has to do with the increase in land values near highways. Although land values increase primarily as a result of improved accessibility, the benefits are distinct, important, and dealt with widely in the literature. Improved accessibility, which really comes about because of reduced travel time and costs, gives rise to many indirect and long-run benefits. Because this report presents and discusses all benefits, regardless of their original or their ultimate recipients after

transferal through the economic system, the reader is again cautioned not to consider the benefits as being additive.

The third major classification discusses benefits arising as a result of improved health and safety aspects of highway improvements, and includes such details as reduced losses from accidents and injuries and the barriers highways create to fire and other hazards.

The fourth category of effects is related to the operational aspects of highways and includes reduced congestion, effects on local street maintenance and repair, bypass and relocation effects, and energy savings.

The fifth major classification of economic effects reflects the improved efficiency in public and private services afforded by highway improvements. Included are such particulars as public transit, health and emergency services delivery, education, civil defense, major disaster relief, and others.

The sixth and last category is not a major one in terms of magnitude of economic effects, but, because of its nature, it cannot be logically classified in any of the previous groups. It is called resource substitution, and relates to the use of materials in highway construction that would otherwise be of little or no value, such as demolition, mining, and other solid wastes, thus freeing more valuable resources (and space that would otherwise be required for their disposal) for alternative uses.

There is an abundant and wide variety of literature dealing broadly with the economic benefits from highways. Some of this literature is very general and nontechnical in nature and provides the reader primarily with a narrative type discussion of benefits (for example, see *122*). For the person only marginally familiar with the field, but who wishes to get into considerable depth, there are a number of excellent publications available. The Federal Highway Administration in 1970 published a document on the benefits of Interstate highways that not only classifies benefits and describes them, but also presents the findings of studies dealing with many of the benefits (*114*). After studying this document carefully, the reader should have a good basic understanding of highway economic benefits and their many complexities.

Other publications providing good background information on economic benefits are the AASHO publication (*3*) on user benefits, which also presents ways of measuring some kinds of benefits, and Burton's (*17*) classification of economic advantages of the highway systems of Virginia. Publications that get into a more technical discussion of highway benefits and costs, and also present classification systems for highway effects, include Weiner and Deak (*120*) and Manheim et al. (*81*).

The concern over environmental effects of highways and the requirement of environmental impact statements for all federally funded projects have stimulated some good articles that deal effectively with benefits. Among these are Allen (*2*) in 1974 and Graff (*45*) in 1971.

For the reader interested in the highly technical treatment of the theory of economic benefits from highways, several publications are strongly recommended. The book by Mohring and Harwitz (*88*), published in 1962, has become a landmark in this area. Many of the important concepts and empirical findings of this work are summarized in a chapter prepared by Mohring for Dorfman's classic (*87*), which appeared in 1964. Another classical work of this type is the book by Garrison et al. (*44*) in 1959.

The Federal Highway Administration, the Transportation Research Board (formerly Highway Research Board), and the National Cooperative Highway Research Program have all published significantly important documents relating to highway benefits. Two publications by the Federal Highway Administration (*115* in 1972, *116* in 1974) discuss many kinds of economic benefits and present supporting data and information from past studies. They also summarize relevant studies recently completed in the various states. Both publications are valuable for source and reference materials.

The Highway Research Board in 1959 and 1960 published two documents (*53, 54*) that contain much valuable information on economic effects, some of which are quite technical. Of particular value in the latter is an article by Lang and Wohl (*67*) on the evaluation of highway impact.

NCHRP Report 18 (see *62*) provides "a state-of-the-art appraisal of studies conducted throughout the United States concerning the economic impact of the construction of various types of freeway facilities." The types of highways analyzed are bypasses, urban circumferentials, and urban radial freeways.

The *NCHRP Report 122* (see *128*) covers the whole field of economic analysis as applied to highway evaluation, but is particularly useful for the theory related to user and nonuser consequences. Both adverse and beneficial impacts are discussed in depth. A particularly useful table of social and economic consequences is provided on pages 116 and 117. An earlier work by Winfrey (*127*) in 1969, is an excellent reference source for basic economic principles and the concepts of engineering economy as applied to highways. It also contains much useful data on many aspects of highway benefits.

A. Economic Growth and Development

1. *Accessibility*

Improved accessibility is the single most important economic benefit arising from highway development. It is primarily a direct highway user benefit. Stated simply, improved accessibility means that the costs involved in travelling from one location to another have been reduced. These reductions in costs come about through a reduction in travel time (which in itself has monetary value to people) and/or vehicle operating costs. Both individuals and firms realize the benefits from improved accessibility. For the commuter, it means more time to spend, either on the job or at nonwork activities, as well as possible operating cost savings. For the firm, it means lower transportation costs, quicker delivery of products to consumers, quicker delivery of needed factor inputs, or, for the highway-oriented retail establishment, a heavier flow of customers.

Time and operating cost savings free resources that can be used to increase productivity in a variety of ways. For example, when firms pass their transportation cost savings on to consumers in the form of lower prices for goods and

services, purchasing power is increased. There can be no doubt that a modern and highly efficient highway transportation system has, through the release of large amounts of resources, stimulated a great deal of economic development.

Highways, by altering the relative accessibility of different locations, play a significant role in the location decisions of firms and individuals. Transportation intensive firms and businesses catering heavily to highway users seek land near major highways with ready access to them. Many housing developments are located to take advantage of the accessibility provided by major highways to jobs, shopping, and other household travel needs. For the community through which a new highway improvement passes, the impetus for economic growth and development as a result of better accessibility is apt to be great. Any such community growth, however, must be considered within the context of the larger regional economy or even the national economy. If community growth reflects primarily a relocation of economic activity from some other region, then the net economic benefits on a broad regional or national basis are much less than the benefits to the community itself. For example, a retail store moving from a central city location to a suburban shopping center represents basically a shift in benefits from one community to another. The suburban community gains, but at some cost to the central city. In many cases, such a move may represent some net gain to the region as a whole, but this gain will be much less than the gain to the community receiving the relocated activity.

Shifts in economic activity occasioned by changes in accessibility can encompass rather large regions. The construction of I-80 through Central Pennsylvania resulted in a shift of a considerable amount of traffic from the Pennsylvania Turnpike and other major highways in the State. The authors are very familiar with these routes, and it is their observation that the truck stops, motels, gas stations, restaurants, and other highway-traveler-oriented businesses that sprung up around many interchanges on I-80 did so, at least to some extent, at the expense of similar enterprises along the other routes.

Improved accessibility may be reflected in one or more of several ways by the behavior of the highway user. First, the trip itself may not involve any change other than driving over the improved route, or there may be a shift from an old route to a newer route. Second, there may be a shift in travel modes; for example, from rail to auto. Thirdly, there may be a shift in travel patterns, such as from old to new shopping areas. Fourth, there may be additional trips undertaken by users because of the improved ease of access. This latter is often referred to as an induced demand. A good theoretical presentation of induced demand benefits is provided by Klein et al. (*66*).

There have been various attempts at measuring accessibility, and these usually take the form of accessibility indexes, graphs of various kinds, and isochronal maps. Most accessibility indexes originate from a gravity or entropy type of model, and are generally in the form:

$$A_{ij} = \alpha_j F_{ij} K_{ij}$$

where:

A_{ij} = accessibility of zone j to zone i;
α_j = some measure of attractiveness of zone j;
F_{ij} = a friction factor between zones based on travel costs; and
K_{ij} = adjustment factor between zones.

A most useful accessibility index is one developed by the Washington, D.C., Council of Governments. This index, for any given location, represents the percentage of total employment in the Washington, D.C., area that can be reached from that location within a travel time of 45 min. An index number is constructed for the population centroid of each small area, similar in size to a census tract (these numbers are not published, but may be obtained from the Council). A more detailed description of accessibility indexes is found in Klein et al. (*66*, Appendix A).

The beneficial effects emanating from improved accessibility are also reflected in many indirect ways throughout a community. There are increases in production, employment, and income within the community as a result of locational advantages to industrial and commercial activities. There may be improvements in the delivery of many kinds of public and private services. And increases in land values generally arise. These beneficial effects will be discussed separately and in greater depth in subsequent sections of this appendix. Within this section, the following direct or immediate benefits from greater accessibility are discussed: locational advantages and the reduction of travel time and vehicle operating costs for the movement of goods and people.

a. *Locational Advantages.*—Highway transportation has become the dominant form of intraregional transport, and for some kinds of goods (high value relative to weight or bulk) the dominant form of interregional transport as well. For this reason, sites with a high degree of accessibility to a modern highway network are highly desired locations for industry, commerce, and residences.

The fact that highways have influenced the location decisions of many firms is readily apparent in the developments that can be observed around interchange sites, on feeder (access) roads to major highways, or even along the highways themselves away from the immediate vicinity of interchanges. However, the gains to communities receiving firms who shift location to take advantage of highway improvements must be balanced against the adverse impact on the communities losing these firms. If the employees do not move with the firm, there will be expanded job opportunities in the "new" community but less employment in the "old." Other businesses that previously served the firm in the old community may also suffer as a result of the firm's moving, but similar firms may gain in the new community.

Wilbur Smith and Associates (*124*) interviewed 59 firms in the I-287 and I-95 corridors in New Jersey and found that proximity to I-287 was mentioned most frequently as the reason for site selection. In a similar study of 73 manufacturing, distribution, and R&D establishments around the Capital Beltway in Maryland, Wilbur Smith and Associates (*123*) reported that 33 percent of the firms responding cited the beltway as a factor in locational

decisions. Connally (*25*) in her study of the impact of the Capital Beltway in Northern Virginia reported that proximity to highways was the reason most frequently given by 54 firms in their siting decisions. Moore et al. (*89*) surveyed 52 commercial business establishments in Alabama and, of 10 dominant location factors, 5 were directly related to highways.

Major highway locations, besides providing better accessibility for customers, employees, and suppliers, also benefit firms by giving them better exposure or advertising prominence. This benefit is discussed in greater depth in publications by the Federal Highway Administration (*114, 115, 116*). For some kinds of activities, such as hospitals and schools, it would seem that, because of the disturbing influence of noise, highway locations would not be desirable. However, it was reported (*116*) that, in a study of 13 hospitals next to freeways, the installation of proper safeguards (air conditioning, double pane windows) reduced freeway noise to levels lower than internal hospital noise. Hospital administrators were unanimous in their opinion that accessibility benefits from the freeway outweighed the freeway disbenefits.

b. *Reduction of Travel Time and Operating Costs.*— Savings in travel time and reduced vehicle operating costs are among the more readily measured benefits from highway improvements. Such benefits are realized by all highway users, individual motorists as well as all types of businesses involved in the movement of goods. But even in this area there are both conceptual and empirical difficulties. These cannot all be discussed here, but among the conceptual problems are those related to trip generation and origin-destination determinants, both of which are necessary for understanding and defining induced demand, and monetizing the value of time (opportunity costs of time). One of the more serious shortcomings of empirically determining travel time and cost savings is the lack of data on freight movements.

Reduction of vehicle operating costs is a direct short-run benefit to highway users and is realized at the time of operation. Such savings accrue to the individual motorist as well as to the shipper of goods and are achieved through better highway design, enabling users to maintain more even driving speeds and, in some cases, to reach destinations by a shorter route than formerly. Elimination of intersections and direct highway access from adjacent property, and reduction in highway grade and radius of turns, are the principal ways by which speed changes and stops are reduced. In urban areas where congestion is more of a problem, multilane highways are able to handle a larger volume of traffic at any one time, reducing slowdowns or stops resulting from overloaded roadways. Travel cost savings of goods movements in many cases will get passed along to consumers in the form of lower product prices. However, some kinds of firms in noncompetitive market situations may not pass along such savings.

NCHRP Report 122 (see *127*) contains an excellent and detailed discussion of vehicle operating costs—fuel and engine oil consumption, tire wear, vehicle maintenance and repair, and vehicle depreciation costs as related to highway use.

Besides reducing vehicle operating costs, modern highways have also reduced the time it takes to drive between locations. This is made possible by increasing legal speed limits, reduction of impediments to the smooth flow of traffic, and in some cases shortening the trip distance. There is also an important psychological aspect to travel time savings that may be more important to the motorists' satisfaction than the actual dollar value. Motorists usually select the quickest route between two locations, even though distance may be somewhat greater; and observation of drivers shows that they are dissatisfied with slowdowns, stops, and delays.

Some of the early travel time saving studies compared what people paid to use a toll bridge or highway rather than to use a toll free route. Work by Claffey (*22*) results in a value of $1.42/hr for a passenger car and its occupants in driving intercity trips. In a later study, Thomas (*109*) examined urban commuter travel at peak hours using a mathematical model much improved over that used by Claffey. His results showed a value for travel time of about $2.80/person/hr for trips of greater than 10 min or 5 mi.

NCHRP Report 122 presents tables showing the value of travel time of intercity cargo vehicles by type of vehicle and by regions of the country for 1965. Value of time savings per hour ranged from about $4.00 for small commercial vehicles to about $8.00 for large trucks. This refernce (*127*) also contains a good discussion of travel time and its value.

Lisco's paper (*75*) on the economics of travel time is another good reference on this topic. He presents conceptual problems in travel time valuation and problems in determination of travel time value, and suggests some general modeling approaches. In an earlier 1967 study in Chicago, Lisco (*74*) found that people who drive downtown were willing to pay $0.30/block or $0.12/min to avoid extra walking.

Lisco's study also arrived at a value of about $2.50/hr/person for those driving an automobile on the basis of comparative time and travel costs for riding rapid transit into Chicago's Loop. This value compares quite closely to the $2.80 arrived at by Thomas in his study published the same year.

