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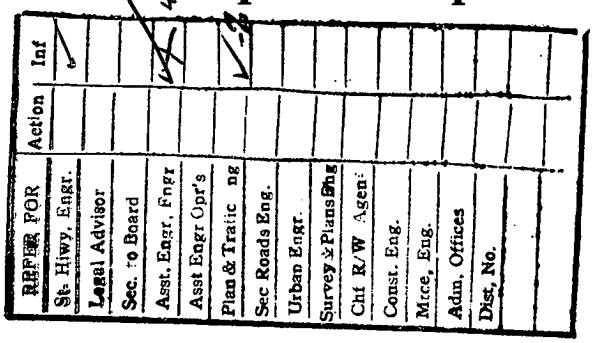
Special Report 56



Economic Analysis in Highway Programming, Location and Design

Workshop Conference Proceedings

September 17-18, 1959

National Academy of Sciences—
National Research Council

publication 775

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SEPTEMBER 17 - 18, 1959

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Foreword

Economic analysis of proposed ventures in investment is traditional in an engineering study for industry. It is a classic device and major determinant in the several fields of transport planning — for many years in railroad location and design. Economic analysis has also been applied in the choice of alternatives in location and design features in highway engineering and with an accelerating acceptance in recent years. An economic analysis of systems is just beginning.

During the last 20 years, students of the highway improvement problem have developed and also adapted from industry various concepts and techniques for use in investment decisions to be made by highway administrators and engineers. Among these are the benefit-cost ratio, incremental solution, the rate of return on investment, total annual transportation costs, sufficiency ratings, solvency quotients, warrants and priority criteria, impact of improvement, and related logic, concepts and philosophies, and their interdependence.

The purpose of this conference was to seek out the relevant factors, methods of measurement, and techniques in relating highway costs with benefits and other consequences of highway provision and use; and to point up the problems and the role of economic analysis (and its several techniques) in highway programming, location and design.

It was felt that such a forum would provide an ideal way not only to expose the present concepts and methods to a careful and critical scrutiny but also to explore the socio-economic territory, the present no-man's land between planner and engineer. This forum would also be the ideal place to introduce questions, exchange ideas, and air concepts, rather than to enunciate conference recommendations. It was intended to provide for a variety of viewpoints to raise and entertain "pro-con" discussions of several fundamental questions.

Certain discussions were sought, such as:

1. What considerations are involved in systems analysis?
2. What are the total values involved?
3. Are sufficiency ratings sufficient in systems analysis?
4. Should highway improvement programs and priorities be economy based?
5. What is the relation of market economics and socio-economics in highway programming?
6. How can monetary evaluations of time, comfort and convenience be objectively determined?
7. What is the relationship of annual costs in an economic analysis to annual costs in cost accountancy?
8. What is the role of non-user consequences in economic analysis?
9. How are net gains and losses determined?
10. Should economic consequences to the non-user be considered in allocating costs of highways?

This is the second of a series of planned economic conferences. The first, Economic Impact of Highway Improvement was held in 1957.

In providing this forum the Highway Research Board does not take or argue for any position but has arranged it solely as a public service to highway administrator, planner and engineer.

In addition to the acknowledgments tendered during the conference to presiding officers, discussion leaders and participants and of record in the Proceedings, grateful acknowledgment is specially made to G. P. St. Clair, the general chairman of the conference, who ably assisted in all pre- and post-conference arrangements and who together with presiding officers Robley Winfrey, James S. Burch, William G. Adkins and Staff Engineer M. Earl Campbell, pre-edited the Conference Proceedings.

The deep appreciation of the Board is also expressed for financial assistance from the Automotive Safety Foundation and the U. S. Bureau of Public Roads which made this Conference possible.

Fred Burggraf, Director

Contents

SESSION ONE

Thursday, September 17, at 9:00 A.M.

THEORY, PRINCIPLES, CONCEPTS, AND APPLICATIONS

G. P. ST. CLAIR, General Chairman, Presiding

St. Clair. — We are here to discuss economic analysis in highway programming, location and design. Discussion is the primary purpose, although there are some prepared papers. Mr. Campbell will read the welcoming remarks of Mr. Burggraf, Director of the Highway Research Board.

Welcoming Remarks

FRED BURGGRAF
Director, Highway Research Board

It is always a pleasure to welcome groups in the pursuit of understanding to this National Academy of Sciences, and it is a distinct personal pleasure to welcome you to this informal workshop conference on economic analysis.

The men who conceived the Highway Research Board in 1920 wanted to get 100 cents worth of value out of every dollar spent in highway transport. Back of every highway research project since has been the question of economy: economy in terms of conservation of human life and energy, material resources, and time—plus the extenstion of the service life of highways and production of better quality of transport service—in short, the reduction of transportation costs and upgrading of its quality. Wise choices are required in evolving a comprehensive plan, and in deciding among all of its possible components, and even among their individual parts, in order to accomplish the most in economy.

In 1920 the total expenditure for highways by all jurisdictions of government was about one-tenth of the expenditures last year (1921 expenditure 1,338 million dollars — 1958 estimate, 9,414 million dollars). If we were concerned about engineering economics 39 years ago we should be ten times as much concerned today and our concern will necessarily be compounded in the years ahead.

In the field of economic analysis and its involvement with socio-political considerations the awareness of problems has truly increased. And this two-day workshop is not expected to lay all of the problems to rest. But we do have great faith in the effectiveness of an exchange of ideas, however diverse. We hope that this assembly, mustered now to discuss, inquire, probe, and reason together will, from aggregated ideas, found the logic of an economic philosophy and the principles of an economic calculus which are suited to the highway field, the starting point for decision-making.

But if you should be able only to delineate specific research problems in one or more areas — problems which are subject to solution by either the rational or empirical method — you will have carried out a principal objective of this workshop, and a primary function of the Board. If you clear away some of the mystery and show the potential role of economic analysis in the highway field you will have performed another service.

The prelude to the convening of this conference provides a typical example of the catalytic action of a stimulating idea. Just after the 38th Annual Meeting we received a communication from C.A. Rothrock asking if we could arrange a schedule of conferences for him with specialists in economic analysis in the Washington area. As conferences were sought, each person approached suggested a broadening of the confer-

ence to include others. The idea mushroomed until it was suggested that a limit of 15 be set for the discussions. It mushroomed again and the limit was set at 25. It mushroomed again with the limit set at 35. We tried to hold it there but as you see we have about 40 participants plus observers.

These eight months have been busy ones, and busy for Mr. St. Clair especially. He, together with Robley Winfrey, Robert G. Hennes, Carl Saal and Earl Campbell, has planned the program. He has persuaded you to do the preparatory homework to guarantee a stimulating conference — we thank you for this. And Mr. St. Clair has been the prime mover in enlisting the Automotive Safety Foundation, the Bureau of Public Roads, and the Highway Research Board to cooperate in the sponsorship of this meeting under the immediate aegis of the Department of Economics, Finance and Administration.

I wish to acknowledge with deep appreciation the contributions of these men and of the sponsoring agencies. In behalf of the Executive Committee of the Board, and also on my own behalf, I want to extend a warm welcome to each of you and thank you now for your participation and contribution.

Economic Analysis: A Study in Uncertainties

G. P. ST. CLAIR, Chairman, Department of Economics, Finance and Administration

● BEN JONSON wrote of Shakespeare that he had "...small Latin and less Greek" (1). As one who has small Engineering and less Economics I feel myself admirably fitted to be General Chairman of a Conference on Economic Analysis in Highway Programing, Location and Design; for a general chairman makes no decisions, and is not obliged to take a position on any subject whatever.

Having been told, nonetheless, by the organizing committee that I was to lead off as a keynoter for this conference, I have conceived the notion that it might be well to start the orchestration by sounding a sour note. I am going to follow the lead of a well-beloved radio and TV figure and of that much less beloved fictional character, Uriah Heep, in preaching a counsel of humility in dealing with the subject matter of the next two days.

There can be heard at times, among those who deal with the economics of highway engineering, a note of undue certainty, of rather questionable positiveness, about the precision of estimates and forecasts, the truth of hypotheses and postulates, and perhaps even the God-given-ness of dogmas and prejudices. One hears accepted experts proclaim the Economic Law, as thunderers from Mt. Sinai; and one sometimes wonders whether this bold front may not mask an inner lack of confidence in the validity of what they preach.

But, one may say, research engineers and research economists are scientists. Their findings, based on experiment, observation, and applications of the statistical method, are the necessary basis of planning and action. This is true; it is equally true that the scientific findings of one day may become the discarded waste of the next. Surely Albert Einstein, in developing the theory of relativity and later the unified field theory, had little doubt that, as his findings displaced the Newtonian physics, so they in turn must give way to new discoveries and a new synthesis. The Einsteins and the Oppenheimers are the humblest and least assertive of men. And so, if we admit that we may be wrong, or that we may have hold of a temporary rather than an eternal truth, we are in the best of company — in the company, indeed, of such as Galileo, Kepler, Newton, and Darwin. That is why I feel that the hesitant suggestion — even the bashful stammer — will be more seemly in our deliberations than the bold, brassy pronouncement.

Underlying all work in economic analysis — although not so readily perceived when we are concerned only with the relative advantages to traffic of alternative locations or designs — is the concept of the economic allocation of limited resources. A corollary of this concept, which in part determines the assumptions and the analytical devices that we use, is the dictum that the market economy of private enterprise is the basic and sure means by which economic allocation of resources is brought about. In the public economy, the maximizing of benefits is substituted for the maximizing of profits; but we attempt to utilize the same frameworks of analysis; and indeed we put benefits in competition with prospective profits or profits forgone when we try to determine the economic warrant for a program of public investment. Each of the following quotations has some bearing on this, or some other, canon of the rites we celebrate at this gathering.

I will lead off with a Golden Text from the recent Brookings publication, "Federal Budget and Fiscal Policy," by Lewis H. Kimmel.

> Underlying the analysis is the thought that the great majority of ideas in economics and finance have a time-and-place significance. They are not immutable truths. Yet specific doctrines are often expounded in a manner that suggests neither temporal

> nor institutional limitations.... Any theory or idea should be appraised in the light of the conditions prevailing in the society in which it was advanced. (2, p. 1)

ALLOCATION OF RESOURCES

John Kenneth Galbraith in "The Affluent Society" says some provocative things about "...the ancient conviction that resources must be allocated efficiently between their various employments and that the free market is the most efficient and possibly even the only satisfactory instrument of such allocation." (3, p. 224) In discussing the position of production in the United States he declares that we do not pay enough attention to increasing the labor force, to increased capital formation, or even to technological improvement; and goes on to state:

> ....Our operative concern for increasing production is confined to the measures — for getting greater resources use efficiency and promoting thrift and diligence — which were relevant a century ago. The newer dimensions along which there might be progress attract our attention scarcely at all. (3, p. 131)

Galbraith drives the point home by contrasting the preoccupation with market-motivated allocation of resources with the direct, purposive action to get the job done, regardless of the conventional standards of efficiency, that takes place during wartime.

> ....Under the stress of circumstance the conventional wisdom is rejected. We set about expanding output along all the relevant dimensions. Serious efforts are made to expand the labor force. It becomes permissible to import toilers with swarthy skins who speak unintelligible languages. The drive for increased saving becomes serious. Where investment is inadequate more is made. There is no involuntary idleness. As in the case of alloy steels, synthetic rubber manufacture, and ship construction in World War II, technology is brought purposefully to play to permit of expanded output with available resources. (3, p. 131)

Although not within the bounds of the conventional wisdon, it is not unheard of to question the effectiveness of resource allocation via the market economy. One might, for example, doubt the economic as well as the social soundness of the relative investment in call-girls and schoolma'ams, albeit bearing in mind that the services of the one and not those of the other may become legitimate tax deductions for business expenses. Galbraith has a word to say on this score:

> In a free market, in an age of endemic inflation, it is unquestionably more rewarding, in purely pecuniary terms to be a speculator or a prostitute than a teacher, a preacher or policeman. Such is what the conventional wisdom calls the structure of incentive. (3, p. 223)

And, perhaps closer to the present focus of interest:

> We view the production of some of the most frivolous goods with pride. We regard the production of some of the most significant and civilizing services with regret ....Automobiles have an importance greater than the roads on which they are driven. We welcome expansion of telephone services as improving the general well-being but accept curtailment of postal services as signifying necessary economy. We set great store by the increase in private wealth but regret the added outlays for the police force by which it is protected. (3, pp. 132-134)

IMPLICATIONS OF THE ECONOMY OF AFFLUENCE

Galbraith's central thesis, of course, is that we are no longer in an economy of scarcity, where the task is to allocate limited resources to the production and distribution of goods and services that will fall far short of meeting the needs of the populace for food, clothing, and shelter; but in an economy of affluence where these elementary needs are satisfied as a matter of course, and all the vast resources of advertising and salesmanship are now marshalled in the effort to create new wants so that the production machine may continue to function and expand. To quote:

> A man who is hungry needs never to be told of his need for food. If he is inspired by his appetite, he is immune to the influence of Messrs. Batten, Barton, Durstine, and Osborn. The latter are effective only with those who are so far removed from physical want that they do not already know what they want. In this state alone men are open to persuasion. (3, p. 158)

In emphasizing this point he further states:

> ....As a society becomes increasingly affluent, wants are increasingly created by the process by which they are satisfied ....If production is to increase, the wants must be effectively contrived. In the absence of the contrivance the increase would not occur. This is not true of all goods, but that it is true of a substantial part is sufficient. It means that since the demand for this part would not exist, were it not contrived, its utility or urgency, ex contrivance, is zero. If we regard this production as marginal, we may say that the marginal utility of present aggregate output, ex advertising and salesmanship, is zero. (3, pp. 158-160)

If this analysis is accepted, then the doctrine that the market economy automatically brings about the most efficient allocation of resources suffers a severe blow. For if the wants must be fabricated with the products, the social and economic essentiality of the goods and services so marketed is ever open to doubt. At the very least we may question whether we are obligated to use the analogies, the coefficients, the factors of the marketplace – commercial interest rates or rates of return, for example – in determining the economic warrant for public investments. On this point let me give one last quotation from Galbraith:

> ....There will be a question as to what is the test of balance – at what point may we conclude that balance has been achieved in the satisfaction of public and private needs. The answer is that no test can be applied, for none exists. The traditional formulation is that the satisfaction returned to the community from a marginal increment of resources devoted to public purposes should be equal to the satisfaction of the same increment in private employment. These are incommensurate, partly because different people are involved, and partly because it makes the cardinal error of comparing satisfaction of wants that are synthesized with those that are not. (3, pp. 320-321)

ANOTHER CONTEMPORARY VIEW

But Galbraith is a Harvard professor, one of a breed notorious for new, unconventional, and unorthodox ideas. Perhaps it would be well to inquire whether such doubts have invaded institutions of learning to the west of Harvard Yard.

In the 1959 publication, "Public Finance," by the Committee on Public Finance, we find a mixed bag of 66 co-authors from colleges and universities scattered from Maine to California, with not a few from the Middle West and South. In this work, surely of impeccable orthodoxy, we find, in a section titled, "The Economic Effects of Transportation Expenditures," the following:

> Government subsidies have been granted to all major types of transportation except pipelines. These subsidies received popular approval because it was believed that they would accelerate the general economic growth of the nation. A secondary basis for this approval arose from military needs. An examination of the history of the United States shows that these were actually sound judgments and compare very favorably with judgments made through the market. Because the market quotes relative values in dollars and even cents, it gives the impression of definiteness, sureness, and accuracy; whereas because political decisions to grant subsidies are the subject of wrangling, charges and countercharges, and compromises, they give the impression of indefiniteness, unsureness, and inaccuracy. Both impressions are largely illusions. Past records of the market and government budgets in allocating and using resources indicate that both have made very grave errors and that both have been very sound in their judgments. (4, pp. 232-3)

AN EARLIER COMMENT

The quoted works are still rather hot off the presses. It is appropriate to inquire whether there is any history of rebellion against the market-based economic analysis. There is time for but one quotation. Professor Horace M. Gray of the University of Illinois, writing in 1940 in the Journal of Land and Public Utility Economics on "The Passing of the Public Utility Concept," made some statements which, though tangential to our theme, seem to imply that the techniques and procedures of public investment are neither to be judged nor to be shackled by the standards and concepts of private enterprise. Referring primarily to public utilities, he wrote:

> ....Under the prevailing system of monopoly capitalism, private enterprise seems to have lost, in large measure, its power to plan constructively for progressive improvement of the economy. This failure is observable in many areas and, in the utility field, is most apparent in connection with water resources, electric power, natural gas, communication, and transportation. (5, p. 9)

In contrast he offered the following:

> Within recent years the "institutional inventiveness" of political leaders and public administrators has produced a number of such new institutional arrangements. Among these are: Direct action by departments or bureaus of the Federal Government to supply needed facilities; public corporations charted under both Federal and State authority; multiple-purpose, regional, water-control projects; rural electric cooperatives; Federal grants-in-aid; Federal-State-municipal cooperation; Public Works loans-and-grants; Reconstruction Finance Corporation loans; and Federal subsidy for desirable services. None of these comes within the traditional public utility concept; they all involve direct, positive action rather than mere negative restraint; ...instead of relying exclusively on the police power of the States and the commerce power of the Federal Constitution, ...they call into play other more positive and less restricted powers of the Federal Government, such as the proprietary, finance, public welfare and national defense powers. In every respect, therefore, these new institutional devices appear more capable of serving modern social needs than do private monopolies operating under public utility regulation. (5, p. 8, 9)

In offering these borrowed observations I have no intention to decry the importance of our task at this conference, or the essentiality of the economic analysis of highway

projects and programs. What I desire is to introduce into the deliberations a flavor of salty skepticism, a disposition toward critical examination, a propensity toward greeting even our own pronouncements with suspicion. If we can get into that mood we will have a successful conference.

This invocation of a mood of caustic inquiry is closely linked with the mode of operation of the conference itself. It is our plan to make the floor discussions equally important with the prepared papers, if not more so. To this end the session chairmen are instructed to cut each speaker short promptly at 20 minutes. The speakers in turn are besought to withhold some of their best ammunition to repel attackers during the floor discussion. To those who are neither chairmen nor discussion leaders I would say, "Spring promptly to the attack. Be searching in your inquiries, merciless but fair in your criticisms, persistent in your search for the truth."

An finally, permit me one last quotation, this time not from an economist but from a poet (6).

> There lives more faith in honest doubt,
> Believe me, than in half the creeds!

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Concepts and Applications of Engineering Economy

EUGENE L. GRANT, Professor of Economics of Engineering, Stanford University

● MANY OF THE professionals in the field of modern engineering economy are too young to be aware that the father of their subject is Arthur M. Wellington. Certain of Wellington's remarks made eighty-two years ago in his classic work, "The Economic Theory of Railway Location," seem to be appropriate to the theme of this conference. For example, he stressed the point that no two problems in railway location were quite alike with respect to traffic, topography, and other matters. In the usual case (in 1877) where railway managements failed to recognize the existence of any economic principles to govern location and design, this diversity of physical and economic circumstances had a number of bad results. One such result was that management was unable to distinguish between good and bad decisions on location and design.

"He who has done well," said Wellington, "is shut off from adequate recognition of the fact. The same is true of one who has done poorly. The level of average practice is restricted not to the sum of the united abilities of all engaged in it, but to the average level of capacity and knowledge. Corporations take it for granted that there is no measurable difference in qualifications for such work, and such work is entrusted to lowly paid subordinates who consider the work mainly from the constructive standpoint. It is assumed that whoever is competent to design the railway structures is competent to design the railway system as a whole. ...And yet there is no field of professional labor in which a limited amount of modest incompetency of $150 per month can set so many picks and shovels and locomotives at work to no purpose whatever."

The purpose in mentioning Wellington is not to stress the well-known similarity between certain types of decision making for highways and for railways. In fact, the attempt to think clearly about matters of highway economy has sometimes been handicapped by drawing too close an analogy between highways and railways. Wellington is mentioned chiefly because the present condition with respect to highway decision making is not unlike the condition that he observed during the great period of railway construction in the United States in the 1870's and 1880's.

At heart, Wellington was primarily an evangelist. He desired to convert railway engineers and railway administrators to his viewpoint that the location and design of a railway should be thought of primarily as a problem in economy. Today, there still remains the job of persuading most highway engineers and administrators that many of their problems are economic ones that are capable of quantitative analysis.

But Wellington was a very practical type of evangelist. He recognized that it was not enough to exhort railway engineers and administrators. He had also to show them how to make the needed economic analyses by developing specific principles and techniques to solve the various types of problems arising in railway location and design.

In this respect, any present-day evangelists who want to promote the use of economic analysis to improve the quality of highway decisions are in a better position than Wellington's eighty-two years ago. Wellington had to start from scratch in the development of principles and techniques. In contrast, today it is possible to draw on general principles and techniques applicable to all kinds of economy studies. Engineering economy is a subject that has been taught in some engineering colleges for nearly fifty years; today, courses on the subject are given in more than a hundred colleges and universities. Moreover, the techniques are widely and successfully applied in private industry. Research on specific techniques applicable to highway economy studies dates back to the early 1920's.

Nevertheless, certain aspects of economy studies for highways are inherently difficult and troublesome — in many respects more difficult than economy studies in private industry. Possibly these inherent difficulties constitute one of the reasons why most decisions today on highway programming, location and design are made without benefit of formal economy studies (even where formal studies are made, some of these studies are made very badly). Certainly there is ample justification for this workshop conference in these inherent difficulties of highway economy, together with the wide-spread failure to use the techniques of engineering economy to guide highway decisions.

This paper outlines a set of concepts out of the general body of concepts in the field of engineering economy; the concepts that seem to have particular application to the highway field have been selected. The concepts themselves should not be regarded as really controversial. However, the applicability of certain of the concepts to specific types of cases has in fact been quite controversial — in private industry as well as in public works.

It will be evident that most of the following nine concepts are not limited to decision making in the field of engineering economy; the concepts are applicable to the making of all kinds of decisions. However, the interest here is particularly in the making of decisions about proposals for the acquisition or construction of tangible physical assets.

1. All decisions are among alternatives; it is desirable that alternatives be clearly defined and that all reasonable alternatives be considered.