The Federal Highway Administration reported in 1970 (*114*) that an average 10 percent reduction in travel time between cities has been accomplished by the Interstate Highway Program. "If the travel on the Interstate system were to be held throughout the program to the lower speeds prevailing on the routes which the completed sections replaced, the added travel time would cost $212 billion at $1.50 per man hour for passenger car occupants and $5.56 per vehicle hour for commercial vehicles" (*114*, p. 3).

Highway ton-miles of freight have increased by over 60 percent between 1958 and 1968 (*114*). In 1969, 35,000 communities were dependent on truck delivery for all consumer goods (*93*). In that same year it was reported that 75 percent of all farm products move to market by truck, including 55 billion quarts of milk (*93*). When one considers the tremendous volume of truck shipments, together with the fact that the cost of one stop and return to speed for a 20-ton truck is $0.20, the savings in freight

goods movement as a result of highway improvements becomes immense.

Hall, Sawhill, and Matteson (*47*) made a study of user benefits on the Seattle, Washington Freeway for the purpose of simplifying the data requirements and the methods of calculating travel time savings. Other studies reporting on travel time savings are Refs. (*73*) and (*89*). Many illustrations and data on travel time savings are contained in Ref. (*9*).

There are a number of secondary benefits that arise directly from travel time savings and a reduction of vehicle operating costs. For some businesses, the assurance of more frequent truck deliveries can mean smaller inventories. For retail food stores, it can mean fresher produce.

Although highway developments often have been cited as causing the shift of retailing activity from central city to suburban locations, this has not been the case for all kinds of retailing. Freeways have increased accessibility to downtown areas and improved the efficiency of the central business district, favoring the kinds of specialized retail activities that still find such locations advantageous (*7, 92*).

2. *Employment, Income, and Production*

To the community through which a new highway improvement is made, the impetus to economic growth and development can be momentous. For many rural communities near interchanges along major Interstate highways, the rapid growth of gas stations, truck service stops, motels, restaurants, and other commercial activities serving primarily the needs of motorists has been phenomenal. In addition, many kinds of industries have sought such locations if a local labor market exists. In communities within reasonable commuting time of major urban areas, housing developments must be added to the list of new or expanded land uses near interchange sites. Because much of the highway literature reports on studies of interchange growth and development, this will be treated separately in a later section. This section will deal with the growth of income, employment, and production in a general way.

Nationally, the motor vehicle and the highways which serve it account for about one out of every 5 jobs. In 1968, this meant about 14 million workers (*93*). In that year, Americans spent about $90 billion to buy, operate, and maintain their vehicles, of which $24 billion alone was in service station business. In 1968 the average American consumer spent about $0.11 out of every dollar for things automotive. In 28 states, recreation or vacation travel is one of three most important sources of income.

The foregoing figures should not be interpreted as *net* contributions to national income. Obviously, expenditures would have to be made for alternative means of moving goods and people if highways were not available. But they do indicate the extent to which resources are being devoted to highway transportation. By the same token, an interchange community's gains in employment and income, although important and real to that community, must be netted out when considering the broader region, for they may represent in part only relocational effects in over-all economic activity (see *52*).

An important benefit may arise, however, from relocation or shifting of economic activity from one location or region to another. The disparity of per capita incomes between regions can be reduced. The principal thrust of the Appalachian Regional Development Act has been towards highway development to spur economic growth and development in this depressed region. To the extent that highways stimulate economic activity in depressed rural areas and thus reduce the incidence of poverty, real economic and social gains are possible (see *126*).

Caution must be exercised when attributing regional and community gains in employment and income to highway development. Thiel (*107*) points out that highways can serve as an accelerator of change that would occur later in the absence of the highway. When evaluating highway impact, one should always attempt to compare the highway development effects to the conditions that would likely exist in the absence of the highway improvement. This is the "with and without" approach in assessing change. In rural communities, an indirect effect of highway development may be to provide more off-farm employment, thus hastening a consolidation of farm units. Increases in labor and capital productivity in agriculture, as a result of technological developments, have greatly transformed American farm units; and this trend is likely to continue, but, in some rural areas, highway development may accelerate this trend. Other indirect effects that may be accelerated by highway development, as discussed by Thiel, include suburban movement, school and church consolidation, improved public services, better opportunities for nonwork activities, and upgrading of residential properties through urban slum removal.

Two documents prepared by the Federal Highway Administration, one in 1970 (*114*) and the other in 1972 (*115*), discuss in general and also present specific findings relating highway development to increases in employment, income, and production. Garrison and Marks (*43*) summarized and provided geographic illustrations of a number of older studies addressing these benefits.

One study of significance, that by Walton (*118*), examined the benefits from highway investment in the State of Virginia. He reported that construction of the Interstate System in Virginia during the period 1961-1968 has served as a catalyst to:

1. Create 22,700 more manufacturing jobs.
2. Contribute 69,475 more jobs in nonmanufacturing sectors.
3. Generate about $2.9 billion in additional personal income.
4. Stimulate about $2.8 billion in private capital investment from 1964-1968.
5. Contribute to the general economy of Virginia an amount equal to the total highway investment plus 6 percent interest compounded annually over six and one-quarter years.
6. Provide, from the nearly $1.3 billion spent in the 1961-1968 time period on construction and maintenance of the Interstate System, an estimated annual net return on investment of 16.25 percent.

Walton claims his figures are measures of the net effects, but admits that losses to businesses hurt or displaced were not considered. His figures, therefore, are not true estimates of the net economic gains from highway development be-

cause he does not consider what the earnings of the various labor, land, and capital resources would likely have been in alternative employment opportunities.

The need to consider the incidence of effects from highway development—that is, what groups in society gain and what groups suffer losses—is stressed by Manheim et al. (*81*, p. 14):

> While highway construction in metropolitan areas increases mobility for those with access to autos, improves the quality of life for suburban residents, and contributes to the overall growth of the region, some groups will suffer the loss of things they value highly, such as homes, jobs, and neighborhood quality.
>
> Every decision about highways will involve the need to balance gains to some groups against losses to others. It is essential that the process of planning, designing, implementing, and operating transportation and highway systems explicitly recognize and take into account such issues of social equity.

It is not possible to identify in this space all the groups within a community that gain and the groups that lose as a result of highway-stimulated growth and development. There are many and varied indirect beneficial and adverse effects that fall on most all residents of a community. Many people today are viewing with considerably less enthusiasm than they did a few years ago the idea that sustained growth is good. For people who place high value on the community's *status quo*, highway-induced growth will be undesirable. It is the researcher's opinion that those individuals in a community who are elderly, retired, or generally not in a position to take advantage of new opportunities afforded by the highway improvement will be adversely affected the most. The ones most likely to gain will be those of working age, who are the most flexible and who are capable and anxious to improve their current status.

a. *Direct.*—There are a large number of studies that have examined the growth of business activity in the immediate vicinity of highway improvements or as a direct result of highway development.

Moore et al. (*89*) in their excellent publication on the initial phase of the Birmingham, Ala., study discuss in detail a wide variety of benefits related to income, employment, and productivity. Increases in productivity of firms can come about as a result of improved locational advantages and greater efficiencies through expansion, consolidation, reorganization, or even less employee tardiness. Decentralization of industry through locating in industrial parks in suburban areas can mean not only a better working environment for employees but also lower taxes to the firm.

Development along the Connecticut Turnpike was studied by McKain (*79*) in the early 1960's and the study has been widely cited in the later literature. McKain used turnpike towns, control towns, and the State as a whole in his comparisons. He reported that manufacturing employment increased 27 percent between 1956 and 1962 in the turnpike towns compared to no change for the State as a whole and a slight decline for the control areas. Transportation improvements were given as the major reason for locational choices by the new firms. The rate of wage increases in the turnpike towns was slightly higher than the State average and much higher than the control areas. In terms of volume of retail sales, there was an increase of 56 percent since opening of the highway in the turnpike towns, which exceeded the rate for both the State and the control towns. For establishments near interchange sites, sales volume increased 300 percent. Prior to the opening of the turnpike, many areas through which it passed were economically depressed. McKain concluded that such a transportation improvement can infuse a depressed area with a spirit of economic optimism for growth.

In another classical study of industrial development along a new freeway corridor, Bone and Wohl (*12*) studied Route 128, a circumferential highway around Boston, Mass. They were not able to estimate the *net* benefits of development along Route 128 because it was impossible to determine the "without" condition—the extent of industrial development that would have occurred anyway in the absence of the new highway. Consequently, their analysis presents only gains resulting from development along the highway, although they did net out the "transfer" effects of firms that were already operating in the metropolitan area. Their findings show that, as of 1958, the net gain of investment in the metropolitan area contributed by Route 128 industrial development was about $129 million, which generated jobs for about 19,000 workers.

A rural area of Wyoming, through which I-80 passes, was studied by Hooker and Potter (*59*) who found that in the 1960 decade private investment in new plant and equipment in the corridor totaled over $4 million. This new development, which was mostly in the form of motels, gas stations, and eating places, would not have occurred in the absence of I-80. Of the total volume of nonlocal traffic, almost 6 percent was induced on I-80 as a result of that highway improvement. Average expenditures per vehicle amounted to $6.21 (1970) of which $1.17 was for meals, $3.08 for fuel, $1.17 for lodging, and $0.79 for miscellaneous items. A total of $700,000 in one year was spent by such induced traffic, which represents a net gain to the local communities as a result of the new highway development.

The study of the Interstate 287 corridor in New Jersey by Wilbur Smith and Associates (*124*) included a comparison of employment before and after relocation near I-287 by 59 firms. Excluding one firm, which reduced its employment after relocation because of a nonhighway-related factor, total employment increased about 24 percent. The firms also reported improved commuting conditions for employees and an improved potential labor market for themselves.

Good studies in other states reporting growth in business activity along new highway improvements include one in Washington, Horwood and Boyce (*61*); two in Georgia, Lemly (*69*) and Wallace and Lemly (*117*); one in Wisconsin, Dodge (*30*) (which examined the influence of a highway on an agriculturally based economy); and one in Oregon, Farness (*34*). The last study looked specifically at the impact of tourism and found that, because of the seasonality of such expenditures by nonresidents, there was only a small favorable impact on employment. Of more interest was his conclusion that the $7.3 million in State gas taxes paid by out-of-state travelers did not cover their

share of maintenance costs of highways and highway facilities, which in effect meant that Oregon residents subsidized tourists.

Sauerlender et al. (*103*) reported in 1972 a study sponsored by the Pennsylvania Department of Transportation. The purpose of the study was to determine the feasibility of developing from secondary data a model for estimating the primary and secondary impacts on local, minor civil divisions caused by a major highway change within a 20-mi corridor centered on the highway. Three major highway corridors in Pennsylvania were studied and data from 126 minor civil divisions within these corridors were used to develop a set of regression equations to explain changes in: employment, population, market value of real estate, and local government adjusted millage rates. The model showed that, when the effects of factors other than the highway were taken into account, the impact of the highway itself could be evaluated by means of the regression coefficients of measures of various aspects of accessibility conferred by the highway.

b. *Indirect.*—Expenditures by nonlocal highway users, through the multiplier effect, generate additional income in a region through which a highway passes. In the terminology of economic base theory, this is called indirect income. It arises through economic linkages between the regional sectors—that is, sectors purchase goods and services from each other and, in this way, part of the income to one sector gets diffused throughout the region. Indirect income not only arises from expenditures by highway users, but it also can arise from expenditures for highway construction and maintenance. The purchasing between sectors is the principal way in which direct user benefits get transferred to nonhighway users.

There have been several studies that have examined the indirect income in a region originating from highway users. Generally, a Leontief type input-output model of the regional economy is used to determine the multiplier (interdependency coefficients) for each type of business sector catering to highway users.

Hooker and Potter (*59*) developed an input-output model for Evanston, Wyo., a small community of about 5,000 population along I-80. They found that direct motorist expenditures amounted to about $170,000 and that the appropriate multiplier had a magnitude of 2.13. This means that any dollar spent in the community by nonlocal highway travelers ultimately generated a total income to the region of $2.13. Applying the multiplier to the total expenditures by highway travelers means that the $170,000 of direct expenditures generated a total income of about $361,000, or $191,000 of indirect income alone.

Gamble, Raphael, and Saurelender (*40*) employed an input-output model to predict the likely direct and indirect economic input of I-80 on Clinton County, Pa. This county is larger in population than Evanston (38,000) and more economically developed; therefore, the multiplier values are likely to be larger in magnitude. The composite multiplier for all business sectors catering to highway users in Clinton County was 2.27. They predicted that the heavily traveled route would generate about $2.2 million of direct expenditures by nonlocal highway users, which, through the multiplier effect, would generate an additional $2.8 million of indirect income to the county, or a total income of about $5 million. It should be kept in mind that this is income to all sectors, and thus represents some double counting of the same dollar. Perhaps, a more meaningful figure is the income that directly and indirectly goes to the household sector only, which would be personal income as compared to total regional income. Households in Clinton County for the year of the study would have realized about $780,000 income from nonlocal highway users.

The important factor brought out in these studies is that expenditures by highway users work their way through the regional economic system and in doing so generate income to many businesses and persons in the region, some of whom may seldom use the highway themselves. This is one important form of indirect income and employment benefits from highways.

Perhaps a more important form or source is from the industries that locate in a highway community because of favorable locational advantages or accessibility as a result of highway improvements. Although the income flowing to an industry may not come directly from highway users, as in the case of motels, restaurants, and gas stations, nevertheless the concept of the multiplier effect and indirect income is still applicable. For many highway communities these new industries contribute significantly to the economic base of the region, although in terms of net benefits for the broader region they may only represent locational shifts.