In all types of decision making, a first step in reaching a sound decision is a clear definition of the alternatives. In fact, it sometimes happens that as soon as the alternatives are clearly defined, the appropriate decision is evident.

It is characteristic of decision making about proposed investments in physical assets that each major alternative has a number of sub-alternatives. Moreover, many of the sub-alternatives will have their sub-sub-alternatives, and so on. For example, for each of two major alternatives in the location of a new highway, many decisions will need to be made between alternative designs of structures, alternative details of location, etc.

In the specialized language that has been developed for discussion of the economics of proposed public works, an analysis to determine whether or not to undertake a major proposal is called "project justification"; an analysis to choice among the numerous alternatives in design is called "project formulation." Many decisions are required in project formulation for every decision in project justification. In both private industry and public works, it is desirable that the criteria and methods of analysis used for project justification should be equally applicable to project formulation.

The need to look at all of the promising alternatives cannot be overemphasized. Often a proposal appears to be attractive only because some good alternate course of action has not been analyzed. This point may be illustrated by the following example which is adapted and simplified from an actual recent study of alternate highway locations.

Proposal A required a major improvement of an existing through highway. Proposal B called for an entirely new location that would relegate the existing road chiefly to the service of local traffic. A prospective favorable consequence of the new location was to make possible the development of new economic activity in a certain area not now served by an adequate highway. This consequence, included in the economic analysis as a "benefit" for B but not for A, was a major factor in the analyst's recommendation favorable to Proposal B. The analyst failed to recognize that the same benefit could be obtained by making a relatively small additional investment to add to Proposal A a low cost secondary road that would serve the new area.

2. Decision making should be based on the expected consequences of the various alternatives. In comparing investment alternatives, it is desirable to make the consequences commensurable with the investments in so far as practicable. Money units are the only units that make consequences commensurable with investments.

Proposals for new physical assets involve many diverse types of items associated with the investment. For example, a new highway may require land presently devoted to a variety of different uses, man hours of many different kinds of labor, various amounts of a great variety of materials, and different numbers of hours of usage of many different sorts of capital equipment. In a similar way, the consequences of investments may be of many diverse types. A new highway may be expected to cause changes in the amount and character of the usage of motor vehicles, changes in the usage of people's time, changes in the production and distribution of the products of farm and factory, changes in patterns of land use, changes in the type and frequency of traffic accidents, etc.

It is obvious that such diverse matters are not commensurable if they are expressed solely in different units such as acres of land, man hours of engineering labor, pounds of reinforcing steel, and gallons of gasoline. In making decisions, there are obvious advantages if the various consequences of alternate courses of action can be made commensurable with one another. The money unit is the only unit that comes close to making commensurable the diverse consequences of alternate investment decisions.

In private enterprise the case is clear for converting the prospective consequences of decisions into terms of money. A private enterprise cannot survive unless it is profitable in the money sense. An essential step in an engineering economy study for private enterprise is to express the expected consequences of a decision in terms of cash flow. Obviously it is necessary to apply the standards of the market place to investment decisions in private enterprise.

In deciding between alternate courses of action, any prospective consequences of the decision are relevant, whether or not it is possible to express the forecasts about these consequences in quantitative terms. In investment decisions in private enterprise, there frequently are expected consequences to which it does not seem practicable to assign specific money amounts. Some forty years ago, J.C.L. Fish coined the phrase "irreducible data of the problem of investment" to apply to such consequences. For the sake of brevity, this paper will refer to them simply as irreducibles. Other terms sometimes used by analysts are imponderables, intangibles, and judgment factors. However, they may be described, it is reasonable that these irreducibles be given weight in investment decisions; they are particularly important in those borderline cases where the comparisons in money terms are fairly close.

3. Only the differences between alternatives are relevant in their comparison.

This is one of the most important principles in all decision making, a principle that often is disregarded. As applied to engineering economy studies, the principle has several aspects.

One aspect is that everything that has happened up to the moment of decision between alternatives is common to the alternatives and therefore is irrelevant in the choice. In general, past investments should be viewed as irrelevant in present decisions except as they may affect the future differently with different alternatives for the future. This aspect is sometimes referred to as the principle of sunk costs. Some of the literature of highway economy has exhibited extremely fuzzy thinking about this matter of sunk costs.

Another aspect is that the use of allocated costs or average costs per unit of output should be viewed with great suspicion in any economy studies. For example, in estimating the saving in motor vehicle operating costs due to a proposed reduction in highway distance, it is the incremental cost per mile of operation that is relevant, not the average cost per mile.

Still another aspect is that each separable increment of investment ought to have its own justification. It sometimes happens that methods of analysis are adopted that make it difficult to judge whether separable increments of investment are economically justified. For example, considering several proposals involving different levels of improvement and different relocations of an existing highway, if the method of analysis used is to compute a benefit-cost ratio for each proposal as compared with the present condition and if these benefit-cost ratios are used as the sole criteria for decision making, there is no adequate basis for judging the relative merits of the different proposals. If the

benefit-cost technique is to be employed in economic analysis, increments of benefits should be compared with increments of cost in addition to comparing total benefits with total costs for each proposal.

4. It is necessary to have a criterion for decision making (or possibly several criteria). The criterion for investment decisions should recognize the time value of money and related problems of capital rationing.

In competitive industry today, a common state of affairs is that the funds available for plant investment are limited and there are many proposals for making such investments. The more sophisticated analysts who deal with problems of capital budgeting in competitive industry view their basic problem as one of finding the best use for a scarce resource, limited investment funds. This view leads to the conclusion that the primary criterion for investment decisions ought to be prospective rate of return on investment. Although there are many different ways of computing so-called rates of return, the only correct methods involve the use of the mathematics of compound interest. (In recent literature of capital budgeting, correct compound interest methods of computing rates of return have been referred to by various names, including the "discounted cash flow method," and the "Investors' Method." A rate of return so computed has been called the "Profitability Index.")

Minimum attractive rates of return used in capital budgeting in competitive industry in the United States vary from industry to industry and from company to company. Typical rates today seem to be from 8 percent to 20 percent after income taxes. Minimum attractive rates of return used in economy studies for regulated public utilities in the United States tend to be equal or slightly above the rates of "fair return" allowed by regulatory commissions in rate making; these rates of return tend to reflect the overall costs of capital to the utilities considering both borrowed capital and equity capital. There are economy studies for public utilities using interest rates from 6 percent to 10 percent after income taxes; it seems that 7 percent after taxes is a common figure.

Where economy studies to evaluate proposed investments employ the techniques of comparative equivalent annual costs or comparative present worths, or the comparison of "benefits" with "costs," the interest rate used in applying these techniques is the minimum attractive rate of return, whether or not it is so described. The common use in benefit-cost studies for public works of low interest rates from 0 to 3 ½ percent implies that such low rates of return are sufficient to justify the investment of public funds. Such rates are too low, all things considered.

5. In considering the predicted consequences of various alternatives and in establishing criteria for decision making, it is essential to decide whose viewpoint is to be adopted.

Economy studies for competitive business enterprise should normally be made from the viewpoint of the owners of the enterprise. Economy studies for those regulated public utilities that are successful in earning a "fair return" on their investments should normally be made from the viewpoint of the customers of the utilities; alternatives in such enterprises should normally be compared on the basis of "revenue requirements."

The matter is much more complicated in economy studies for public works because it obviously is incorrect to make such studies merely from the viewpoint of the effect of investment proposals on the cash flow of the particular governmental unit. In most cases, it is desirable to take the viewpoint of the entire public. The often-quoted phrase "benefits to whomsoever they may accrue" from the Flood Control Act of 1936 indicates the generally accepted viewpoint.

However, it would be much better if the viewpoint were now expressed as "consequences to whomsoever they may accrue." It is characteristic of many public works projects that they result in favorable consequences to some of the public and unfavorable consequences to others. The concentration of attention on "benefits" in the economic evaluation of proposed public works has often led analysts to consider the favorable consequences and disregard many of the unfavorable ones.

The inherent difficulties of economic evaluation of proposed expenditures for high-

ways and other public works are related in large measure to the problems caused by the need to estimate consequences to the entire public. In part, these are difficulties of fact finding about the effect on the public of various aspects of specific public works. But in part, also, they are conceptual difficulties related to making sure that certain consequences are not counted twice and that other consequences are not disregarded.

6. In so far as possible, separable decisions should be made separately.

In both competitive enterprise and public works, decisions on financing are largely independent of decisions on the specific assets to be financed. In both fields, attempts to base the economic analysis of proposed assets on some particular scheme of financing the assets has been responsible for much muddled thinking.

One example is the advocacy by some engineers and administrators of a 0 percent interest rate in economy studies for proposed highways on the grounds that because highways are financed by current taxation no money for highway construction has to be borrowed.

Another example is the practice of judging the economy of a proposed highway improvement on the basis of the fuel taxes to be collected on the particular stretch of highway. If this method of analysis were carried to its logical conclusion, no reduction in highway distance would ever be justified.

The third example is more subtle because it cannot be proved that the mental block that prevented the analyst from making a sensible economic analysis was related to a proposed method of financing. In previous discussion of the importance of examing all the reasonable alternatives, an example was given in which an analyst had failed to consider the alternative of adding a certain secondary road to a proposal for the improvement of an existing through highway. It seems likely that, because the secondary road would have to be financed locally whereas 90 percent of the cost of either through road would be financed from Federal funds, it simply did not occur to the analyst to consider anything that required 100 percent local financing.

7. In organizing a plan of analysis to guide decisions, it is desirable to give weight to the relative degrees of uncertainty associated with various forecasts about consequences. In this connection, it is helpful to judge the sensitivity of the decision to changes in the different forecasts.

In certain cases, such as the design of drainage structures against extreme floods, it is appropriate to use the mathematics of probability to deal with problems of uncertainty. But for many of the elements of an economic analysis of highway alternatives, there is no rational basis for the estimations of probabilities.

It is always worthwhile to remember that the end product of an economy study is a decision among alternatives (or possibly a recommendation for a decision). In his initial analysis to guide the decision, an analyst should make the best estimates he can about the various elements in his economy study. But where there is question about particular estimates, he can vary these estimates within reasonable limits and determine how the decision will be affected by each assumed variation. The more sensitive the decision to a particular type of estimate, the more care it is desirable to take with that particular estimate.

(The useful descriptive word "sensitivity" as applied to the foregoing type of analysis is a comparatively recent term that was introduced in the literature of operations research. However, the type of analysis itself has been used for many years.)

8. Decisions among investment alternatives should give weight to any expected differences in consequences that have not been reduced to money terms as well as to the consequences that have been expressed in terms of money.

In connection with this topic of the "irreducible data of the problem of investment," there are three points related particularly to economy studies for highways.

The first is that many of the consequences of highway decisions that are not consequences to highway users are likely to fall in this class of irreducibles; at least, this

is likely to be true until further research makes it possible to place monetary values on these consequences. The fact that these non-user consequences are treated as irreducibles is not a valid reason for disregarding them in economy studies for highways. (Neither is the fact that many highways are financed largely or entirely from user taxes a valid reason for disregarding non-user consequences.)

The second point is that in economy studies for public works there are certain types of consequences for which the market provides no valuation, even though the consequences may be forecast in other than money units. A proposed highway improvement may have a number of consequences of this type. For example, it may be estimated that the number of fatal accidents will be decreased by so many fatalities per year, that time and saving by pleasure vehicles will be so many vehicles minutes per year, and that there will be increased "comfort and convenience" for so many miles of vehicle operation per year. A critical issue arises in economy studies for public works on the question of whether it is better to treat such extramarket consequences as irreducibles or to assign them more or less arbitrary money valuations and thus include them in the formal economic analysis.

It seems that there is no justification whatsoever for a practice of failing to identify such extramarket consequences separately in computing and reporting benefit-cost ratios or other criteria for decision making. If, for example, a computed benefit-cost ratio is 0.8 with extramarket consequences omitted and 3.0 with them included, this fact should be disclosed by the analyst in summarizing his economic analysis.

A third point is the fact that decisions on public works are sometimes made by legislative bodies or the electorate largely or entirely on the basis of irreducibles does not constitute a valid objection to the making of any economic analysis. The public is entitled to have economic analysis used in design decisions (that is, in project formulation) even though some projects are undertaken that are selected primarily on the grounds of irreducibles. Moreoever, legislative bodies and the public are entitled to a measure of their extravagance when they authorize projects that are not justified solely on economic grounds.

9. Decisions among investment alternatives must be made at many different levels in an organization. The implementation of rules aimed at rational decision making may appropriately be different at different levels.

Both in private industry and in public works, the major emphasis in recent literature has been on the analysis of major investment proposals for presentation to top management — analysis at the level of capital budgeting in private industry and at the level of project justification in public works.

Although it is essential to have rules and procedures for implementing economic analysis at the top management level, it seems that it is equally important to give attention to the problems of implementing such analysis at the level of design or project formulation. A great many design decisions are made between sub-alternatives for every decision that top management makes between major alternatives. Unless there are some ground rules for economic design that are clearly understood, some designers are bound to overdesign in the sense of making unproductive increments of investment and other designers are likely to underdesign in the sense of avoiding investments that could be extremely productive.

It is inherently more difficult to implement economic analysis at the design level. Even in fairly large organizations, a relatively small number of professional specialists may be involved in economic analysis at the capital budgeting level. In contrast, hundreds of engineers and other persons may be involved in design decisions — persons whose major interests and fields of competence are in areas quite different from economic analysis.

Neither industry nor government have yet found a satisfactory solution to the problem observed by Wellington 82 years ago, a problem arising out of the uniqueness of sets of engineering alternatives. Wellington said: "He who has done well is shut off from adequate recognition of the fact. The same is true of one who has done poorly." Perhaps the future will bring, in industry and government, some system of internal audit of decision making that will make it possible to identify the economic designers and the uneconomic ones.

This paper has intentionally avoided a discussion of the merits of the benefit-cost ratio as the major criterion for decision making on public works. It is the author's view that other criteria are superior to the benefit-cost ratio. One of the chief objections to the benefit-cost ratio technique is that analysts who compute the ratios and administrators and legislators who use them as a basis for decisions seem, generally speaking, to be unaware of certain special characteristics and limitations of this technique.

Discussion

Burch. — As contrasted to the normal viewpoint of the economist and those who deal in the realm of corporate profit-based decisions for corporations, we in public service have certain basic peculiarities, and I think they are well recognized. Dr. Grant has referred to several of them and they certainly are basic.

In the first place, our function is not the creation of profit, but rather our function is in terms of service, a very intangible element.

Secondly, we are properly subject to political decisions in the higher sense — the decisions of the people for whom we work, and we work for all of the people. The people are at the same time our stockholders and also the customers of our service. They pay for it and they expect to get it. We are constantly under public pressure and the demand for immediate performance and urgency. All too often, there is a complete lack of interest in the cost of the service or the economic considerations or results.

We work in a field highly charged with local "pride and prejudice." The people with whom we are concerned are always a local group, concerned almost always with "our community." And they ask for immediate help through some highway or street improvement.

Furthermore, we are in an atmosphere of constantly changing personnel, whether it is legislative or highway department, or Bureau of Public Roads, in which our products outlast our personnel. That is not customary in most corporate operations.

We can not gage our services exactly to the need. As one man has expressed it in terms of secondary roads, you can't build a little road. If you have a little bit of traffic, you can't put a 2-ft wide road there to serve it or a 2-ft bridge, nor a 2-ft anything else. We have to move in certain more-or-less standardized gages. Our product is absolutely immovable. Once it is there, it can not be moved. Our operations must be tuned always to the flow of funds over which we really have no control.

Surely we have made progress through these years, and every year brings a certain amount of clarification, perhaps, with a certain amount of additional confusion. But more recently we have been able to get away from some of the difficulties through photogrammetry, through the use of digital computers, thus being able to compare more alternates with each other than had been possible in the past because of the urgency under which we worked. The adaptation of sufficiency ratings has become a tool which is very effective in showing to pressure groups some of the facts of life, which they are more inclined to accept with the sufficiency ratings than otherwise.

But the final questions come down to this, it seems to me, and this is a question that comes up every day with any one in state highway administrative work and in many other fields. Just who or what are we serving? Of course, we do serve. We do not create economic values. The building of a super highway through the Sahara Desert would create no economic values, I presume. There is nothing there to serve. So we do not create economic values but certainly we have a function in serving the creation of economic values. But who and what are we serving? Simply, it is the users of the highway or the street, simply the users; and if so, is it the users of today or the users of tomorrow? Are we also serving land? If so, to what extent? Which comes first, agriculture or industry? Existing or future development? Are we serving tourists? Certainly. Real estate? Certainly. The promotion of land development, the movement of goods — all of these are certainly in the picture, but which are we going to stress the most? These considerations become controlling in everyday operations.

Finally, as a public agency, we must serve every one equitably or attempt that noble purpose.

We must attempt to establish a uniform level of service, a uniform level of traffic service, if possible; even though to do so would mean the involvement of subsidy on the one hand and lost operation on the other, and I am sure that every highway system has a great many miles that must subsidize a great many other miles.

Lindman. —Professor Grant, your paper has done an excellent job of dividing this problem into several compartments, and I am directing my attention to this sentence, "I could give you many examples of errors in analysis caused by the introduction into our economic analysis of considerations related to a particular method of financing."

Can we have a method of economic analysis that is independent of the method of financing? I think that one of the concepts of economic analysis that has prevailed through the years, based upon an annual cost with depreciation, interest, and so forth, — this method I think, has resulted in the development of methods of highway financing that have proved to be unacceptable.

I have in mind methods dating back to the 30's when there was considerable discussion of the public utility method of highway financing. More recently, I would say there was the Clay Report which involved interest and long-term use of credit.

Actually, the method of financing which is most prevalent in the highway field currently, and has been for 25 or 30 years, is the pay-as-you-build method of financing. Those of us who work closely with the financing problem and try to develop economic analyses which are in tune with and based upon that method of analysis find that we use approaches that do not include depreciation accounts and return on investment, etc. We are more prone to start with the program costs, the costs that the legislators talk about, the costs that have to be budgeted, etc., and work back from there. I suspect that engineering economics (starting with Wellington) developed under the economics of the marketplace.

We are involved in major decisions which are not made in the marketplace. Our major decisions are not made in Wall Street with respect to highways. To the extent that we have toll roads and the like, the use of market economics is fine, but that is just a part of the over-all picture. It seems to me we are faced with the fact that our major controlling decisions are made at 1600 Pennsylvanie Ave. and in the state legislatures. These decisions are basically political. Those of us who are trying to introduce economic concepts find that engineering economics do not seem to fit too well. It seems that you are suggesting that we should have two different methods of analysis, one for the financing part of the problem and another for the specific engineering decisions.

If that is the case, I think it is going to add confusion because the two will be constantly mixed up. We will have one type of decision resulting from the major decisions that are political in nature, which will require a metamorphosis to bring them down to the operating level. We will have the design decisions occurring at the operating level, which may be in conflict with the chain of decisions starting at the top.

Other aspects of this distinction between different methods of finance and methods of economic analysis will come out from time to time at this conference, but I want to set it forth in general language at this point.

Grant. — Let me clarify a bit: I was trying to say that decisions that are separable should be made separately and financing is usually separable from decisions among physical alternatives, for example, the choice among several possible locations.

Let's take a case entirely apart from the public works field where the financing decision is not separable from the decision of physical alternatives. Suppose you are considering the alternative of home ownership versus renting, and you have enough for a down payment on a home but you do not have enough to purchase your home outright.

Then, associated with the alternative of purchase of the home, you have a specific scheme or perhaps several alternative schemes of financing and this is part of the consideration of home ownership versus renting. Here is a case where financing is definitely tied up with the physical decision.

Let's take a decision in industry. Here is equipment that conceivably might be purchased from equity funds or it might be purchased partly from borrowed funds. It might be leased. There, we see, are three schemes of financing.

Now, you are going to judge the productivity of this equipment. This is perhaps

materials handling equipment, that is to save operating costs in the manufacturing operations. If you tie to this a particular scheme of financing with 20 percent equity funds and 80 percent borrowed money and you borrow at less than the return available from the materials handling equipment, there is in effect a leverage there so that the rate of return on your equity funds seems to be very high indeed. If you change the ratio of equity funds, you get different prospective rates of return on equity funds. These are basically irrelevant as far as the merits of the equipment is concerned. That is what I meant when I said I could give illustrations from industry.

When you get to the issue "Should investments in public works be productive," it seems to me that the advocates of the zero interest rate are in a very weak position when they say that all that is necessary from public works is that the public gets its money back without interest. If the highway agencies are not able to invest taxpayers' funds productively enough to earn a return commensurate with that earned by a taxpayer, this is an unwise collection of taxes.

Let me say how we look at the actions of the highway users in judging benefits, in judging what weights they put on such things as comfort and convenience. About 80 percent of the highway users, in financing their automobiles, borrow money. If you really analyze the cost of this borrowed money to finance an automobile, it is in the general neighborhood of 12 or 15 percent. If you say you can take from this highway user some of his funds that he can invest directly at 15 percent by not borrowing to buy his automobile, and invest it in highways at zero percent return, I think you are mistaken.

Lindman. — What I want to emphasize at this time is that the concept of borrowed money seems to result in going to the legislature with programs that they will not accept. Congress has many other things to consider besides the engineering merits of the project when it comes to a question of whether or not they are going to use credit financing for a public investment; and we surely have come to the conclusion that the public utility method of setting up highways is unacceptable on a large scale. From the financing viewpoint, I think economic analysis methods result in suggested programs which have proved unacceptable in the finance field.

Gardner. — I think we quite often overlook the very pertinent fact that a state highway department is run on income and it has to spend that income on improvements and maintaining the road. Very recently in making a quick analysis, I came to the startling finding that in Pennsylvania no 2-lane highway of 24 ft or less in width can be self-sustaining on our present tax revenue. The only highway that I could find self-sustaining was the median, or divided type, with its volume of traffic, and this analysis was on the basis that we are providing a level of service that is generally accepted.

So, in economic analysis, if we find that a highway is going to cost more than the state highway department is taking in, I raise the question, where does the financial aspect fit into the economic analysis. Are we spending ourselves into bankruptcy, and I am quite certain that in Pennsylvania we have been doing so. (See Appendix A.)