One might conceive of income and employment benefits arising indirectly from highway improvements other than through the multiplier concepts previously discussed. Some kinds of business firms are directly related to highways, but they derive their source of revenue from nonhighway users. Chief among these is the billboard and outdoor advertising industry. Thiel and Yasnowsky (*108*) and Moore et al. (*90*) present data on the billboard industry and discuss some of the likely effects of the Highway Beautification Act on this industry.

3. *Agglomeration Economies and Economies of Scale*

An efficient transportation system is a prerequisite for the smooth functioning of a modern technological society. Specialization in production is the logical consequence of technological innovation, but consequent increases in the productivity of land, labor, and capital can only be realized with the help of an adequate transportation system. In a modern society the transportation system expands to meet the demands for it. In time, the transportation system which becomes established will greatly influence the spatial form or settlement pattern of society.

Economists generally agree that, if it were not for the modern highway network, the degree of urbanization that now exists could not have been achieved. Such urbanization contributes to, and is also influenced by, certain kinds of internal and external economies of production. Isard (*63*), using Hoover's classification, defines three forms of such economies which, together, he calls agglomeration factors. The three economies arising from agglomerations are:

1. Economies of scale imply decreasing average costs of production with increasing levels of output and firm size. Since location is one of several factors determining relation-

ships between costs of factor inputs, highway improvements can have an important influence on economies of scale.

2. Localization economies influence all firms in a single industry at a single location, resulting in an expansion of output of that industry at that location. Firms able to achieve reductions in cost for certain common factor inputs because of volume purchasing is an example of such an economy.

3. Urbanization economies apply to all firms in all industries at a single location. Such economies originate from a greater use of the many and varied goods and services available only in urban areas, any one of which may not be a primary factor input such as labor, but, collectively they are important to the efficient operation of the firm.

Highway improvements enhance the liklihood of agglomeration economies. Stated another way, one of the indirect and long-run benefits of highway improvements is an increase in agglomeration economies for many firms in urban areas. Outside of the literature dealing with location theory, regional science, and micro- and macro-economic theory, there appears very little on this subject in the highway field. Of the few authors treating this topic are Garrison et al. (*44*), who discuss the effects of the Interstate System on the size and pattern of service areas and the movement of goods and people among them. Such movement encourages an urban form of spatial development, leading to benefits of scale and agglomeration.

It must be pointed out that urbanization and agglomeration may also lead to external diseconomies that impose costs on firms. Congestion on city streets and higher costs for some kinds of municipal services (fire, police) are examples of such diseconomies. Congestion costs and higher taxes (to cover higher municipal service costs) are reasons why some firms have left central city locations in favor of suburban industrial parks. Congestion costs fall on highway users the most, but indirect effects from congestion, such as greater air pollution, fall most heavily on residents living near the highway. Some of these people, such as inner city ghetto residents with low incomes, may not be highway users at all.

4. *Interchange Development*

A previous section treated employment, income, and production benefits from highway improvements in a very general way without regard to the specific locational aspects of such benefits. Because many studies have been conducted on the growth and development that occurs near major highway interchanges, it was felt necessary to devote a section of this report to this topic. By the middle of the 1960's, in cooperation with the Bureau of Public Roads (now FHWA), nearly half the states had undertaken studies on interchange development. Many of these are explicitly concerned with bypass effects that will be dealt with separately later. Only a few of the more noteworthy studies will be presented.

Stein (*105*) published an article in 1969 in which he summarized the data from studies on 332 interchanges in 16 states. The type of intersecting highway and the relative accessibility of the interchange quadrants were important variables affecting land development at interchange sites. General observations of Stein were that around rural interchanges development was mostly in the form of motorist serving activities (motels, gas stations, restaurants), but in suburban areas rapid growth in numbers of apartment houses, churches, schools, shopping centers, and industrial parks predominated at interchange locations.

In one of the early landmark studies of interchange development, Frey et al. (*38*) studied the economic and social impact of the Pennsylvania Turnpike and US 22 interchange on Monroeville, Pa. Public records, field observations, interviews with households and businessmen, records of private organizations, and other sources of data were used and statistically analyzed to describe the change in growth and to isolate the variables that might account for such change. In order to make meaningful comparisons, 38 control communities were selected for comparative analysis. The years of study were 1950-1958. Monroeville showed much more rapid growth in all kinds of activities and land uses than did the control areas. In terms of population, Monroeville grew 119 percent compared to 25 percent for the control areas. Much of the growth in commercial activity was along US 22 near the turnpike, which gave rise to severe traffic flow problems. Because of unlimited access, this major intercity thoroughfare lost much of its usefulness for through traffic, and became the main street of the community's business district. Since the completion of that study, a limited-access highway (I-376) has had to be constructed bypassing the community. Thoughtful planning in the beginning might have avoided this costly step.

Ashley and Berard (*5*) made an intensive study of interchange development along 180 mi of I-94 in Illinois. They were able to show comparisons of growth at major city, secondary city, small town, and rural interchanges. The important question was not of growth or benefits, but rather of their magnitude. For example, at major city interchanges, service stations within 400 ft of the interchange averaged twice the gallonage of those 400 ft to 1 mi away from the interchange. They state (*5*, p. 58):

> The limited access highway has broken the mold of the old highway commercial pattern. It concentrates development rather than diffuses it and consequently allows investment in more lavish improvements. It has given a permanency to investments that never existed before in the history of highways.

A number of studies have attempted to define the important variables that influence the amount and type of development around interchanges. Sauerlender, Donaldson, and Twark (*102*) studied 36 interchanges in Pennsylvania using simple correlation analysis. They found that: (1) highway-oriented commercial development accounted for more than two-thirds of total development; (2) industrial, residential, and recreational development located primarily away from the interchange; and (3) development was closely related to average daily traffic on the cross route, topography at the interchange community, distance to nearest urban area, and availability of public services (water, sewage) at the interchange community.

In 1967 Twark (*112*) reported a follow-up study of 105 nonurban interchanges in Pennsylvania. He developed a system of 5 simultaneous equations to explain the development of: service stations, restaurants, motels, nonhighway-oriented establishments, and the annual rate of growth in market value of real estate for the local community in which the interchange was located. He found significant interrelationships among the 5 different types of development that occurred. His study introduced a high level of statistical sophistication in estimating the parameters of his model.

Pendleton (*98*) in 1965 used multivariate techniques in examining data on 33 toll and 31 nontoll interchanges and found that development was strongly correlated with (1) percentage of land area developed before construction of the highway, (2) population of the nearest urban center, and (3) distance from the nearest urban center.

Eyerly (*33*) made a 6-yr study of changes within a 2-mi radius of 4 interchanges near York, Pa. He hypothesized that interchange communities should experience a shift from lower order land uses to higher order uses, but was able to attain only partial validation of his proposition. The generally held expectation of rapid and dramatic increase in business activity and land values was found in only two of the interchange communities. The few interchanges studied make it impossible to draw general conclusions from this study.

Corsi (*27*) reported on an 18-yr study of all interchanges along the Ohio Turnpike. The majority of the interchanges experienced little shifting of land to urban uses after an initial increase in development of service stations, motels, and restaurants. Where rapid and sustained transformation of land to urban uses did occur, it was explained primarily by proximity of these interchanges to large and small urban centers, the growth rate of the nearest urban centers, the existence of extensive public facilities in the interchange community, and the amount of traffic on the turnpike and on the cross routes.

In a detailed study of interchanges along major highway corridors in the Birmingham, Ala. area, Moore et al. (*91*) document and analyze the changes in land use that occurred at these locations following highway improvements.

Interchange areas, because they represent the focal point of accessibility to major highways, are highly desirable for the location of commercial, industrial, residential, and other types of urban land uses. But because of the complexity involved in locational choice and decision-making and the great number and variety of factors that exist at any interchange site, it is difficult to predict the amount and type of development that may concentrate around a specific site.

5. *Joint Development*

The concept of joint development involves the utilization of a highway corridor for purposes other than a roadway. It is relevant primarily to urban areas and serves to improve the corridor with multiple and complimentary uses as part of the total urban environment. In its fullest expression it involves not only the development of a wider corridor but also the utilization of the air space above the roadway itself. As stated in the 1972 Federal Highway Administration's publication (see *115*, p. 27):

> Such a development can provide improved housing not only for those residents displaced by the highway but for other residents as well. In addition, it can improve the quality of many residential neighborhoods by allowing for the provision of parks, playgrounds, and other social facilities.

The report discusses in greater detail some of the advantages and disadvantages of joint development and presents some examples of the application of the concept in several cities. There have been very few studies, however, that have rigorously examined the economics involved. A later Federal Highway Administration publication (*116*, p. 80) points out that only in those downtown city areas where land costs are extremely high will utilization of air space over the freeway be economically feasible:

> Based on economic considerations . . . land apparently needs to be worth at least $20 per square foot ($850,000 per acre) to justify using space over highway right-of-way. Land values are lower than this in downtown areas of all but the very large cities; few, if any, suburban areas have land valued so high.

Levin (*72*), in referring to the multiple use of land adjoining the right-of-way rather than airspace over the roadway, feels that in many situations, the cost of acquiring an entire block of property will be only slightly higher than the cost of acquiring the minimum freeway right-of-way and paying severance damages.

It appears that joint development does offer an opportunity for economic benefits to an urban area. Land values would most likely increase and substandard housing could be improved unless no effort was made to prevent the displaced occupants from fostering in time new slums, in which case both the occupants and substandard housing would be merely transferred to another area in the city.

B. Land Values

One of the principal ways in which user benefits (reduced travel time and vehicle operating costs, improved safety, and greater ease and comfort) get transferred to nonusers is through the real estate market. Land values in close proximity to most (but not all) limited-access highway interchange sites appreciate significantly in value. Buyers of land at these locations, in effect, are purchasing accessibility benefits. The future savings in travel time and vehicle operating costs that they will realize through use of the highway have been effectively discounted to their present value and transferred to the sellers of land. This is as true for the industrial firm faced with shipping cost savings for factor inputs or products as it is for the householder faced with commuting costs to and from work. For the commercial establishment catering to highway users (service station, motel, restaurant), expected higher future earnings because of locational advantages in being closer to potential customers have been discounted into present land values.

These indirect benefits from highways are very long term in nature. The landowner who reaps a large windfall gain because of a new highway near or across his property

might enjoy such benefits for life and even pass them on to his heirs. If he is improvident and squanders his new wealth, it is merely transferred to others in society. The net gains to society as a whole, however, as a result of land value appreciation around highways, are difficult if not impossible to ascertain. It is obvious that the purchaser of land near an interchange had to obtain his assets from somewhere. In the short run, from the viewpoint of the total economic system, the increase in land values of plots that are sold merely represents a transfer of wealth between members of society. In the long run, the benefits to society from increased land values are contingent on the way in which resources are employed. All the evidence, however, points to very substantial increases in net benefits to society.

Virtually all of the studies, and they are voluminous in number, which have examined the effects of highways on land values have considered the benefits only in terms of the landowners—that is to say, they have looked only at the increase in land values in a community or region as a result of highway improvements. The authors are aware of no study that has attempted to trace the flow of capital assets, either forward or backward, and to ascertain the likely alternative returns they might have earned if employed in another manner. Perhaps such a study is not possible.

There are some excellent references that deal in a general and/or theoretical way with the influence of highway improvements on land values. *NCHRP Report 114,* (*85*) is one of these. An article by Wendt (*122*) appearing in *Bulletin 268* of the Highway Research Board reviews theories of urban land values with particular reference to the effects of transportation changes on land values. Zettle (*130*), in an excellent article that appeared in 1959, discusses the shifts in land values likely to result from highway improvements and cautions against double counting of highway benefits. Klein et al. (*66*) present a good theoretical discussion of property value determination in relation to transportation systems.

Two publications by the Federal Highway Administration (*115, 116*) discuss in a general way the influence of highways on property values. *NCHRP Report 18* (*62*) also provides good reference material on this topic.

Several general comments relevant to determining the effect of highway change on property values are in order. First, there is a distinction between land values and property values, and it is important to keep this in mind. Land values generally refer to the basic value of the land itself, and reflect (1) the inherent productive capacity of the land to produce food or fiber and (2) its site or location value. Changes in the transportation system have no effect on the capacity of the land for production. Their effect is solely on the locational features of that site; that is, its accessibility to other sites. A change, such as a new highway, may either increase or decrease the accessibility characteristics of a given tract.

Property values, on the other hand, reflect two components of value—the land *and* the improvements on the land (structures). Most students of land economics agree that the effects of highway change are reflected solely in the change in land values and not in improvement values. Two houses that cost exactly the same amount to build may be priced differently, the difference in price (property value) reflecting the different locational or accessibility characteristics of the two sites. The houses are valued the same, but the lot values are different.

Second, it is very difficult to determine precisely the effect of a transportation improvement on the price of land. The value of a given parcel of land is a function of many variables, the most important one being the uses to which adjoining or nearby tracts of land are put. Other factors that influence land values besides accessibility are community services (water, sewage, etc.), land use controls (zoning, subdivision regulations, and the like), topography, drainage, natural amenities, regional growth or decline, interest rate, availability of capital funds, and supply and demand relationships in the local real estate market.

Although the influence of regional access on property values is felt most keenly on those tracts of land near a major highway, it is important to point out that these influences extend also to tracts of land quite remote from the highway—but, in such cases, the effect on value will be much less. Thus, a major highway, such as the beltway around an urban area, will affect the accessibility of all land in the metropolitan area. Considering the dynamics of growth of urban areas, especially the development of the over-all transportation system, it becomes apparent why it is so difficult to measure the specific effect from highway accessibility on property values.

Many highway-related studies have examined land values near major highways before and after construction and have inferred that the increase in values results from highway improvements. Such conclusions are not correct, because no attempt was made to account for the influences of nonhighway variables on land prices. Nonhighway-induced growth in the area, in addition to other factors, might account for significant land value increases. Two approaches to determining the effect of a transportation change on land values seem best. The first is to use multiple regression analytic techniques on a sufficiently large number of observations both close to and away from the highway to ensure statistical reliability. The second would be to carefully select control areas where it is evident there is no influence from the highway, and statistically compare land values in the control areas to land values near the highway. Extreme care must be exercised in selecting control areas to ensure that the nonhighway-related variables in both areas are as alike as possible. This in itself might necessitate careful statistical analysis.

Because of the large number of studies relating highway improvements to property values, coverage of all would not be feasible for this report. Only the more significant studies will be presented. The first part of this section will discuss the beneficial effects on private land values; the second part will discuss the more indirect effects of property value increases on the local tax base.

1. *Private Property Values*

Adkins (*1*) presents a good discussion of methodologies for measuring land value changes and presents findings from his own studies of expressways in Houston, Dallas,

and San Antonio, Tex. Adkins, using control areas, found that in San Antonio land values went up about 200 percent (from 1941-45 to 1952-56) in study areas along expressways compared to an increase of 67 percent in the control areas. This study followed rigorous experimental procedures.

In a study of expressways in the Atlanta, Ga., area, Lemly (*69*), also using the control area approach, found dramatic increases in land values near expressways. Some industrial lands increased as much as 2,000 percent during the study period. Property values increased more on streets crossing the expressway than on streets that did not cross.

Using regression analysis on samples of residential properties throughout Fairfax County, Va., Gamble et al. (*41*) found that improved accessibility from the Capital Beltway (I-495) increased the value of an average single family residence by almost $200 for each one-hundredth unit increase in the Washington Council of Governments' accessibility index. For the average property in the community of North Springfield, Va., located on the beltway, this meant an increase of about $3,000, or 9 percent of the total value.

Pendleton (*99*) in a study, also done in the Washington, D.C., metropolitan area, attempted through multiple regression analysis to isolate the component of residential sale price that represents accessibility. He found that three different measures of accessibility were significant explanatory variables when all other variables were held constant. The results of such studies seem to support the belief that accessibility influences the value of urban land over wide areas surrounding highways, and is not influential only at interchange sites or in areas closely adjacent to the right-of-way.

Longley and Goley (*76*) analyzed 5,000 rural land sales in the United States to determine the differentials between value of farm real estate by type of road as to price per acre and price per farm and distance from nearest trading center. The Monroeville, Pa., study by Frey et al. (*38*) found that the value of real property in that interchange community increased 336 percent between 1950 and 1957 as compared to a 74 percent increase for the control area properties. Approximately two-fifths of the change in real estate value was accounted for by appreciation, whereas the other three-fifths was explained by added capital investments.

Studies have revealed a wide variation in land value increases as illustrated in the following several studies cited.

McKain's (*79*) study of the Connecticut Turnpike indicated that the average annual appreciation in value of residential properties between 1958 and 1961 was 3.6 percent compared to 2.5 percent in the control areas. The appraised value of all property in the vicinity of the interchanges more than doubled. The Ashley and Berard (*5*) study of expressways in Illinois found service station sites selling for up to $170,000 per acre, and restaurant and motel sites selling for up to $12,500 per acre. On the Lexington, Va., bypass there was a 4 to 5 percent increase in land values above the increase normally expected, with an 11 percent increase in land values above normal on highway abutting land (*20*). In another study in Texas, Buffington and Wootan (*15*) determined that adjusted land values increased 169 percent ($269 per acre) for lands within 1.5 mi of the highway, whereas land in the control area increased 73 percent (or $65 per acre) for the same time period. Other studies reporting beneficial effects of highways on land values are contained in Refs. (*10, 51, 78, 80, 96, 97, 102, 125,* and *130*).

Not all highway studies show dramatic increases in land values. Eyerly's (*32*) study of four interchanges near York, Pa., revealed that land values increased at an annual rate of about 3.8 percent, but in the areas surrounding the interchange communities the appreciation was about 4.4 percent annually. The study of I-80 in Wyoming (*59*) showed no discernible impact of that highway on residential or agricultural land values, but it did show positive impact on nonresidential urban land values. Dodge's (*30*) study in Wisconsin found that highways did not influence agriculture land values on farms remaining in agriculture, but land values increased when farmland shifted to other uses.

There is a growing realization that, under certain conditions or in some locations, there are negative effects from highways on land values. Studies that compare the increase (or decrease) in value of properties along highways to the value of similar properties in control areas are measuring the net effect from the highway. However, there may be both positive and negative effects working together. For example, properties located very close to major expressways may be positively influenced by accessibility improvements but at the same time adversely affected by highway-generated noise and air pollutants. This situation was examined by Gamble et al. (*41*) in their study of North Springfield, Va., along I-495. They found that the average residential property abutting the highway was adversely affected by about $1,500 as a result of highway-generated pollutants (predominantly noise), and at the same time there were accessibility benefits amounting to about $2,950 per property.

Colony (*23*), in a 1967 study of expressway traffic noise in Toledo, reported that houses within 50 ft of the highway right-of-way declined in value more than homes not in proximity to the highway.

Two studies dealt specifically with the likely influence of highway beautification on land values. Thiel and Yasnowsky (*109*) and Williams and Davis (*125*) reported positive effects of scenic enhancement and billboard removal on surrounding land values.

2. *Tax Base Effects*

An indirect benefit to communities whose land values have been significantly increased as a result of highway improvements is the subsequent effect on the tax base and tax revenues. Tax revenues increase as a result of (1) higher valuations of the land component of real property, and (2) more capital improvements on the land, assuming assessment ratios and millage rates remain about constant. However, in many growing municipalities, such as those near new highway interchanges, assessment ratios and tax rates do not remain constant but increase to meet the rising demand for more municipal services. Such a situa-

tion then raises important questions concerning the distributional effects of public revenues and costs.

There is a considerable body of theoretical work dealing with the economics of public revenues and expenditures, but this cannot be addressed here. In the following discussion only brief mention will be made of some of the more important issues that are likely to arise.

In rapidly growing areas many municipalities are hard pressed to keep up with the demand for more and better public services: water, sewage disposal, education, police and fire protection, health care, and the like. Although total assessment values rise dramatically, tax rates also rise in order to provide sufficient revenues. For some kinds of landowners, particularly farmers, such tax burdens become tremendous and can result in premature shifting of land out of agriculture. For some prehighway residents of the jurisdiction who may have benefited only slightly from land value appreciation because of their location away from the highway, it is very likely that their tax increases will exceed their benefits from expanded municipal services. For the community as a whole, tax revenues may not be sufficient to cover municipal costs, particularly if the community is largely residential and has no substantial amount of industrial land on the tax rolls. In assessing the merits of an increasing tax base resulting from highway development, a careful analysis must be made of the relative shifting of tax burdens and benefits. It is important to identify those individuals in the community who might realize a net gain from tax changes, and those who might be harmed, and to estimate the magnitude of these effects. One of the reasons many people today are actively opposing growth in their communities is because of the large added tax burden that generally accompanies such growth, together with what they perceive to be a noncomparable increase in quantity or quality of community services.

The Real Estate Research Cooperation in the late 1950's surveyed communities of various sizes throughout the country, and their findings in part were as follows (*101*, p. 80):

1. Highway effect upon the tax base of the assessment jurisdiction is almost directly related to the size of the city located within the area.
2. Smaller communities tend to benefit less from highway effect on the local tax base unless the community is so located as to serve as a terminal point.
3. Limited-access highways traversing largely rural areas and having few, widely-spaced access points, have enhanced very little, if any, the value of the areas which they transit, except near interchanges.
4. If the local government does not take appropriate action through zoning and reassessment to transmit to the tax base the beneficial impact of the highway improvement, the effect will be dampened, particularly if current zoning is for agricultural uses.

In a study of the return on investment of Virginia's Interstate System, Walton (*118*) reported that such construction had generated about $184 million more in real estate taxes to communities having Interstate highways (gross benefits) and resulted in $52 million more in State income taxes between 1961 and 1968. In his study of the Connecticut Turnpike, McKain (*79*) found that new summer homes and motels added $4 million to the tax rolls of towns in the vicinity of the turnpike. The Route 128 study in Massachusetts by Bone and Wohl (*12*) concluded that new tax revenue from industrial development helped the highway communities meet a part of the rising cost of municipal services that would otherwise be borne by home owners. Henderson (*50*) in an economic impact study of I-71 in North Central Ohio found that the increase in land values around the highway more than offset the loss in value of land taken, resulting in a net gain in yields of local tax revenues. Other studies reporting on local tax benefits from highway improvements are *103, 112, 124, 131.*

C. Improved Health and Safety

1. *Accidents, Injuries, Fatalities*

One of the clearest benefits resulting from highway improvements is the increased safety they offer for the highway user. Studies have repeatedly shown that the traffic accident rate is lower on modern expressways as compared to uncontrolled access highways. The separation of opposing traffic lanes, the ability to handle large volumes of traffic at higher speeds, the elimination of intersections and stops, and the control of access and egress have all contributed to this achievement. In general, fewer accidents on improved highways accrue a short-run benefit, whereas improved health can have both short- and long-run benefits.

The Automotive Safety Foundation (*9*) reported in 1964 that urban accident rates on fully access controlled highways were about 150 per 100 million veh mi, but on highways with no controlled access they were about 500 per 100 million veh mi. There were twice as many fatalities per 100 million veh mi on urban highways with no controlled access as compared to highways with full access control. Wilbur Smith and Associates (*124*) reported in their New Jersey study that the accident rate on freeways was less than 25 percent as high as the accident rate on other state highways. Mattson (*83*) has a good article on the traffic accident outlook, written in 1964. Hoch (*57*) studied the accident experience on Chicago expressways and found that the cost in 1958 (fatalities, injuries, and property damages) for 1 million veh mi of travel was $6,200 on arterial roads and $1,282 on expressways. Hoch found enough evidence to indicate that one expressway mile in Chicago yields as much as $7.7 million worth of accident reduction over the anticipated life of the highway.

In a 1970 report by the Federal Highway Administration (*114*), a total of $15.8 billion was estimated for the saving in accident costs between 1956 and 1974, the year the Interstate System was expected to be completed. This estimate is based on the additional costs of fatalities, injuries, and property damage that would result if travel accidents on the Interstate System were at the same rates as on the formerly traveled routes (*114*, p. 9). The estimate was based on the finding that the Interstate System is almost twice as safe as the older roads.

Winfrey and Zellner (*128*) claim that the economic cost of accidents in one year is about $11 billion, but do not state the source of such an estimate or explain how it was derived. This cost closely approximates the total amount spent annually (about 1970) on highway construction and maintenance. This reference has a useful and informative

discussion on the relationships between various types of highway design and accident rates. Other good sources of the probable rate of reduction in accidents are studies by Jorgenson and Associates (*65*) and Cornell Aeronautical Laboratory (*26*).

Accidents are costly to motorists not only in terms of out-of-pocket costs for vehicle and property repairs and medical expenses, but also in terms of earnings lost as a result of long convalescent periods or permanent disability. Indirectly, such lost time can be costly to employers, and under certain circumstances such costs may be passed along to consumers through higher product prices. Higher accident rates mean higher insurance premiums for vehicle owners.

To such monetary costs must be added the nonpecuniary costs associated with accidents, such as the inconvenience of being without a vehicle and of overseeing the repair of damages. Injuries and fatalities are not without their pain and sorrow, both physical and mental, that can endure for lifetimes. Within this context, the beneficial effect from improving highways is long run.

Highway improvements lead to reductions in all of these costs, and such benefits on a nationwide scale are tremendous. In addition, there is a social value, not measurable, attached to the comfort and ease of mind of the motorist in knowing that he is traveling a safer route.

2. *Health Care Delivery*

Highway transportation improvements enable a better utilization of health care services. The benefits associated with health care from highway improvements are both direct and indirect, short and long run. Transportation improvements have enabled the development of more sophisticated mobile health units, such as mobile x-ray vans, to reach a broader spectrum of the public. Public health inspectors and nurses have better access to populations in remote areas, and can make more visits in a day.

In a landmark study reported in 1959, Garrison et al. (*44*), using empirical observations from Western Pennsylvania and Seattle, estimated the impact of highway development on the utilization of physician's services. They developed a model from pertinent market and trade theory and compared it to empirical data to predict movement of people. Their findings showed that there had been a change of medical practices occasioned by the automobile, and these changes had the general effect of concentrating physicians in fewer places and enlarging their trading areas. In former times, physicians traveled to their patients who largely lacked mobility. Today, patients can easily travel to the physician's office, and with better highways people can travel greater distances in the same amount of time. Because the physician avoids having to absorb travel time, he can treat more patients in a day.

Highways appear to be of greater benefit to physicians than to patients. The patient bears the cost of travel, not the doctor; and improved highways mean more patients for the physician. Patients do benefit, however, in that they receive faster service. Concentrated health facilities, including regionalized hospitals, mean more specialists available and more modern and better equipment.

3. *Barriers to Fire, Other Hazards*

Highways can serve as effective barriers to the spread of fire in both urban and rural areas. In woodland areas they are frequently used as fire lanes for controlling forest fires. In the 1930's the Civilian Conservation Corps constructed many woods roads, as much to provide barriers to the spread of wild fires as to provide access to remote areas for firefighters. However, improved roadways have also made woodlands more accessible to the general public, thus increasing the incidence of forest fires. In urban areas severe conflagrations can jump narrow city streets, but modern expressways serve as effective barriers.