Berry. — I would like to direct a question toward Grant's second concept having to do with the fact that all decisions are among alternatives. Professor Grant mentioned two kinds of decisions, one on project justification and one on project formulation. Apparently the rest of it relates to project formulation rather than project justification. I want to ask, in this project justification area in highway work, do we not get into the priority aspect? Presumably benefit costs are felt not to apply for that, but I was wondering what Professor Grant's view is.

Grant. — It is clear that matters of priority are decided on political grounds in many instances. I suspect however, that the legislators would have a better basis for these politically based decisions, or perhaps highway commissions or highway administrators responsible to legislators would have a better basis for these decisions, if there were an opportunity to look at the prospective rates of return on the various alternatives.

Let's look at the prospective rates of return. We will then array these proposals in order of prospective rate of return. We wouldn't necessarily take the top ones because there may be irreducibles or considerations of company policy or in highway agencies considerations of "We can't get the votes from these cow counties unless we take this relatively unjustified proposal on economic grounds."

But it seems to me that in this there would be a more sensible basis for decision making than in just conversation.

Of course, you can have the conversation approach in industry and you do have. There was a good paper in the Harvard Business Review [1] by Joel Dean a few years ago taking the point that the rate of return approach is appropriate in industry. He classified the capital budgeting decision-making procedures. In many companies that he observed this was all done by conversation — the department head who was the best politician, or the one who pounded the table the hardest, was the one who got the money. This was not really in the interest of the company and competitive industry to make decisions that way. The objective analysis is bound to leave some things out but you have a better start for your decision making.

Jorgenson. — What is your approach to the problem of dealing with roads of relatively low volume on which the rate of return would be relatively low; that is, I gather from your discussion you are talking about projects and not integrated systems.

Grant. — I am not a highway agency man. I have not lived with this problem. My assignment was to take out of the general body of engineering economy principles some things that seemed to me to be applicable to highways. I think my answer is substantially what I answered Professor Berry, that you need to look at these things and finally someone has to make up his mind that for one reason or another certain decisions that are not purely economic will be made.

Again this is a matter of looking at consequences. If the consequences of not building certain roads are that there will not be enough votes to finance the needed highway funds, this is quite relevant.

Jorgenson. —I did not mean to imply that this was a political decision. I think it is an engineering decision that highway engineers have to make all the time in programming the improvements to be made. I was proposing this just as a question that you might be helpful on. There is a huge area of highway improvements in which this is the case. Whether it occurs in every state at 24 ft or less I do not know; but if so, there is the big bulk of the highway transportation facilities in this country. How can we go about arriving at a judgment of these economic values with respect to road improvements that are not going to pay their own way.

Grant. — Keep in mind that I do not accept their pay-their-own-way status in the sense of gas tax revenues as a relevant matter. If you are talking about so-called solvency, it seems to me this is an entirely different proposition. What you should look at is the savings of various sorts and the other favorable consequences to the public of the construction of the highways.

I spent a couple of weeks in New Mexico pounding over very interesting dirt roads— trails as it were — that were not in the state highway system, and it would be nice to have those improved to serve some of the people with cattle ranches, but this would not be an economic thing to do. I think that economic analysis is relevant even on the minor roads, not merely on the major roads.

Moskowitz. — What we are getting into here, is the question of deciding what are the limits of the projects to which economic analysis is to be applied. The broadest concept lies in the thought that if you do not have these roads that do not pay for themselves either by solvency or by the benefit approach, you might not have any traffic at all for any other kind of roads.

That is the broadest look at this problem that we can take in deciding what are the limits of what we are going to call a project. Of course that comes right on down to an individual project. What we, in California, do call a project is normally about 10 mi long. If you make it 6 mi long it might not do the job or it might have an entirely different rate of return than if you made it 10 or 20 mi long.

In other words, everything you said is without doubt entirely true; but the difficulty

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[1] Joel Dean: "Measuring the Productivity of Capital," Harvard Business Review (January - February, 1954)

of doing what you are supposed to do makes it almost impossible.

Grant. — What Mr. Moskowitz says is something that is very important. Having to leave out some things, I left out the operations researchers who have brought in a lot of new lingo. One of their favorite phrases is "suboptimize." Another phrase is "systems viewpoint." In decisions in a limited area — design decisions — one has to look at them essentially in relation to the specific alternatives, for example, a drainage crossing. Here are several competing designs for this drainage crossing. Which will we take?

In addition to suboptimizing, one needs to take a broader viewpoint. Often the decision that is appropriate, looked at narrowly, is not the decision that is appropriate when looked at more broadly; and this is a matter of what your alternatives are. It is an inherently troublesome matter in industry as well as in government to be able, as one has to in design decisions, to take a narrow look; and then to take a broader look. I do not think there is any disagreement among us. This is important.

Moskowitz. — There are so many alternatives. In fact, there are an infinity.

Lockner. — I think Mr. Moskowitz has a point. We have to recognize how far we can go as engineers or as engineer economists or whatever we call ourselves. If the agency people come over with all of the sufficiency ratings and on the basis expect to have all the highway programs made up, or if the governor calls up and says he wants the road built here, and that is frequently done — we do have a very good use for these studies. I found them very helpful, and I think we ought to recognize that field and try and stick with it and not get off into this other one, which, possibly being cynical, according to our democracy, we are not going to fix. It is going to stay that way, so we ought to stick to our own knitting.

I am concerned because we set up criteria that I would certainly question. For example, we analyze a project in an urban area and decide to use parallel ramps; our traffic estimate shows that those ramps are going to be adequate for a 20-yr period of time. But in 21 years are they going to be adequate? Was our economic analysis worth anything at all?

Hoch. — In the eighth concept in his paper, Grant said, "However, it seems to me there is no justification whatever for the practice of failing to identify such extramarket consequences."

It seems to me there might be such a justification in that you might not be able to identify these things. These things might not be known in the first place. In the second place, you might have no way of evaluating them even if you could identify them, that is, at best you could only express your own personal preference about them. In sound economic analysis, this would not get you very far. This is a minor question about this particular sentence.

Grant. — What I meant was if you put a money value on these extramarket consequences, you ought to say that these are relatively arbitrary money valuations that do not have a money market value and separate them in the rate of return, or whatever the criterion is, from those consequences on which you have a market figure.

Hoch. — There seem to be a lot of non-user costs which cannot be evaluated except perhaps as some sort of personal preference.

Grant. — I entirely agree. All I said was that if you in your wisdom decide it is better on account of certain extramarket consequences to assign a money value and then you give to some one else the results of your study, you ought to identify that segment of the benefits, or whatever you call it, that you attributed to the extramarket consequences. You can still say there are a lot of other favorable or unfavorable market consequences, particularly non-user consequences, on which we cannot place a money valuation. I do not think there is any disagreement at all.

Concepts and Applications of Engineering Economy in the Highway Field

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● ANALYSES of the engineering economy of "for profit undertakings" are well understood and extensively practiced in industry, having reached the age of maturity. In public works understanding and application are far from reaching a desirable maturity. Highways are particularly troublesome. Highways are an in-between activity. They are a direct instrument of commerce and industry, resemble the public utility, are a government service to its people, and they affect the whole nation, through economic and social factors. Beyond all of these characteristics, there is a definite public policy supporting highways through a tax system that applies, not to the people generally, but to the specific users of highways in accordance with their use, or the value of their use. Thus, there is an analogy with sales in industry, if it is considered that the user pays a price for his highway service.

Because of these peculiarities, it is to be expected that highway administrators and highway engineers are in a quandary about certain aspects of the economic analysis of proposed highway facilities. The highway engineering profession has been long ready for a thorough searching discussion of the principles, theories, procedures, and interpretations involved in these economic areas.

Although such factors as interest rate, time value, comfort, and convenience, and benefits and losses to business are important factors, there is no intention of discussing herein their appropriateness, or the choice of numerical values. Brief comparison is made of the rate-of-return solution and benefit-cost ratio solution, and a few other technical aspects. Although the intention is not to take sides on items in controversy, some of the attitudes and concerns of the author will be expressed.

NATURE AND OBJECTIVES OF ECONOMIC ANALYSES

From Grant's previous paper one can readily and justifiably conclude that the one basic objective in making an engineering economy analysis of a proposed facility is to determine whether the anticipated monetary benefits will justify the monetary cost. All of the principles, procedures, and theory applicable to engineering economy studies for private industry also apply to all forms of public works, including highway facilities. Management's decision to go ahead with the proposal or not to go ahead may also be based upon other factors, but usually the economic analysis is the factor frequently given the greater weight. Public officials may place greater weight upon intangibles or factors not closely related to monetary benefits than do the officials of private enterprise. In private industry the immediate or longtime economic consequence is the main determining factor.

In both industry and public works, final decisions may not be wholly money based, but the economic analysis itself is wholly money based. That is its purpose. It should not include other factors not readily and reliably money based. It is highly important to keep in mind when making an analysis for engineering economy of highway improvements that such analysis is to determine the economic consequences only. It is not related to the method of financing. Financing is something separate and may be analyzed after the economics of the proposal have been determined. The economic results, however, bear strongly upon the decision whether to finance the proposal. Why else do bankers insist upon a rigid analysis of the economy of any proposal they may consider underwriting? Public works and highways are as important to analyze from the viewpoint of the money value of benefits and costs as are proposals for profit-making private ventures. This is true even though in the end the final decision is based upon social, educational, or other non-economic factors.

Analysis of the economic benefits to be obtained from a proposed highway facility as related to the economic costs of the facility could be made for the following specific objectives:

1. To determine whether the facility is economically justified.
2. To aid in the choice of engineering features of design.
3. To offer one means of determining priority of one highway facility as related to others.
4. To assist in tax or cost allocation studies or decisions.
5. To develop information which would aid in evaluating a specific highway proposal as against other proposals in public works or community projects.

The analysis for these economic consequences involves such factors as: motor vehicle operating costs; time value of individuals; safety of individuals and property; changes in the economic value of land, buildings, business, and resources; economic cost of capital investments; and maintenance and operating costs of physical property.

Economic analysis is economic, not social, not political, not financial. Only those factors which can be reduced to supportable and realistic dollar values should be included. Educational, defense, social, and general community values should be given such weight as they deserve by consideration outside the economic analysis.

HIGHWAYS COMPARED WITH INDUSTRY

For each economic factor in private industry which bears upon the economic wisdom of making an investment there is usually to be found the same or a comparable factor in highways. Although in quality the factors may be the same, frequently they are assigned different quantitative value or they may be given different weights.

Private industry makes decisions which affect its commitment of capital to the production of goods and services. At the same time it controls production, price, and distribution. In other words, industry has full control over its entire activities. In highways, the highway official does not have full control. The highway official is responsible for commitment of public resources to investment in highway facilities; but the highway official has but little control over the use of these facilities, nor of the price to be paid for their use. The services and goods produced by private industry are purchased by consumers in accordance with their personal choice. Although highway users may have a choice on occasions to go or not to go, they have little choice in their routing, in the quality of the highway facility to fill their particular needs, nor the price (tax) they pay.