On flood plains beside rivers and streams highways can serve as effective dikes to flooding. Coordination of efforts between highway planners and agency personnel charged with flood control efforts (Army Corps of Engineers and Soil Conservation Service) can result in substantial savings in costs of flood control measures. Both highways and dikes (or levees) require substantial rights-of-way, and combining the two into one structure in areas where easy access to the waterfront is not of paramount consideration can be highly beneficial. In some cases, elevating a highway only a few feet can provide substantial flood protection.

Modern expressways can provide partial protection by acting as buffer zones or barriers separating hazardous activities from other industrial, commercial, or residential areas in which damages might be excessive in case of accidents. For example, oil refineries, gasoline or munitions storage depots, and some kinds of chemical plants might pose high risks to nearby activities. Highways can separate such uses and reduce or minimize damages to the surrounding areas in case of accidents. Users of the highway, however, will be exposed to greater risks than if the traffic were routed at another location.

D. Operational Effects

1. *Bypass Effects*

Many state highway departments, as well as others, have sponsored studies to examine the effects of bypasses on existing communities. Part of the concern over bypass effects rests with merchants along the older routes, who fear loss of customers after the new highway is put into use. Not all of these fears rest with the owners of businesses catering primarily to highway users. There has been bitter controversy in many communities between the local business interests, who oppose a rerouting of the old highway, and the motoring public who want the time, cost, and safety benefits of the modern highway. Such conflicts have delayed and even cancelled some highway improvement projects.

For purposes of this report, bypasses include those relatively short segments of new highway that reroute through traffic around a downtown area but leave the intertown or intercity route unchanged; and those much longer segments of new highways that follow completely new alignments for the right-of-way but parallel closely the old highway route. To the town or city bisected by the old highway route, the effect can be virtually the same in either case.

There are two important effects from bypasses. The first

has to do with the lessening of the volume of traffic on the old route, which benefits many people in those communities as a result of less congestion on local streets. The second effect deals with the impact of the bypass on local business establishments. Both of these will be treated separately in the sections that follow.

There are several good references that discuss bypass effects in a general manner. Two publications (*115, 116*) by the Federal Highway Administration that discuss social and economic effects of highways are good. Moore's (*89*) indepth study of highways around Birmingham, Ala., also has a good section on bypass effects. An excellent reference concerning the effects of bypasses on local business establishments is provided by Horwood, Zellner, and Ludwig (*62*). This will be discussed in greater depth in a later section.

Because of the very large number of bypass studies that have been done, only a few of the more significant ones will be presented in this report.

a. *Reduced Congestion on Local Streets.*—An important indirect and long-run benefit to highway nonusers as a result of relocating a major highway artery away from the downtown area is the lessening of congestion on the old route (generally the city's main street) and other local streets. In general, life can become more pleasant in the town or city. Not only will it be easier and more convenient for the residents and others to get around, but there should be also a reduction in noise, air pollutants, and other objectional effects from heavier traffic. Congestion should be reduced on more than just local streets. More parking spaces will be available for local people, and there should be shorter waits for service in businesses catering to motorists. For some kinds of local business establishments in communities that are heavily congested from through traffic, the rerouting of this traffic to areas outside the town may actually result in an increase of sales and income as the local people find it more convenient now to shop downtown (*30*).

Not only will rerouting the traffic mean fewer accidents and, thus, a reduction in these costs to local residents, but it will improve also the safety for school children and other pedestrians on local streets (*77*). Besides the cost savings in fewer accidents, local motorists will benefit also from lower vehicle operating costs as traffic flow is improved and fewer and shorter stops will be necessary.

An additional benefit for local communities following construction of a bypass will be a reduction of risks from major hazards. Trucks hauling gasoline, explosives, highly toxic chemicals, or other dangerous cargo can cause tremendous property damage and loss of life when they are involved in an accident. An example is one of the worst disasters suffered by the State of Oregon, when on 7 August 1959, in the City of Roseburg, a dynamite truck parked next to a downtown service station blew up as a result of a fire that began in the service station. Thirteen deaths, many injuries, and over $10 million in property damage resulted.

Shifting such cargo from narrow downtown streets to a bypass removes the peril from the more heavily built-up and occupied sections of the community. A study by Henderson (*5*) in Mansfield, Ohio, revealed that the I-71 bypass reduced vehicular traffic on US 42 by 5,000 vehicles per day, including 1,000 trucks. Some of these trucks undoubtedly were hauling potentially dangerous cargo.

In a theoretical treatment of the economics of highway congestion, though not specifically related to bypasses, Thompson (*110*) suggests that congestion may be a form of economizing on public capital by trading motorists' time for money. He presents arguments for highway user charges and feels that reducing congestion through bridge, highway, and parking tolls would improve public transit and in effect be an income transfer to lower income groups.

b. *Local Businesses.*—The concepts of accessibility suggest that, when a segment of a major highway is relocated so that it no longer passes through the downtown area of a community, the effects of consequent changes in accessibility will be felt by local business establishments. These effects, moreover, will not be felt equally by all establishments. Businesses catering largely to the needs of transient motorists will be adversely affected the most, if they remain in their original location near the old route. Businesses serving largely the needs of local residents may be little harmed, if at all, and some may even realize an increase in business due to reduced congestion. For the community as a whole, however, the important question is what has been the net effect of the bypass on economic activity? For bypass highways, as for any capital improvement or development involving large public expenditures, some individuals may gain and some may lose. However, bypasses are justified on the expectation that they yield net benefits to society as a whole.

The most thorough and conceptually sound study of bypass effects was done by Horwood, Zellner, and Ludwig (*62*) as reported in the *NCHRP Report 18*. They critically examined 24 bypass studies that related to 72 communities varying in size from hamlets of 125 persons to cities of over 135,000 population. They found that community size may be important in terms of adjusting to economic change. Places of 5,000 population and over seemed better able to adjust; however, as Pashek pointed out in a later review (*60*), community size may not be the important variable but rather the relationship of the community to surrounding areas, such as a trade center, as well as other geographical relationships.

Analysis of the 24 bypass studies showed that retail establishments catering mostly to motorists (service stations, restaurants, and motels) were adversely affected the most. Service stations and restaurants in some cases were able to adjust by reorientating their merchandise to local trade, but motels and hotels could not readjust. Total service station sales in all bypassed towns showed little change after the bypass; restaurant sales showed a 13 percent decline; and motel and hotel sales showed a 23 percent decline. Total retail sales for all establishments (highway and nonhighway oriented) showed an 8.5 percent increase after the bypass became operational.

As in other impact studies involving indirect economic effects, the most valid conclusions came from studies in which control areas are used as a basis for comparison. By carefully selecting control areas that have as closely as possible the same conditions as exist in the study areas, except for the presence of a bypass, one is better able to

account for the effects of nonhighway-related variables on changes in the parameters. The Horwood study found that the results were somewhat tempered when data from only those studies in which control areas were used were analyzed. These more sophisticated studies showed that there was little effect from the highway bypass.

Studies subsequent to Horwood's analysis (1965) appear not to alter his findings. A study by Wallace and Lemly (*117*) of bypass effects on two towns in Georgia, using control areas, found growth in all business sectors, although some older businesses catering to motorists did decline. Business improved on the downtown streets. The authors felt that good site locations and good management are important factors in determining the ability of businesses to adjust to transportation changes.

The study in Wyoming by Hooker and Potter (*59*) found distributional effects among some business enterprises, but total purchases and sector purchases changed little. They noted that small towns were adversely affected, but in large towns spending increased.

Most of the old establishments on a bypassed highway in five northeastern Mississippi towns investigated by Wells (*121*), who used control areas, experienced heavy losses in business, but these were largely offset by gains to new large establishments on the bypass route. This follows a trend that has been going on for some time. Interchanges on new bypass routes, offering advantages of space and better accessibility, have become highly favored sites for motels and restaurants associated with large national and international chains. These establishments, following a marketing trend in many other kinds of retail businesses, have forced many small independent entrepreneurs out of business.

Other studies reporting largely beneficial effects from bypass development include Refs. (*14, 85, 101*).

2. *Relocation Effects*

Forced eviction from one's home or business and relocation in another neighborhood or community is generally not a pleasant experience. The literature has treated the social and psychological consequences of this impact from highway development rather extensively, but few studies have been directed toward careful analysis of some of the economic consequences. Most studies dealing with relocation (or displacement of people and businesses) emphasize the negative impacts, which, in the past at least, have been substantial. It was largely as a result of these studies that federal regulations were changed to permit a substantial increase in financial assistance paid to homeowner, tenants, and businesses displaced. In fiscal year 1973, 29,000 people (22,000 urban and 7,000 rural), 2,700 businesses, 240 farms, and 70 nonprofit organizations were paid federal assistance totaling $44 million to aid them in relocating new quarters (*116*).

For some persons and businesses relocated, there are several possible beneficial economic effects. First, the quality of the house or other structures may be upgraded. Relocatees faced with higher costs for comparable housing can be compensated, moreover, for such costs—up to $15,000 for homeowners and $4,000 for tenants. However, as pointed out by Hartman (*50*), higher quality housing may mean higher living costs in the form of taxes, maintenance and repairs, insurance, and other homeowner costs. In the long run, the net economic benefits may be minimal or even negative.

For the community as a whole, significant upgrading of housing and other structures as a result of relocation, balanced by the elimination of older more run-down structures in the new highway right-of-way, will result in a net economic benefit, at least in the short run. If the occupants in the better housing after relocation permit their homes to deteriorate over time, however, the community may be no better off.

A second possible benefit from relocation is that the new location may provide better accessibility for the relocatees to employment opportunities, shopping, recreational facilities, and other nonwork activities.

A study of 250 relocated households in the Cleveland, Ohio, area by Colony (*24*) revealed that housing purchased by those relocating cost about $5,000 more than their original housing before displacement. About 75 percent of those purchasing houses in excess of $20,000 added personal funds to the State relocation payments, thus voluntarily improving their housing. The relocatees did not achieve a net increase in accessibility to work or church, however.

Quite similar findings were reported in a study in Texas (*106*) that interviewed 170 families displaced by new freeways near Houston and Austin. Among homeowners, about 13 percent, upgraded their housing through relocation payments only, whereas another 66 percent of homeowners upgraded their housing with use of their own funds in addition to relocation payments.

3. *Local Streets*

A relatively minor indirect effect of major freeway construction, but one that might have significant meaning to some small rural towns, is the upgrading and improvement of feeder roads to interchanges and cross roads. Widening, grading, and paving are ways by which such secondary roads might be improved (*101*). The reduced traffic load on local downtown streets following a bypass improvement may mean lower maintenance costs for some municipalities. Snow removal and traffic control chores also would be easier and less time consuming for municipal employees.

4. *Energy Savings (Reduced Fuel Consumption)*

The huge balance of payments deficit that will be faced over the next few years, because of the sudden and large increase in world petroleum prices, can cause severe economic repercussions not only in the United States but throughout the world. We should make every effort to reduce our consumption of imported oil until we can develop a near self-sufficiency in energy resources.

A modern highway requires less energy to move the same number of people or tons of freight as compared to an old highway with its steeper grades, more congestion, and more frequent speed changes and stops. An earlier section of this report dealt in detail with the cost savings achieved

by modern highway use. A substantial portion of these reduced costs are savings in fuel. Solomon (*104,* p. 298) indicates that, for a 3 percent grade compared to a 6 percent grade, there is a 20 percent fuel savings for autos and a 70 percent savings for trucks. To this extent, modern highway improvements are contributing in a direct but real way to achieving a reduction in energy consumption so sought after as a national goal.

However, a word of caution is necessary. Better highways have also induced travel demand—that is, not as many automobiles or trucks would be operating today if highway travel had remained as difficult as it was prior to the advent of the Interstate System. Up until a year or so ago, though, transportation decisions, both public and private, were made under a set of market prices (primarily for fuel) that dictated the system that now exists. The question of how much less energy would be consumed today in the absence of an extensive network of limited-access freeways and relatively low-priced fuel is really academic. The much more relevant and important question is: how can one best utilize the present system so as to still achieve reduction in total energy demands?

This report cannot get into a detailed discussion of the answers to such a question, although it may be one of the most important questions facing transportation planners and decision makers at this time. But there are a number of steps that can be taken in the short run that will enable one to use modern highways to best advantage so as to provide the energy saving benefits one earnestly seeks. Quite simply, these steps have as their common objective reducing the number of vehicles on the highway without reducing significantly the total number of passenger miles. In this way the benefits of reduced travel time and vehicle operating costs offered by modern freeways can be taken advantage of in reducing total energy demands. Briefly, these steps are:

1. Highways can be utilized much more extensively by mass transit, such as buses. Reserving lanes only for bus use during commuting hours, as is done now in some cities, will encourage a shift to public transit.
2. By means of parking tolls or bridge tolls, discourage the single occupancy of cars for commuting purposes. The toll would be reduced as the number of car occupants increased.
3. A graduated tax on horsepower on automobile engines will discourage the purchase of high-powered cars that consume excessive amounts of gasoline. There are recognized problems with the horsepower tax because many vehicles, once purchased, can have the horsepower and fuel consumption augmented by the mechanically knowledgeable owner.
4. Control the supply of public and private parking space in downtown areas so as to increase parking costs to a point where many drivers find it more economical to use public transit or form car pools.

E. Improved Efficiency in Public and Private Services

There are many kinds of public services offered at the community, regional, state, and national level that are closely oriented to highway use. In fact, the original justification for establishing the Interstate Highway System was to improve national defense. Public bus transit, both intracity and intercity, is completely dependent on the road system. The efficiency of many other kinds of services, both public and private, is in some measure a function of the quality of the highways—police, fire, medical, educational (school busing), and postal and banking services are a few examples.

The concentration and regionalization of facilities made possible by modern highway developments, enabling the provision of better services and more modern equipment, the broadening of the trade area, and the capacity to serve more customers in a day, apply to many kinds of services. They are characteristic of our modern economy and describe some of the most important indirect benefits emanating from highway improvements.

1. *Public Transit*

Buses are completely dependent on the highway system for their existence. Since buses are highway users, many of the benefits that accrue to other highway users, such as motorists, also accrue to bus passengers. This is undoubtedly the case with time savings where buses utilize limited-access highways. Whether savings in reduced vehicle operating costs are passed along to passengers depends on the rate structure and the competitive nature of the market for public transit. The authors know of no studies that have examined this question.

Where special freeway lanes are reserved for bus use only during commuting hours, efficiency in bus transport is increased significantly. The higher costs of energy today would seem to indicate a greater demand in the future for bus service. As more motorists shift to public transit there should be a corresponding decrease in congestion during rush hours, more saving of fuel, and a further reduction in travel time and costs.

Buses that travel on local streets for all or part of their trips gain indirectly from highway improvements to the extent that freeways, by reducing congestion on these local streets, improve efficiency of bus operation.

2. *Emergency Services*

Police, ambulance, and fire fighting services are able to respond more quickly to emergency calls when good highways are available and there is less congestion on local streets. Time is of crucial importance, and lives and property can be saved through prompt response by ambulances and fire trucks. Quick police response to emergency situations can be a strong deterrent to crime. No studies are known that have attempted to quantify these kinds of highway benefits, which are predominantly short run in nature.

There are other indirect benefits that can be identified in the form of improved standby service as a result of improved mobility. A major highway linking nearby communities can obviate the need for extensive emergency equipment in each community. By concentrating better equipment in one central location, over-all savings can be realized by not having to duplicate equipment and better

quality service can be rendered through more highly trained personnel. This benefit can be realized in very remote rural areas as well, where forest fires pose a serious threat.

One of the few studies undertaken on this subject pointed out that a rural community now traversed by a major highway may have to upgrade its fire, police, and ambulance services in order to cope with the emergency demands placed on them by highway users (*16*). Economic benefits from better services would thus "spill over" to residents in the community.

Frankland (*37*) in a study of freeway interchanges in California reported in 1965 that in the Los Angeles area there are at least 12 hospitals located next to freeways. Benefits of such locations seem to be the greater speed and comfort in transporting patients to the hospital; better accessibility for doctors, nurses, and other staff personnel; and a certain visibility benefit to motorists traveling the freeway, who are in sudden need of medical attention but who are unfamiliar with the location of a medical facility until they spot the hospital.

3. *Education*

Busing of school children, both public and private, has grown apace with the development of highways. This does not necessarily suggest a cause and effect relationship, but certainly highway development has improved the efficient operation of school busing.

Because school buses do not commonly use limited-access highways but instead travel more on local streets, the benefits are of a more indirect nature and arise in large part from reduced traffic and congestion on the older roads.

A more efficient busing of school children has contributed to the consolidation of schools, primarily in rural areas. Although some people argue that consolidation does not necessarily improve the quality of education, for many rural and suburban youth it has broadened the content—more varied programs and more facilities and equipment are possible, and it is likely that school boards find it easier to attract more highly qualified teachers where consolidation has enabled the construction of larger and more modern schools.

4. *Civil Defense*

The legislation creating the approximately 42,000-mi Interstate System specifically indicated that it was not only an "Interstate" system but a "National Defense" highway system. Therefore, standards of width, load carrying capacity, and clearances were established to handle any military vehicle or mobile armament anticipated for the future. However, defense of the country is unlikely to require the movement of military units and supplies crossing the entire continent over our highway network. It is more likely that defense will involve movement over shorter distances and therefore be similar to the discussion for emergency services in the preceding section and major disaster relief in the following section. Freeways will provide the same type of rapid response capability for local and national defense as is available for emergencies and disasters. The availability of multiple lanes, often the opposing lanes being separated by a reasonable distance, and the higher standards for construction will contribute to the higher probability of survival and serviceability.

5. *Major Disaster Relief*

Freeways can provide much better access for emergency vehicles and for relief shipments of food, clothing, and medical supplies to communities suffering from a major disaster. Earthquakes, tornadoes, hurricanes, floods, and fires may quickly devastate a community and leave it without sufficient resources to survive on its own resources even in the short run. Major highways not only would speed relief shipments but they also would make evacuation of the injuried or infirmed easier. Major freeways, built to more rigid specifications than older roads and because of their greater width, would likely hold up better and survive a major catastrophe in a more usable condition. Interstate 80 was the only major highway route that remained open for travel across Pennsylvania during the height of hurricane Agnes in 1972. Most such benefits are short run.

6. *Health*

The reader is referred to Section C.2 for a discussion on health-care delivery services.

7. *Other Services*

The benefits from the following services are short run in nature.

a. *Postal Services.*—In 1969, the U.S. Post Office Department operated about 59,000 vehicles that traveled more than 550 million mi and carried about 78 billion pieces of mail (*93*, p. 31). Without an adequate high-speed highway system, such volumes of mail could not be moved without costly delays. Highway improvements have meant a consolidation of post offices, reducing over-all costs of the service.

b. *Mobile Homes and Preconstructed Homes.*—These are now the main source of new housing for lower income families, and are completely dependent on highways for delivery to their final sites.

c. *Banking.*—Most of the delivery of coins, currency, and cancelled checks to banks is done by motor vehicles. An antiquated highway system might seriously jeopardize the efficient operation of our banking system, resulting in higher costs for all.

F. Resource Substitution

The construction of any highway requires the use of select material in the subbase, base, and wearing course of the pavement. Highway maintenance and operation require material with specific characteristics, particularly during the winter months in those states that experience snow and ice. These materials are usually acquired as near to the location utilized as possible; however, all areas, even within a single state, do not possess the volume or quality of materials needed in either construction or maintenance. In such cases, substitute materials could be utilized.

There are all types of waste products created in our society, many of which could be used in highway construc-

tion and maintenance. One of the major sources of waste material is that from mining operations. Huge slag heaps dot the countryside in mining areas. Both open pit and tunnel mining produce vast quantities of waste material. Stone quarries, metal processing plants, and many industrial operations produce quantities of waste products that require handling and storage before eventual disposal. The reduction of ores in the production of iron and aluminum result in large quantities of waste. In gold mining areas around Johannesburg, South Africa, giant slime dumps continue to grow rivaling the tall skyscrappers of the central city for dominance of the skyline.

Many types of material have been suggested and utilized in both the construction and maintenance of highways. Solid wastes have been used in Arkansas and California (*48, 64, 111*) in both construction and maintenance. A study in Texas (*39*) examined the use of litter collected from the highway. This served the dual functions of replacing a scarce resource and providing a location for the disposal of the waste material.

Utilization of substitute or waste materials in highway construction and maintenance could be beneficial in two ways: (1) it could lower costs for materials, and (2) it would be using an abundant commodity or resource for which disposal is a problem in place of a scarce resource. Not only would eyesores be reduced, but scarce resources would be freed for alternative kinds of uses either now or at some future time.

Many wastes are not usable in their existing state, requiring some type of processing before becoming acceptable as a surrogate for more conventional kinds of aggregate. Firing to form larger size materials or crushing may be necessary. Removal of deleterious material, such as toxic chemicals, may be required to prevent them from eventually finding their way into water supplies.

Winter maintenance in the northern states usually required a combination of salt and some type of fine aggregate such as sand, fine gravel, coal wastes, or cinders. When railroads used steam engines there was an abundance of cinders, but these are no longer available. Flyash from coal burning, electric power generating stations continues to be a source of material for highways. Additional uses of waste products are described by Solomon (*104*). A detailed discussion and listing of promising replacements for conventional highway use aggregates are contained in *NCHRP Report 135* (*82*). As the more common aggregates and other highway materials become shorter in supply, the list of substitute materials from growing supplies of waste material will become more competitive and find increasing use in highway construction and maintenance.

ECONOMIC BENEFITS BIBLIOGRAPHY

1. ADKINS, W. G., "Land Value Impacts of Expressways in Dallas, Houston and San Antonio, Texas." *Hwy. Res. Board Bull. 227* (1959) pp. 50-65.
2. ALLEN, G. R., *Incorporating Economic Considerations in the Preparation of Environmental Impact Statements: A Suggested Approach.* Virginia Highway Research Council (1974) 30 pp.
3. AMERICAN ASSOCIATION OF STATE HIGHWAY OFFICIALS, *Road User Benefit Analyses For Highway Improvements.* Washington, D.C. (1960) 152 pp.
4. AMERICAN ASSOCIATION OF STATE HIGHWAY OFFICIALS, *A Policy on Design of Urban Highways and Arterial Streets.* Washington, D.C. (1973).
5. ASHLEY, R. H., and BERARD, W. F., "Interchange Development Along 180 Miles of I-94." *Hwy. Res. Rec. 96* (1965) pp. 46-58.
6. AUTOMOTIVE MANUFACTURERS ASSOCIATION, *Urban Transportation—Issues and Trends* (1963).
7. AUTOMOTIVE SAFETY FOUNDATION and JOINT COMMITTEE ON HIGHWAYS OF THE AMERICAN MUNICIPAL ASSOCIATION—AMERICAN ASSOCIATION OF STATE HIGHWAY OFFICIALS, *The Sagamore Conference on Highways and Urban Development (Guidelines For Action).* Washington, D.C. (1958) 29 pp.
8. AUTOMOTIVE SAFETY FOUNDATION, *The Hershey Conference on Freeways in the Urban Setting.* Washington, D.C. (1962) 18 pp.
9. AUTOMOTIVE SAFETY FOUNDATION, *What Freeways Mean to Your City.* Washington, D.C. (1964) 56 pp.
10. BARDWELL, G. E., and MERRY, P. R., "Measuring the Economic Impact of Limited-Access Highway on Communities." *Hwy. Res. Board Bull. 268* (1960) pp. 37-73.
11. BEATTY, R. L., "Speed Analysis of Accidents on Interstate Highways." *Public Roads,* Vol. 37, No. 3, pp. 89-102 (Dec. 1972).
12. BONE, A. J., and WOHL, M., "Massachusetts Route 128 Impact Study." *Hwy. Res. Board Bull. 227* (1959) pp. 21-49.
13. BOWERSOX, D. J., "Influence of Highways on Selection of Six Industrial Locations." *Hwy. Res. Board Bull. 268* (1960) pp. 13-28.
14. BUFFINGTON, J. L., *A Study of the Impact of Interstate Highway 45 on Huntsville, Texas.* Texas A&M University, Texas Transportation Institute, *Res. Rep. No. 4-9* (1967) 40 pp.
15. BUFFINGTON, J. L., and WOOTAN, C. V., *Economic Impact Study Along Interstate Highway 30 in Rockwall County, Texas.* Texas A&M University, Texas Transportation Institute, *Bull. No. 24* (1963) 67 pp.
16. BUREAU OF SOCIO-ECONOMIC RESEARCH, INC., *Socio-Economic Impact of I-495 on Police and Fire Protection Services.*
17. BURTON, R. C., *Economic Advantages of the Highway Systems of Virginia to the Public, to Political Subdivisions, and to the Commonwealth.* Virginia Council of Highway Investigation and Research (1962) 8 pp.
18. BURTON, R. C., *A Study of the Effects of the US-220 Bypass Upon the Town of Rocky Mount Virginia.* Virginia Council of Highway Investigation and Research (1963) 39 pp.
19. CALTRAUS, *1973 Accident Data on California State Highways* (1974).
20. CHILDS, G. W., *The Influence of Limited Access Highways on Land Value and Land Use: The Lexington, Virginia, Bypass.* Virginia Council of Highway Investigation and Research (1958) 27 pp.