Industry has production cost (including sales and distribution expense) and sales income as its two basic factors on which to base capital investment decisions. Industry is not concerned with the adverse effects of its decisions upon its competition, nor is it concerned with the adverse consequences in other economic and social areas of the country. Public officials directing a highway improvement program, however, must not ignore the adverse consequences of highway improvements upon other forms of transportation or upon other economic and social areas. Although these consequences cannot be measured with any high degree of accuracy in an economic sense, still, they must be given consideration. When public resources are committed to highways, such resources are not available for any other activity, public or private.

Private industry has sales which measure day-by-day use and success of the product. These sales in combination with the cost of producing the sales result in a profit and loss statement. Thus, it is comparatively easy to measure the economic consequences of capital investments in industry. Highways on the other hand do not have easily measured "sales." Reliance must be placed on an estimation of benefits derived from the cost of moving motor vehicles over the highway and to the personal benefits enjoyed by the persons transported. Fuel tax and license fee revenues must be considered as sales income, particularly when measuring monetary solvency of a highway. However, many highway improvements are constructed to reduce fuel consumption; in this light, the "sales income" would be reduced by investing in a new highway. As measures of the profitability of highway improvements, motor vehicle operating costs, accident cost, value of time, and general community economic consequences are analyzed.

This general comparison of industry and highways brings out the importance and difficulties of reaching sound decisions on capital investment in highways. Highway facilities are non-usable for purposes other than for highway transportation. Any error in judgment on the commitment of funds is a long-lasting, inalterable error.

HIGHWAY VS OTHER INVESTMENTS

The decision to commit public resources to the construction of a highway facility is a form of capital budgeting. Highway officials make such commitments in their belief that such investment is in the public interest and that such commitment is economically sound; that is, the economic consequences justify the commitment of the capital. Frequently, there are social factors involved which may contribute a certain weight to the decision.

When the highway official commits tax resources to a highway improvement, he has created three situations. The monies commited to the highway improvement are not thereafter available for commitment to: (a) educational facilities, fire or police protection, recreational developments, or other public works or public function; (b) private business ventures; and (c) personal pleasures, needs, or satisfactions.

In making this commitment to highways it is essential, in the interest of public welfare, to determine that the highway improvement will render benefits of greater value than will commitment of the same monies to other public works or private ventures. The resources of the public are limited. Monies spent to build highways can not build schools, churches, and swimming pools; or provide more police and fire protection, or a better home or extended vacation.

In commitment of public resources to highway improvements, it is compelling upon the public official to determine (a) that highway improvement is the highest and best use of the resources available, and (b) that the specific project to be built is the one that will return to the public the highest return or that it will render services of greater importance than any other highway service that could be rendered at that time.

Comparing the need for highway improvements with the need for school facilities and parks is somewhat like making a personal choice between committing the family income to a vacation trip or buying new furniture. Nevertheless, similar decisions are made daily by families and yearly by city councils, boards of education, legislatures, and the Congress.

Knowing the economic consequences of a proposed highway facility will permit administrative boards to make decisions of greater potential correctness, than can be made without the advantage of economic analysis.

Industry is not confronted with the value of time simply as time. Time reductions or time increases brought about through the betterment of procedures and equipment result in decrease or increase in unit cost of production. In highways, a saving of time is frequently at increased cost of motor vehicle operation. The saving of transportation time probably results in increased vehicle-miles of travel, but here again there is no way to measure the benefit or profit of increased travel. The time saving of motorists probably is devoted to some activity other than increased travel. The value of time is a critical value in the economic justification or comparison of proposed highway projects.

In industry usually there is a minimum of intangible values to consider. It is true that industry must consider the effect of proposed changes upon employee morale, public relations, and the like, but generally speaking, decisions are almost wholly based upon economic considerations. In highways, transportation has great effect upon education, social exchange, health, recreation, community pride, and national defense. It is difficult to put a monetary value on any of these benefits. Therefore, it is probably best to leave all such elements out of economic analysis and let them be weighed at the end in accordance with the judgment of the officials who must make the final decision. These extra non-user benefits are consequences of the highway improvement which should not be permitted to cloud or merge with the economic factors which can be easily isolated and priced.

PRINCIPLES OF RETURN ON INVESTMENT

For long ages, the managerial principle controlling business decisions has been that a reasonable return on investment, commensurate with the risks involved, is not only desired but is something the investor must expect or he would not invest. Money is invested in private business to earn dividends or returns. The same principle is applicable to public enterprise, though frequently it is difficult to measure the returns in monetary symbols.

There is no foundation for the conclusion that public enterprise can justify a lesser return than investment in private enterprise, the risks being comparable. There is no justification for the conclusion that a public enterprise of comparable risk should earn only 3 percent, whereas in industry it would be permitted to earn a 10 percent return. Lower interest rates and returns in public works as compared to private industry are used because of the lesser risk.

Risk, in private capital, is the uncertainty that the investor will (a) get back his original investment, and (b) a fair return on his investment. These two elements, in turn are measured by the degree and speed that changes in the arts and customs take place, and the continued acceptance (purchase) of the product by the customers.

Since highways are operated without a system of cost accounting and without specific sales income, there is no positive measure of the risk factors of return of and return on the investment. But these risks do exist. The degree of risk in highways can be expressed by the uncertainty of the number of years of useful life of the facility and the uncertainty that the traffic will develop in volume, character and running cost as predicted. In other words, the economic analysis is based wholly on predictions of costs and benefits. The uncertainty that these predictions will materialize is the risk involved. When 50 years is used as the period of analysis, it means that the facility should render the service for at least 50 years, and that the benefits would have to continue for 50 years as forecasted or in greater amounts for fewer than 50 years.

Throughout the history of highway development, there has been a comparatively high rate of obsolescence, inadequacy, and physical wear and tear. There have also been great changes in modes of transportation from the pony express down to the monorail and jet-powered airplane. The electric interurban railway and the street railway have come and gone. Even railroad passenger service is on a rapid decline. With this history, what justification is there in economic analysis service lives of 50, 75, and 100 years for elements of the highway? Yet analysis after analysis of the economic justification of highways, or the selection of elements of engineering design, have been made using such long periods. It is particularly alarming when these long lives are combined with low interest rates of 2 and 3 percent in calculating the annual cost of owning and operating highway facilities.

Industry is quite prone to use 1 to 5 years, and occasionally 10 years as the length of time over which sales or reduced operating cost will produce sufficient return to pay for the entire capital investment plus a return of 10 to 20 percent. Because of the nature of highways and certain other forms of public works, longer periods of analysis and lower rates of return can be used than industry does, but shorter life and higher interest than many analysts are using.

Although private industry will use short life and high rates of return in their economic analyses, it does not follow that their cost accounting sets up depreciation rates based upon these short lives. In cost accounting they use service lives based upon their best estimate of the number of years that the property will remain in useful production.

A similar procedure should be followed in the economics of highways. That is, economic analyses should be made with conservative lives or analysis periods and rates of return comparable to what the public is paying. In cost accounting for highway transportation, service lives should be used in accordance with the best estimate of the number of years the facility is likely to remain in profitable use.

Highway officials must recognize the degree of risk in the construction of highway facilities. The longer the period of time required to produce economic justification of a specific highway improvement, the greater is the degree of risk that such economic consequences will be favorable. Almost no one would commit his private capital to an

investment (not stock or bonds) that would require 50 years to pay out without opportunity to sell in the meantime even at a high rate of interest of 8 percent.

Because of the rapidly changing social, economic, and physical environments, the uncertainties of the future are great. We must be concerned about the risk of the distant future and be more willing to forego probable long-term benefit in favor of the more realizable short-term benefits.

FACTORS INCLUDED

The factors and their consequences involved in the economic analysis of a proposed highway facility may be grouped as follows:

1. Consumption or conservation of physical goods and natural resources.
2. The use of time by individuals.
3. Value of non-highway property, goods, and services.
4. Mental and physical condition of the traveler and personal consequences of his choice of route.
5. Other factors, preferably not included in the solution — social life, environment, political organization, esthestics, recreation, pleasures, scenic view, and other intangibles.

Groups 1 and 2 factors may be more or less readily converted to dollar values. They are also distinguished by the fact that resources — goods and time — are consumed. Main items are motor vehicle running costs, goods consumed because of accidents, and the time of driver and passengers during travel.

Group 3 factors are economic insofar as they pertain to dollar values, but differ from Group 1 and 2 factors because they merely represent a change in the market value of property or business opportunity. Initially, they represent only "paper" values, since the real net consequence of gain or loss is not realized until the property is transferred in ownership. These factors cover widespread geographical areas, thus, making it difficult to determine all plus and minus changes from which the net consequence is obtained.

Group 4 factors are intangible insofar as they are not physical property, are not services, and are without any standard means of measurement as to their existence or as to their monetary worth.

Group 5 factors are those consequences of highway improvements which are difficult to trace solely to highways, which are without means of direct measurement, which have no accepted unit by which to evaluate their worth, and which are of general community interest rather than specific to individuals. The factors in this group are best considered as extra-market consequences outside the economic analysis and given such weight as may be just and right in each case by those officials who have final responsibility of approval of improvement projects.

The analysis should be arranged in parts so that the money-based items of real tangible character (Groups 1 and 2) are separated from the intangible items money-based purely by assumption of unit values. Time value is preferably separated from motor vehicle operation.

The economic analysis of a specific proposal for a highway improvement, requires two basic decisions: (a) selection of the economic factors to include in the analysis, and (b) selection of unit dollar values to assign to each economic factor to be included in the analysis.

Since the analysis is to determine the net economic consequences brought about because of use of the proposed facility, each factor included must be an economic one. To ascertain that a factor is economic in result, its true character and end result in the economic system are explored. Are goods, supplies, and resources consumed in the use of the facility? If their consumption is reduced can these goods, supplies and resources be used to economic advantage elsewhere? Is the time devoted to travel of economic value? If the travel time is reduced or increased does this increment of change have economic value? To what profitable use will the time be applied?

Do the social and economic systems permit of assignment of economic values to

impedance, comfort, convenience, pain, misery, pleasure, mental anguish, and other personal factors? Is it in the best interests of the public to base the construction of highway facilities upon the value of time, the value of personal comfort and choice? Similarly, for changes in land and business values.

Even after the factors to include in the analysis are chosen, there remains the difficult task of assigning units of measurement and unit values to these units. Material goods are generally valued upon market conditions. But this process is still uncertain with motor vehicle operations, because there is a wide void in knowledge of vehicle performance and consumption of fuel, rubber, and a vehicle as a whole, under specific conditions of speed, gradients, curves, stops, and constant speed vs variable speed driving.

The value of time to the highway user has not yet been systematically evaluated, so assumed values are used. The personal items of impedance, comfort, etc., when used, are based entirely on assumption without any guide, whatsoever. The general practice for time and personal factors is to follow along with unit values with what some other person used. Thus, each subsequent analyst cites a prior authority.

A highly important consideration, so far only alluded to, is the necessity of eliminating duplications and overlapping of the several economic elements. What is involved in the final solution is the "net economic consequence." Often, a gain is accompanied by a loss. Time is gained by higher speeds, but vehicle running costs are increased; time is saved by routing around delays, but at an increase of distance; land values adjacent to a highway facility are increased, but farther away they are decreased; business activity is greatly increased along the new route; but decreased (or fails to locate) elsewhere; highway travel is increased; but expenditures for luxury goods and other pleasures are decreased. One community may lose business and tax income which is actually transferred to the adjacent community as a gain. These duplications and overlaps can be avoided only by careful and systematic scrutiny of each factor and its unit value.