21. CLAFFEY, P. J., "Characteristics of Passenger Car Travel on Toll Roads and Comparable Free Roads." *Hwy. Res. Board Bull. 306* (1961) pp. 1-22.
22. COLONY, D. C., *Study of the Effect, If Any, Of An Urban Freeway Upon Residential Properties Contiguous to the Right-of-Way.* Ohio Department of Highways.
23. COLONY, D. C., *Expressway Traffic Noise and Residential Properties.* Univ. of Toledo, Research Foundation (1967).
24. COLONY, D. C., "Residential Relocation: Experience in Ohio." Paper presented at a 3-day pilot course sponsored by the Federal Highway Administration, Washington, D.C. (Dec. 1973).
25. CONNALLY, J. A., *The Socio-Economic Impact of the Capital Beltway on Northern Virginia.* Univ. of Virginia (1968) 123 pp. and appendix.
26. CORNELL AERONAUTICAL LABORATORY, *Accident Rates as Related to Design Elements of Rural Highways. NCHRP Rep. 47* (1968) 173 pp.
27. CORSI, T. M., "A Multivariate Analysis of Land Use Change: Ohio Turnpike Interchanges." *Land Economics,* Vol. 50, No. 3, pp. 232-41 (Aug. 1974).
28. CURRY, D. A., and ANDERSON, D. G., "Procedures for Estimating Highway User Costs, Air Pollution, and Noise Effects." *NCHRP Rep. 133* (1972) 127 pp.
29. DANSEREAU, H. K., FREY, J. C., MARKHAM, J. W., PASHEK, R. D., and TWARK, R. D., "Blairsville: A Bypass Study, The Economic and Social Impact of a Highway." *Ag. Exp. Station Rep. No. 35,* The Pennsylvania State University (1962).
30. DODGE, W. H., "Influence of a Major Highway Improvement on an Agriculturally Based Economy." Univ. of Wisconsin, Bureau of Business Research and Service, *Wisconsin Commerce Papers,* Vol. 3, No. 2, 171 pp. (1967).
31. DOOM, I., "A Study of the Economic Effects of the Emporia Interchange Bypass, and Business Loop." *Progress Rep. No. 4,* Virginia Council of Highway Investigation and Research (1963). 35 pp.
32. EYERLY, R. W., "Land Use and Land Value in Four Interchange Communities: An Interim Report on the York Study." *Res. Publication No. 46,* The Pennsylvania State University, Institute for Research on Land and Water Resources (1966) 29 pp.
33. EYERLY, R. W., "Economic Impact of an Interstate Highway on Four Selected Pennsylvania Interchange Communities." Ph.D. dissertation, The Pennsylvania State University (1972) 201 pp.
34. FARNESS, D. H., "Benefits and Costs of Tourism: A Regional Point of View." *Transp. Res. Rec. 490* (1974) pp. 1-9.
35. FEE, J. C., "Accident Experience on Speed-Change Lanes of the Interstate System." *Public Roads,* Vol. 37, No. 2, pp. 61-64 (Sept. 1972).
36. FOWLER, R. D., STOCKS, A. H., and THOMPSON, W. F., "Land Use Regulation To Promote Highway Objectives in West Virginia: A Research Summary." *Res. Rep. V,* West Virginia Center for Appalachian Studies and Development (1966) 15 pp.
37. FRANKLAND, B., "Land-Use Control at Freeway Interchanges in California." *Traffic Quarterly,* Vol. 19, No. 4, pp. 541-556 (Oct. 1965).
38. FREY, J. C., DANSEREAU, H. K., PASHEK, R. D., and MARKHAM, J. W., "The Economic and Social Impact of Highways, A Progress Report of the Monroeville Case Study." *Prog. Rep. 219,* The Pennsylvania State University, Ag. Exp. Station (1960).
39. GALLAWAY, B. M., LEDBETTER, W. B., and EPPS, J. A., *Feasibility of Using Highway Litter in Highway Construction and Maintenance.* Texas A&M University, Texas Transportation Institute (Dec. 1971).
40. GAMBLE, H. B., RAPHAEL, D. L., and SAUERLENDER, O. H., "The Direct and Indirect Economic Impacts of Highway Interchange Development." *Hwy. Res. Rec. 149* (1966) pp. 42-55.
41. GAMBLE, H. B., SAUERLENDER, O. H., and LANGLEY, C. J., "Adverse and Beneficial Effects of Highways on Residential Property Values." *Transp. Res. Rec. 508* (1974) pp. 37-48.
42. GARRISON, W. L., "Approaches to Three Highway Impact Problems." *Hwy. Res. Board Bull. 227* (1959) pp. 66-77.
43. GARRISON, W. L., and MARKS, M. E., *Influence of Highway Improvements on Urban Land: A Graphic Summary.* Univ. of Washington, Seattle (1958) 70 pp.
44. GARRISON, W. L., BERRY, B. J. L., MARBLE, D. F., NYSTUEN, J. D., and MORRILL, R. L., *Studies of Highway Development and Geographic Change.* Univ. of Washington Press (1959).
45. GRAFF, D., "Interstate 105 Design Team Concepts." *Hwy. Res. Rec. 356* (1971) pp. 171-172.
46. GREENBIE, B. B., "Interchange Planning in a Rural Area." *Traffic Quarterly,* Vol. 24, No. 2, pp. 265-277 (Apr. 1970).
47. HALL, J. W., SAWHILL, R. B., and MATTESON, J. H., *User Benefits in Economic Analysis of Metropolitan Freeway Construction.* Univ. of Washington, Seattle (1970).
48. HANNON, J. B., and FORSYTH, R. A., *Highway Research Report: Fill Stabilization Using Non-Biodegradable Waste Products. Phase I.* California State Division of Highways, Sacramento (Aug. 1973).
49. HARRISON, J. W., *Economic Effects of U.S. Route 11 Bypass at Lexington, Virginia, on Business Volumes and Composition.* Charlottesville, Va. (1958) 40 pp.
50. HARTMAN, G. W., "Current Research Relating to Relocation of Families and Businesses." *Hwy. Res. Board Sp. Rep. 110* (1970) pp. 19-24.
51. HENDERSON, R. H., *Economic Impact of I-71 on North Central Ohio.* Ohio Department of Transportation, 284 pp.
52. HIBBARD, T. H., and MILLER, F., "Economic Analysis and the Environmental Overview: Suggestions for Project Recommendations by Local Governments." *Transp. Res. Rec. 490* (1974) pp. 10-19.
53. HIGHWAY RESEARCH BOARD, "Economic Analysis in

Highway Programming, Location and Design." *Sp. Rep. 56* (1960) 187 pp.
54. HIGHWAY RESEARCH BOARD, "Some Evaluations of Highway Improvement Impacts." *Bull. 268* (1960) 119 pp.
55. HIGHWAY RESEARCH BOARD, "Highway Capacity Manual 1965." *Sp. Rep. 87* (1965) 418 pp.
56. HIGHWAY RESEARCH BOARD, "Environmental Considerations in Planning, Design, and Construction. *Sp. Rep. 138* (1973) 161 pp.
57. HOCH, I., "Chicago's Accident Experiences on Arterials and Expressways." *Traffic Quarterly,* Vol. 14, pp. 340-362 (July 1960).
58. HOCH, I., "Considerations in the Development of Limited Access Highways." *Traffic Quarterly,* Vol. 14, pp. 397-413 (July 1960).
59. HOOKER, R. W., and POTTER, K. R., *The Economic Impact of I-80 on Southwestern Wyoming: A Summary.* Univ. of Wyoming, College of Commerce and Industry (1971) 167 pp.
60. HORWOOD, E. M., "Community Consequences of Highway Improvement." *Hwy. Res. Rec. 96* (1965) pp. 1-7.
61. HORWOOD, E. M., and BOYCE, R. R., *Studies of the Central Business District and Urban Freeway Development.* Univ. of Washington Press, Seattle (1959) 184 pp.
62. HORWOOD, E. M., ZELLNER, C. A., and LUDWIG, R. L., "Community Consequences of Highway Improvement." *NCHRP Rep. 18* (1965) 37 pp.
63. ISARD, W., *Location and Space-Economy.* MIT Press (1956) 350 pp.
64. JAMESON, G. D., and WYATT, W. V., "The Location and Potential Highway Use of By-Products in Arkansas." Final report, Arkansas State University, Department of Physical Science (1973).
65. JORGENSON, R., AND ASSOCIATES, "'Evaluation of Criteria For Safety Improvement on the Highway." Special report to the U.S. Department of Commerce, Bureau of Public Roads (1966).
66. KLEIN, G. E., CURRY, D. A., ELLIS, H. B., FRATESSA, C. L., MCGILLIVRAY, R. G., MOON, A. E., THOMPSON, G. I., and TILTON, P. D., *Methods of Evaluation of the Effects of Transportation Systems on Community Values.* Stanford Research Institute (1971) 290 pp. and appendix.
67. LANG, A. S., and WOHL, M., "Evaluation of Highway Impact." *Hwy. Res. Board Bull. 268* (1960) pp. 105-119.
68. LARSON, T. D., and MCKELVEY, F. X., "Environmental Impacts of Transportation Facility Design Decisions." Course notes, The Pennsylvania Transportation Institute, The Pennsylvania State University (1973).
69. LEMLY, J. H., "Expressway Influence on Land Use and Value, Atlanta, 1941-1956." *Res. Paper No. 10.* Georgia State College, Atlanta (1958) 137 pp.
70. LEOPOLD, L. B., CLARKE, F. E., HANSHAW, B. B., and BALSLEY, J. R., "A Procedure for Evaluating Environmental Impact." *Geological Survey Circular 645* (1971).
71. LEVIN, D. R., "Identifying and Measuring Non-User Benefits." *Hwy. Res. Board Sp. Rep. 56* (1960) pp. 136-147.
72. LEVIN, D. R., "The Joint Use Concept and Urban Freeway Development." *Appraisal J.,* Vol. 35, No. 3, pp. 408-413 (July 1968).
73. LEVIN, D. R., and GROSSMAN, D. A., "The Expressway Impact on a Secondary Central Business Distance." *Traffic Quarterly,* Vol. 15, pp. 185-207 (Apr. 1961).
74. LISCO, T. E., *Value of Commuters Travel Time—A Study in Urban Transportation.* Univ. of Chicago (1967).
75. LISCO, T. E., "The Common Economics of Travel Time Value." *Technical Paper and Note Series No. 13.* Office of Research and Development, Illinois Department of Transportation (1973) 33 pp.
76. LONGLEY, J. W., and GOLEY, B. T., "A Statistical Evaluation of the Influence of Highways on Rural Land Values in the United States." *Hwy. Res. Board Bull.* 327 (1962) pp. 21-55.
77. MCELHINEY, P. T., "Evaluating Freeway Performance in Los Angeles." *Traffic Quarterly,* Vol. 14, pp. 296-312 (July 1960).
78. MCGOUGH, B. C., "Methodology For Highway Impact Studies." *Appraisal J.,* Vol. 36, No. 1, pp. 64-72 (Jan. 1968).
79. MCKAIN, W. C., "The Connecticut Turnpike: Ribbon of Hope. Univ., of Connecticut, Storrs Ag. Exp. Station (1964) 120 pp.
80. MCKINNEY, D., and LOWRY, P. R., *Interstate Right-of-Way Acquisition and Road Closures in South Mississippi.* Univ. of Mississippi (1963) 89 pp.
81. MANHEIM, M. L., SUHRBIER, J. H., RENO, A. T., BENNETT, E., COLCORD, F. C., JR., BLEIKER, H., COHEN, H., GIEL, R., PETERSILIA, M., and TRYENS, J., "Community Values in Highway Location and Design: A Procedural Guide." *Rep. No. 71-74,* MIT Urban Systems Laboratory (1971).
82. MAREK, C. R., HERRIN, M., KESLER, C. E., and BARENBERG, E. J., "Promising Replacements for Conventional Aggregates for Highway Use." *NCHRP Rep. 135* (1972) 53 pp.
83. MATTSON, J. O., "The Traffic Accident Outlook." *Traffic Quarterly,* Vol. 18, pp. 310-320 (July 1964).
84. MILLER, G. K., and GOODMAN, K. M., *The Shirley Highway Express-Bus-on-Freeway Demonstration Project/First Year Results.* National Bureau of Standards, Technical Analysis Division (Nov. 1972).
85. MILLER, S. F., JR., "Effects of Proposed Highway Improvements on Property Values." *NCHRP Rep. 114* (1971) 42 pp.
86. MINNESOTA DEPARTMENT OF HIGHWAYS, *Economic Effects of a Highway Bypass on Austin, Minnesota* (1968) 67 pp.
87. MOHRING, H., "Urban Highway Investments." *Measuring Benefits of Government Investments.* Brookings Institution (1964).
88. MOHRING, H., and HARWITZ, M., *Highway Benefits: An Analytical Framework.* Northwestern University Press, Evanston, Ill. (1962) 209 pp.

89. MOORE, C. T., MAYER, M. L., LIPSON, H. A., and JOYCE, G., "A Study of the Expected Economic and Social Impact of Interstate Highways in the Industrial and Commercial Trading Area of Birmingham, Alabama—The First Phase." *HRP Rep. No. 38,* Alabama Highway Department (1968) 132 pp.
90. MOORE, C. T., MAYER, M. L., TREAS, C. E., MASON, J. B., and DAWSON, L. E., *Capital and Income Effects of Signboard Regulation, Control, and Removal on Selected Kinds of Businesses and Land Segments Located on Interstate and Primary Highway Systems in Alabama.* Univ. of Alabama, Alabama Highway Research Group (1967) 121 pp.
91. MOORE, C. T., MASON, J. B., MAYER, M. L., and DAWSON, L. E., JR., *Land Use Analysis in a Highway Corridor.* Univ. of Alabama, Alabama Highway Research Group (1968) 121 pp.
92. MORRIS, S. S., "Freeways and the Urban Traffic Problem." *Traffic Quarterly,* Vol. 27, No. 4, pp. 519 (Oct. 1973).
93. National Highway Users Conference, *The Highway Transportation Story in Facts* (1969) 42 pp.
94. OGLESBY, C. H., *Highway Engineering.* John Wiley & Sons (1975) 783 pp.
95. OHIO DEPARTMENT OF HIGHWAYS, Economic Research Section, *Land Economic Studies in the State of Ohio: The North-South Freeway I R-71 (Franklin County)* (1968) 257 pp.
96. OREGON STATE HIGHWAY DEPARTMENT, *Valued Trend Studies: Residential Subdivisions Along Suburban Freeways—Greater Portland Area* (1961) 32 pp.
97. PENDLETON, W. C., "Relation of Highway Accessibility to Urban Real Estate Values." *Hwy. Res. Rec. 16* (NOV. 1962) pp. 14-23.
98. PENDLETON, W. C., "An Empirical Study of Changes in Land Use at Freeway Interchanges." *Traffic Quarterly,* pp. 89-100 (Jan. 1965).
99. PENNSYLVANIA STATE PLANNING BOARD, *A New Front Door.*
100. REAL ESTATE RESEARCH CORPORATION, *A Study of the Impact of Major Highways on Local Tax Bases* (1960) 83 pp.
101. SANDERS, R. D., *The Economic Impact of Interstate Highway 35 on Towns in North Central Oklahoma.* Oklahoma Department of Highways (1973) 293 pp. and appendix.
102. SAUERLENDER, O. H., DONALDSON, R. B., JR., and TWARK, R. D., "Factors That Influence Economic Development at Non-Urban Interchange Locations." *Res. Pub. No. 48.* The Pennsylvania State University, Institute for Research on Land and Water Resources (1966) 53 pp.
103. SAUERLENDER, O. H., REA, J. C., TWARK, R. D., HERENDEEN, J. H., JR., PAGANO, A. M., ROBERTS, C., SPOTTHEIM, D., and THOMPSON, H. T., *The Highways Corridor: Predicting the Consequences of Alternative Highway Locations.* The Pennsylvania State University, Pennsylvania Transportation and Traffic Safety Center (Nov. 1972) 228 pp. and appendix.
104. SOLOMON, D., "Environmental Research and Highways." *Public Roads,* Vol. 37, No. 8, pp. 297-305 (Mar. 1974).
105. STEIN, M. M., "Highway Interchange Area Development—Some Recent Findings." *Public Roads,* Vol. 35, No. 11, pp. 241-250 (Dec. 1969).
106. TEXAS A&M UNIVERSITY, *Consequences of Freeway Development to Urban Residents in Low-Valued Housing.* College Station, Texas (1973).
107. THIEL, F. I., "Social Effects of Modern Highway Transportation." *Hwy. Res. Board Bull. 327* (1962) pp.1-20.
108. THIEL, F., and YASNOWSKY, J., "Some Effects of Highway Beautification." *Hwy. Res. Rec. 233* (1968) pp. 1-15.
109. THOMAS, T. C., *The Value of Time for Passenger Cars: An Experimental Study of Commuters' Values.* Stanford Research Institute (1967).
110. THOMPSON, W. R., *A Preface to Urban Economics.* Johns Hopkins Press (1965) 411 pp.
111. THORTON, S. I., and WELCH, R. C., *Arkansas Waste in Municipal Areas Suitable for Highway Construction or Maintenance.* Arkansas University, Department of Civil Engineering (1973).
112. TWARK, R. D., "A Predictive Model of Economic Development at Non-Urban Interchange Sites on Pennsylvania Interstate Highways." Ph.D. dissertation, The Pennsylvania State University (1967).
113. U.S. DEPT. OF COMMERCE, BUREAU OF PUBLIC ROADS, *Highways and Economic and Social Changes.* Washington, D.C. (1964).
114. U.S. DEPT. OF TRANSPORTATION, FEDERAL HIGHWAY ADMINISTRATION, *Benefits of Interstate Highways.* Washington, D.C. (1970) 37 pp.
115. U.S. DEPT. OF TRANSPORTATION, FEDERAL HIGHWAY ADMINISTRATION, *Economic and Social Effects of Highways—1972,* 373 pp.
116. U.S. DEPT. OF TRANSPORTATION, FEDERAL HIGHWAY ADMINISTRATION, *Social and Economic Effects of Highways*—1974, 180 pp.
117. WALLACE, R. J., and LEMLY, J. H., *Analysis of Economic Impact of Highway Change on 2 Small Georgia Communities.* Georgia State College (1969) 110 pp.
118. WALTON, L. E., JR., *A Return on Investment Analysis of Virginia. Interstate System.* Virginia Highway Research Council (1970) 55 pp.
119. WASHINGTON STATE UNIVERSITY, Highway Research Section, Engr. Res. Div. *A Study of the Social, Economic, and Environmental Impact of Highway Transportation Facilities on Urban Communities.* Pullman, Washington (1968) 208 pp.
120. WEINER, P., and DEAK, E. J., *Environmental Factors in Transportation Planning.* D.C. Heath and Co. (1972) 283 pp.
121. WELLS, D. R., *An Economic Impact Study of the Effects of Interstate 55 on The Highway Related Businesses in Five Northeastern Mississippi Towns.* Univ. of Mississippi, Bureau of Business and Economic Research (1967) 58 pp.
122. WENDT, P. F., "Influence of Transportation Changes

on Urban Land Use and Values." *Hwy. Res. Board Bull. 268* (1960) pp. 95-104.
123. WILBUR SMITH AND ASSOCIATES, *Maryland Capital Beltway Impact Study*. Columbia, S.C. (1968).
124. WILBUR SMITH AND ASSOCIATES, *A Socio-economic Study of Highway Development I-287, I-95 Corridor, Middlesex and Somerset Counties, New Jersey —1967*. Columbia, S.C. (1968) 172 pp. and appendix.
125. WILLIAMS, H. L., and DAVIS, W. D., "Effects of Scenic Easement on the Market Value of Real Property." *Appraisal J.*, Vol. 36, No. 1, pp. 15-24 (Jan. 1968).
126. WILLIAMS, R. L., and KOSHAL, R. K., *Highways and Economic Development in Ohio*, Vol. 1. Ohio University (1970).
127. WINFREY, R., *Economic Analysis for Highways*. International Textbook Co., Scranton, Pa. (1969) 923 pp.
128. WINFREY, R., and ZELLNER, C., "Summary and Evaluation of Economic Consequences of Highway Improvements." *NCHRP Rep. 122* (1971) 324 pp.
129. Wisconsin State Highway Commission, *Wisconsin Interchange Land Transaction Study—Preliminary Summary Report* (1967) 7 pp.
130. ZETTEL, R. M., "The Incidence of Highway Benefits." *Hwy. Res. Board Sp. Rep. 56* (1960) pp. 148-163.
131. ZICKEFOOSE, P. W., "Economic Survey of Raton, New Mexico, 1958-1966." *Bull. 37*, New Mexico State University, Engineering Experiment Station (May 1968) 62 pp.

APPENDIX D

GLOSSARY

ENVIRONMENTAL

Adventitious Plants—plants, originating in foreign countries, which grow particularly well on recently disturbed sites. Most are considered weeds.

Aquifer—a porous water-bearing deposit (e.g. gravel, sand, bedrock), which stores and transmits an appreciable supply of water.

Design Element—any characteristic of a plan that is attributable to the intent of the designer, and that usually is delineated in drawings produced during the planning process.

Forbs—broad leafed herbs; all nonwoody land plants except grasses.

Highway Geometrics—the configuration of the highway alignment.

Invertebrate Animals—all animals without backbones, including insects, worms, and snails. Mammals, birds, reptiles, amphibians, and fishes are the only animals with backbones.

Karst—a type of limestone or dolomite terrain that possesses a topography peculiar to and dependent on underground solution weathering and the diversion of surface waters to underground routes.

Landscape Form—the shape or external appearance of the land and any of the elements that contribute to the appearance of the landscape.

Monoculture—cultivation of a single species of plant, excluding most other possible uses of the land.

Perched Water Table—the upper surface of a body of ground water that is separated from an underlying body of ground water by unsaturated rock, and whose position is controlled by structure or stratigraphy.

Permeability—the capacity of a rock or soil to transmit a fluid.

Scenic Corridor—the strip of land that is seen from the highway, the boundaries of which are the natural or man-made limits of the view.

Soil Configuration—the constituents of the soil and their spatial relationships.

Spatial Relationships—the pattern of space in the landscape, including the spatial array of urban development, the pattern of natural features in the rural landscape, and combinations in the display of man-made and natural spaces.

Visual Access—providing or improving the opportunity for viewing an object.

Visual Coherency—a state of accord among the elements of a view (i.e. an aesthetically consistent landscape).

Visual Continuity—close union of the objects that are in the motorist's view. The view for the motorist proceedes without interruption.

Visual Encroachment—any intrusion into the sight of the motorist that detracts from his view.

Visual Experience—a collection of continued and varied observations through which the viewer gains impressions.

Visual Quality—the relative extent to which the characteristics of a scene are pleasing to the viewer.

SOCIAL

Living Space—specific places of dwelling as well as open space areas surrounding urban areas and villages that are frequented by the public.

Outdoor Recreation—leisure activities taking place in an outdoor setting.

Pleasure Driving—the use of a motor vehicle for direct recreational benefit or as a means to reach an area in which to recreate.

Provincialism—essentially the strict adherence to local cus-

toms or ideas, with a concomitant lack of awareness or rejection of alternative customs or ideas.

Social Mobility—a change in an individual's socioeconomic status.

Socioeconomic Status—as used by the U.S. Bureau of the Census, refers to people's occupational, income, and educational levels of attainment.

ECONOMIC

Agglomeration Economies—efficiencies gained by the clustering of interdependent firms, usually derived from lower transportation costs for interfirm shipments.

Direct Effects—direct highway effects are those benefits or costs, monetary or nonmonetary, that accrue to highway users, be they individual motorists, highway-user-oriented businesses, or highway transportation dependent firms.

Double Counting (of highway effects)—the counting of a highway economic effect more than once, as when a direct effect and its subsequent indirect or secondary effects are added and claimed as the total effect. The best example of double counting is adding travel time and cost savings to increases in land values stemming from highway change to get total economic benefits.

Economic Impact—the change, for better or for worse, in the income, wealth, or welfare position of individuals, communities, or regions as a result of highway development expenditures.

Economies of Scale—the improvement in production efficiency as firms become larger, as shown by decreasing average costs of production with increasing firm size and levels of output.

Gross Benefits—the total of all benefits resulting from a highway improvement without taking into account any of the associated direct or indirect costs.

Improved Accessibility—a reduction in travel time and costs for the movement of goods and/or people between a given location and other locations as a result of highway developments.

Improved Efficiency—a lowering of the costs of producing one unit of output, or decreasing average costs of production.

Incidence of Effects—identifying which individuals or groups in society experience benefits and/or costs resulting from a highway development and identifying the nature and/or magnitude of such effects.

Indirect Effects—effects from highway improvements that are associated with highway nonusers; such effects imply a disassociation between highway use and the receiving of an effect, and may arise from a transference of user effects to nonusers.

Induced Travel Demand—additional trips or use made of a highway as a result of improved accessibility.

Interregional Effects—changes in the social and economic characteristics in one region as a result of a given highway improvement in another region.

Joint Development—utilizing a highway corridor or a right-of-way for purposes other than the use of motor vehicles.

Locational Advantages—the benefits derived from a specific site or location as compared to some alternative site. As related to highways, locational advantages generally arise because of better accessibility.

Long Run Economic Effects—those economic effects that are apt to persist or remain with the recipient over a considerable period of time, usually years.

Net Benefit—measure of benefit derived by subtracting from the total or gross monetary and nonmonetary benefit the total monetary and nonmonetary costs associated with a highway improvement.

Nonuser Benefits—the benefits accruing to individuals and firms whose gains are a result of the highway but come about indirectly, generally through a transfer from highway users.

Opportunity Cost—the returns that would be earned by a capital asset or a factor of production if employed in the most profitable alternative way.

Short Run Economic Effect—an economic effect from a highway that is transitory in nature, and remains with the recipient for only a few hours, days, or weeks.

Social Economic Effects—those beneficial and adverse effects from a highway improvement that alter the income or wealth position of an individual, firm, or community but which cannot be adequately measured in terms of value.

User Benefits—those gains accruing to individuals and firms that result from their direct use of a highway. These benefits usually are in the form of reduced vehicular operating costs; travel time savings; and reduced accidents, injuries, and deaths.

THE TRANSPORTATION RESEARCH BOARD is an agency of the National Research Council, which serves the National Academy of Sciences and the National Academy of Engineering. The Board's purpose is to stimulate research concerning the nature and performance of transportation systems, to disseminate information that the research produces, and to encourage the application of appropriate research findings. The Board's program is carried out by more than 150 committees and task forces composed of more than 1,800 administrators, engineers, social scientists, and educators who serve without compensation. The program is supported by state transportation and highway departments, the U.S. Department of Transportation, and other organizations interested in the development of transportation.

The Transportation Research Board operates within the Commission on Sociotechnical Systems of the National Research Council. The Council was organized in 1916 at the request of President Woodrow Wilson as an agency of the National Academy of Sciences to enable the broad community of scientists and engineers to associate their efforts with those of the Academy membership. Members of the Council are appointed by the president of the Academy and are drawn from academic, industrial, and governmental organizations throughout the United States.

The National Academy of Sciences was established by a congressional act of incorporation signed by President Abraham Lincoln on March 3, 1863, to further science and its use for the general welfare by bringing together the most qualified individuals to deal with scientific and technological problems of broad significance. It is a private, honorary organization of more than 1,000 scientists elected on the basis of outstanding contributions to knowledge and is supported by private and public funds. Under the terms of its congressional charter, the Academy is called upon to act as an official—yet independent—advisor to the federal government in any matter of science and technology, although it is not a government agency and its activities are not limited to those on behalf of the government.

To share in the tasks of furthering science and engineering and of advising the federal government, the National Academy of Engineering was established on December 5, 1964, under the authority of the act of incorporation of the National Academy of Sciences. Its advisory activities are closely coordinated with those of the National Academy of Sciences, but it is independent and autonomous in its organization and election of members.

TRANSPORTATION RESEARCH BOARD
National Research Council
2101 Constitution Avenue, N.W.
Washington, D.C. 20418

ADDRESS CORRECTION REQUESTED

NON-PROFIT ORG.
U.S. POSTAGE
PAID
WASHINGTON, D.C.
PERMIT NO. 42970

OOOO15MOO3
MATERIALS ENGR

IDAHO TRANS DEPT DIV OF HWYS
P O BOX 7129
BOISE ID 83707