CRITICALNESS OF CERTAIN FACTORS

Such factors as interest or rate of return, service life or analysis period, unit motor vehicle operating cost rates, intangible factors such as time, impedance, comfort, and convenience will prove that most any quantitative answer can be obtained if one desires to manipulate these factors between their minimum and maximum values.

In a comparative analysis of two proposals, the improved highway may reduce motor vehicle running cost by 1 cent a vehicle-mile. As an added factor, if 0.5 cent per mile is allowed for comfort and convenience, the benefits are thus increased by 50 percent. Similarly, if $1.50 an hour is taken as the value of time as compared to $1.00 an hour, the benefits of time saved are increased 50 percent.

An illustration of the magnitude of these factors and their influence is given in Tables 1, 2, and 3. Table 1 gives the total cost of motor vehicle running costs and value of time for a typical relocation of a primary 2-lane highway from a location through the city to south of the city. Table 2 gives the increase or decrease in these costs on the new location as compared to the old city route. The value of the factor of comfort and convenience at 0.5 cent per vehicle-mile is also shown.

The motor vehicle benefits (savings) are only $33,934 as compared to a time value saving of $705,885. Here is a case where one factor — motor vehicle costs, only 4.6 percent of the total — can be worked out within reasonable degree of refinement and closeness and the other factor, 95.4 percent of the total, is based wholly on a judgment value. Where time is a factor it will usually far outweigh motor vehicle costs because, at $1.35 per hour, its value is 2.25 cents per mile at 60 mph. Few projects will decrease motor vehicle running costs as much as 2.25 cents a mile.

Important also, is the personal factor of comfort and convenience. At 0.5 cent per mile this factor amounts to $96,618 for this relocation of route. This sum is almost three times the reduction in motor vehicle costs.

Table 3 indicates a wide variance in annual highway capital costs as interest rate varies and as the number of years used in the analysis varies. Each of these two values are chosen by judgment. The range in capital cost is from $41,765 at 2 percent and 100 years to $211,428 at 10 percent and 20 years.

TABLE 1

MOTOR VEHICLE RUNNING COSTS AND VALUE OF TIME

Vehicle Class	Vehicle-Miles per yr	Vehicle Running Costs		Value of Time	
		¢ per mi[1]	$ per yr	Hours of Travel per yr	Value $ per yr[2]
A	B	C	D	E	F
(a) Old Route Through City					
Passenger cars	16,472,815	3.875	638,366	721,017	973,373
Single unit trucks	1,869,895	6.851	128,113	93,380	196,098
Combinations	981,120	18.817	184,616	53,594	141,488
Total	19,323,830	—	951,095	867,991	1,310,959
(b) New Route, South of City					
Passenger cars	14,256,170	4.534	646,416	340,892	460,204
Single unit trucks	1,556,725	7.669	119,392	40,529	85,111
Combinations	771,975	19.606	151,353	22,636	59,759
Total	16,584,870	—	917,161	404,057	605,074

[1] Quotient of Column D divided by B. Column D calculated from unit costs on level tangents, horizontal curves, gradients, and stops by speeds.
[2] Based on rates per hour of $1.35, $2.10, and $2.64 for cars, trucks, and combinations, respectively.

Too often the critical factors of time, personal comfort, interest rate, and period of analysis are chosen without serious consideration of their effect on the final answer. Frequently too, the final report upon which the public official bases his decision does not disclose these factors and their values. Only benefit-cost ratios are reported.

In contrast with industry, the current, most frequent highway economic analyses have to do with selection of alternates for a project already accepted for construction. Thus, the solution for choice of "with or without" — economic justification of constructing or not constructing the project — is the infrequent solution.

Fortunately, as of today in route location solutions, the choice of factors and their values — motor vehicle operating cost, value of time, and others — does not influence the choice of project greatly because the factors have about the same weight and influence in each alternate considered. Nevertheless, effort needs to be made to seek correct factors, proper values thereof, and to apply them correctly. To this end, study and research should be directed.

TABLE 2

BENEFITS IN MOTOR VEHICLE RUNNING COSTS AND IN SAVING OF TIME — NEW ROUTE OVER OLD ROUTE[1]

Vehicle Class	Motor Vehicle Running Cost, $ per yr	Value of Time $ per yr	Total	Comfort and Convenience at 0.5¢ per mi, $ per yr
Cars	- 8,050	513,169	505,119	82,364
Single unit trucks	8,721	110,987	119,708	9,349
Combinations	33,263	81,729	114,992	4,905
Total	33,934	705,885	739,819	96,618

[1] From Table 1.

TABLE 3

ANNUAL HIGHWAY COST AT SEVERAL RATES OF INTEREST AND ANALYSIS PERIODS

Interest Rate (%)	Annual Capital Cost ($)				
	20 Years	40 Years	60 Years	80 Years	100 Years
2	110,083	65,801	51,782	43,290	41,765
4	132,448	90,941	79,564	75,265	73,454
6	156,933	119,632	111,377	109,031	108,319
8	183,334	150,948	145,436	144,306	144,065
10	211,428	184,066	180,594	180,088	180,013

Notes:

Total construction cost including ROW and engineering – $1,800,000.

Annual maintenance, operation, and administration – $18,000.

Add $18,000 annual operation and maintenance to capital cost to get annual highway cost.

PROCEDURE OF ANALYSIS

The exact step-by-step procedure to follow in the economic analysis should not affect the final answer. Yet, the final answer may be more easily achieved and may be interpreted to better advantage under one procedure than another.

The procedure of analysis is one in which the primary objective is to compare highway cost plus motor vehicle costs plus other costs for one condition (say the existing one) with the same cost elements for one or more proposals for new facilities.

$$T = (C+M+H) + (V+A+T+P) + E$$

in which

T = Total annual cost, incurred in moving the vehicles over the project;
C = Annual capital cost of the highway;
M = Annual maintenance cost of the highway;
H = Annual headquarters, administration and operation cost;
V = Annual cost of vehicular operation;
A = Annual cost of traffic accidents;
T = Annual value of time of transportation;
P = Annual personal value of travel (comfort, impedance, strain, etc.); and
E = Other economic costs.

It is not to be assumed that each of these factors is to be included in every analysis, but they represent specific factors that have been used by certain individuals.

The final answer of the economic consequences of a proposal or group of alternates is more useful to those top officials who are required to make the final decisions when separate answers as well as the grand total, are presented for such factors as (a) motor vehicle costs, (b) value of time, (c) comfort and convenience, impedance or other personal factor, and (d) community factors pertaining to non-user consequences. In other words, these factors are to be combined at the end rather than at the beginning of the analysis. Separate calculation and reporting of these factors permits of according them different weights in the final analysis.

Consequences as a result of growth in traffic should be separated from current traffic because of uncertainty, necessity of discounting benefits from the future to the present, and the fact running costs are not subtractable from the costs of existing traffic to arrive at total benefits.

The analysis of economy is best handled procedurely, by computing costs and values

TABLE 4

CALCULATION OF RATE OF RETURN, BENEFIT-COST RATIO, AND CORRESPONDING INCREMENTAL SOLUTIONS

Plan	Constr. Cost ($1,000)	Annual Cost ($1,000) Capital[1]	Oper. and Maint.	Highway Col. 3 + Col. 4	Veh. Oper.	Total Transp. Col. 5 + Col. 6	Benefits ($1,000) Annual 500-Col. 6	Net Annual Col. 8 - Col. 4	Rate of Return[2], (%) Col. 9 ÷ Col. 2	Benefit-Cost Ratio Col. 8 ÷ Col. 5
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
P	—	—	60	60	500	560	—	—	—	—
A	1,800	91.8	50	141.8	200*	341.8	300*	250*	13.89	2.12
B	1,500	76.5	45	121.5	205	326.5*	295	250*	16.67	2.43
C	1,300	66.3	43*	109.3	220	329.3	280	237	18.23	2.56*
D	1,200	61.2	50	111.2	225	336.2	275	225	18.75	2.47
E	1,000	51.0	55	106.0	250	356.0	250	195	19.50*	2.36
F	800	40.8	70	110.8	280	390.8	220	150	18.75	1.99
G	700*	35.7*	65	100.7*	300	400.7	200	135	19.29	1.99

Incremental Solutions		Rate of Return (%)	Benefit-Cost Ratio
Plan A/Plan G	= 115/1,100	= 10.45	100/41.1 = 2.43
Plan B/Plan G	= 115/800	= 14.37	95/20.8 = 4.57
Plan C/Plan G	= 102/600	= 17.00	80/8.6 = 9.30
Plan D/Plan G	= 90/500	= 18.00	75/10.5 = 7.14
Plan E/Plan G	= 60/300	= 20.00*	50/5.3 = 9.43*
Plan F/Plan G	= 15/100	= 15.00	20/10.1 = 1.98
Plan A/Plan E	= 55/800	= 6.88	50/35.8 = 1.40
Plan B/Plan E	= 55/500	= 11.00	45/15.5 = 2.90
Plan C/Plan E	= 42/300	= 14.00	30/3.3 = 9.09*
Plan D/Plan E	= 30/200	= 15.00*	25/5.2 = 4.81
Plan A/Plan D	= 25/600	= 4.17	25/30.6 = 0.82
Plan B/Plan D	= 25/300	= 8.33	20/10.3 = 1.94*
Plan C/Plan D	= 12/100	= 12.00*	5/negative
Plan A/Plan C	= 13/500	= 2.60	20/32.5 = 0.62
Plan B/Plan C	= 13/200	= 6.50*	15/12.2 = 1.23*
Plan A/Plan B	= 0/300	= negative	5/20.3 = 0.25

[1] At 30 % for 30 years.

[2] Based on first year benefits divided by construction cost. A more precise rate of return would be the rate corresponding to Col. 10 values when considered to be the capital recovery factor.

* Most favorable result.

in every case for every factor and item for each alternate proposal. The difference in these costs are then the economic consequences. Thus, by this system savings or benefits are not computed directly, but they result only by comparison of costs of the alternate proposals considered. This procedure simplifies the calculations, maintains consistency in unit values, and provides direct means of comparing the consequences whether positive or negative.

RATE OF RETURN VS BENEFIT-COST SOLUTION

A few comments on the rate of return and benefit-cost ratio solutions are appropriate. These methods deserve a lengthy discussion to present an adequate measure of their merits and shortcoming, but these comments may be helpful.

Industry uses the rate of return solution and government, generally, uses the benefit-cost ratio. Industry is accustomed to the rate of return or profit concept because its whole structure is based upon profits as related to investment. In government the

benefit-cost ratio is widely used, perhaps largely because of the "green book" of May 1950 (1). This pamphlet sets forth concepts and practices for economic analyses in an attempt to clarify the stipulation in 1936 by Congress that only water resource projects with benefits in excess of costs should be undertaken. In the highway field the benefit-cost analysis is currently popular because it is the basis of the AASHO manual of 1952 (2) now the standard pattern for State highway departments. When correctly handled both the rate of return solution and the benefit-cost-ratio methods produce the correct result, but not necessarily results which would rank several proposed alternates in the same order. The rate of return solution measures the rate of return on the investment after the annual maintenance and other current costs are subtracted from the annual benefits. Thus, the rate of return is dependent on the ratio of annual maintenance cost to invested capital.

The benefit-cost ratio solution is dependent on the interest rate and analysis period assumed in the analysis. It gives an abstract number, difficult for most persons to comprehend and until the basis of its calculation is known, the benefit-cost ratio has little real meaning.

Each method is subject to the incremental analysis, that is, a measure of the desirability of the increments of benefit and of cost between a range of alternates. The economical grade reduction or the culvert size problem are good examples to illustrate the increment concept.

Starting with a grade of 10 percent, it could be that the annual benefits could be greater than annual costs for a reduction in grade down to 0 percent. An incremental, percent by percent, analysis might show, however, that reduction to a 3 percent grade would be in order for at this point an additional dollar spent in grade reduction would produce benefits, the present worth of which would be less than one dollar. Thus, the increments of grade below 3 percent were less in benefits in proportion to costs than obtained by reduction from 10 to 3 percent.

Similarly, when the capacity of a culvert is to be determined in relation to benefits and costs there is a wide range of culvert sizes to choose from. By studying the alternates on an incremental basis the size that maximizes the benefits and returns in relation to cost will be determined.

This principle of incremental analysis is applicable equally well to highway location selection between several alternates.

Table 4, a set of hypothetical data, illustrates the incremental method and gives a comparison of the rate of return and benefit-cost solutions.

Because of the variable ratio of operation and maintenance costs to construction costs, the rate of return solution and benefit-cost ratio methods do not rank the alternates A to G in the same order. Likewise, in the incremental analysis. In the end, however, alternate B is selected by both solutions as being the economical choice.

The rates of return and benefit-cost ratios, columns 10 and 11, are in comparison with the existing highway facility P. These answers do not indicate a comparison of alternates A to G one with the others, but only as compared with the present P facility.

In the second series of solutions the comparison is with alternate G. A comparison with E is next made and finally comparisons are made with C and B. Alternate B, the final choice reached by both methods is the one that has the lowest total annual transportation cost, column 7.

Should the analysis by increments not have been made, the choice would have been alternate E by the rate of return method and alternate C by the benefit-cost ratio method.

QUESTIONS FOR RESEARCH

There is need for an intensive and extensive research on practically every aspect of the analysis of the economic consequences of highway improvements. Although the subject has been given attention in the past and analyses are being made today, the total process has not yet reached maturity. There are many misunderstandings about the subject, areas of conflict of opinion, and a lack of factual data on costs and performance of vehicles under specific road conditions. Some of the questions research could answer are as follows:

1. How should each specific type of highway proposal be analyzed? For instance, should urban expressays be analyzed in a different manner than rural expressways? How should an urban widening and resurfacing project be analyzed? What is the proper procedure to follow in determining the economic value of frontage roads?
2. What are the costs of operating cars and specific weight trucks on specific gradients, on horizontal curves, in traffic congestion, at different speeds for each condition, on rough pavements, for each stop from different speeds? What is the influence of lane width and of shoulder width on motor vehicle running cost?
3. By what different types and weights should traffic be grouped for convenience, and yet accuracy, in the analysis?
4. What is the correct consideration to accord future changes in traffic volume? Is generated traffic handled the same as existing traffic? As normal growth traffic?
5. For the economic analysis, just what cost items pertaining to accidents and death are admissible and what unit value is to be ascribed to each item? What are the offsetting items?
6. Whose time is valuable and under what conditions? How valuable is time? Is 1 min each for 1,000 cars as valuable as 20 min each for 50 cars?
7. When and at what price is there value to comfort, to convenience, to strain, to annoyance, to uninterrupted movement, to movement at uniform speed, and to personal preference?
8. What is the nuisance value of dust, of noise, of billboards?
9. Does the change in market value of land and business constitute an includable item? If so how far afield from the highway project are the economic consequences to be measured? Does the change in vehicle operating cost and time value measure the change in value of land and business?
10. What is the answer to the proposal of including any changes in real estate taxes?
11. Can the increase in business and industry along the route be considered a net benefit to justify construction? Or is it just a transfer benefit, or loss elsewhere?
12. Shall education, postal service, fire, police, health, social change, and other community aspects be evaluated and included in the analysis?
13. What is the proper rate of interest or return to use? How should it vary with type of facility?
14. Shall full economic service lives be used or some shorter analysis period?
15. Should recreation, sports, and general pleasure be evaluated and included in the analysis?
16. What value is to be ascribed to national defense benefits?

The economic analysis to justify construction of a highway facility or to select one proposal in preference to others is of great weight. The official having final decision is entitled to have before him an accurate, unbiased, complete analysis based on sound and fully acceptable principles, concepts, and values. By concentrated and diligent search by a group of devoted economists and engineers the foundation of such a high type of analysis will become possible.

REFERENCES

1. "Proposed Practices for Economic Analysis of River Basin Projects." The Inter-Agency Committee on Water Resource, Washington, D.C., Revised (May 1958).
2. AASHO, "Road User Benefit Analysis for Highway Improvement." 917 National Press Building, Washington, D.C. (1952).

Discussion

Van Riper. — You did not refer to savings in accidents. Operation on freeways in comparison to the city street system is a very realistic factor and it should be considered.

Winfrey. — It is mentioned briefly in the paper. However, to the extent that accidents consume resources and goods, they must be evaluated. Certainly, medical supplies

and labor would be in Group 1 that I mentioned; it would be included in the time element, Group 2.

On the other hand, how do you place a unit value on these factors after including them? In connection with accidents, there is a tremendous amount of overlapping which is ignored because people have not thought it through. There are many negative and many positive reactions to accidents. You take a man off the job, for instance. He is not producing, therefore we can say it is an economic loss, but how do you know somebody else did not step in and produce what he would have done? Is there a net loss in production?

For an extreme example, I am not sure a fatal accident is an economic loss. It may be a gain because it gives a job to somebody else. If we take a fatality as an economic loss, what about the savings in future goods which he does not consume because he is dead? Certainly we are saving consumable supplies by letting the person die, so what is the difference between not consuming goods and not driving over the highway? In both cases, one is not consuming goods. We need to do a lot of exploring in those fields.

Newcomb. — Would you suggest killing everybody and save everything?

Winfrey. — Would you say stop using motor vehicles so we do not use gasoline? Why would you not consider saving of food?

Cherniack. — I have three points to bring out. One of them is the fact — and I am paraphrasing now — that tax resources once committed deprive those same funds from being used for public projects, for private projects and for personal projects.

A tax commitment for highways deprives City X of building schools, or deprives Corporation XYZ of building a plant, or deprives City Y from building a park. What I want to add is that that is not quite so, that they are not mutually exclusive (that money spent for highways may bring monetary savings in other areas) that the building of a highway may make safer the journey of children to the schools that are in existence. The building of that same highway may make more accessible the plant of corporaation XYZ, and the building of the highway may make a park more accessible and used, to a greater extent than it is now. Therefore, we are dealing not mutually and exclusively with commitments, but simply with whether we are to attain these same objectives through a tax commitment or through spending by the public or by private persons, etc.

We must take into consideration that in our democracy it is within the wisdom of the legislature to commit these taxes to highways or schools, etc., and we do this in fact despite what we may think about our encounters with legislators.

Mr. Winfrey said that when we are dealing with economic studies, we should mutually exclude social benefits. I maintain that the wear and tear of a car is an economic cost but the wear and tear on the nerves of the driver is also an economic and not a social cost. That is the way the driver makes his living, so the wear and tear on his nerves is an economic factor and it should be brought into the data. The fact remains that you cannot compartmentalize these economic and social benefits. They are intertwined.

The third thing that was said was that analysts or consulting engineers may get any desired results for unit values by playing around with figures. Of course, I violently object to that kind of manipulating. We do have to start with a certain amount of integrity here, but I would say from my own experience that it is possible with adequate and sufficient data and with statistical procedures actually to bring into relief these things and to evaluate these intagibles. The measurable economic benefits are to be viewed as in the analogy of an iceberg where the measurable benefits are the part seen above the water and the unmeasurable are the part we do not see. What we have done thus far is to send down a lead, and we find they are three or four fathoms deep when trying to measure them directly; whereas if we use the physicist's approach and take account of the relative density of ice and water, we would find the surprising result—the unmeasurable values (about 8/9 of the mass of the iceberg is submerged) are far greater than the measurable. So, it behooves us to do a little more digging and assembling of data in order to quantify these intangibles or, as they were referred to, these imponderables.

Winfrey. — Mr. Cherniack, I am going to disappoint you. I am going to agree with you. I did not say that a city could not build schools and parks and highways; I simply said, or intended to say or convey, that the money that they commit to a highway project is not available to build parks or schools. It is committed but they then find money from some other resource to build the schools and the parks. But they cannot do it with that same money committed to the highways, so if they commit money to the highways then they have to find other money to do what they would have done with that money had they not committed it to highways.

Congress struggled almost 9 months with that very same problem. They committed money to highways. They did not have enough for certain other things. They finally came back and raised more money by an increased gas tax. So that is my answer to the first point.

With respect to the second point, I do not in my mind think that my mental or physical anguish is a social benefit or social factor. If you want to consider nervousness or fatigue or mental strain as an economic factor, you have the privilege, but in the end, all I ask is that you show in your analysis that it is economic and in some way it is an economic consequence on the production or utilization or consumption of goods and services.

If you go to the office and produce only six hours work in quantity because you were so physically worn out in driving through the traffic that morning, then we can say the mental strain of driving through the traffic is an economic factor because it reduces production, and the output was lower so it becomes an economic point. But my point is you have to prove it. You cannot just assume it.

On the third point, all I ask is that you do not take this entire iceberg, that which you can see and that which you cannot see and wrap it up and give a single figure for it. I want it presented in two figures so that I know what you have done. Then the top official can use his weighting and judgment as to that imponderable, to that thing he cannot see or feel or measure, or that he cannot put a price on; and then he can give it whatever weight he wants to. But when you wrap it up in one solid iceberg, visible and invisible, then you do not know what to do.

Berry. — Mr. Winfrey, I would like to comment on the example of an interchange problem. With an interchange, as I understand it, you have a considerably greater ratio of annual cost to the annual capital costs as compared with the normal continuing highway project. Therefore, with that greater M over A ratio, you are likely to come out with differences in rankings on a rate-of-return basis as compared to the calculation of benefit-cost ratios. Northwestern University ran a study using actual data from several states and it was on an interchange type of problem that we found this difference. But for the building of projects where you are dealing with normal highway construction and the design standards do not produce much difference between the ratios of operating costs to annual capital costs, the rankings by the benefit cost versus the rate-of-return give about the same values. I wanted to bring out that the example you picked served to emphasize rather than minimize — you could have had the other kind of example.

Hennes. — My first point is to return to this dollar for highways which cannot be used for schools. It is true that any dollar used for transportation cannot be used for any other purpose so if we add this all up we conclude that if we did not spend any more money on roads we would have more for schools — which is not true. This gets back to net consequences of highways. There is a net consequence of this improvement that is over and above the choice between the different outlets for investment.

The second thing goes to the economic life. You mentioned how many highways, 50 or 75 years ago, are still in service. Perhaps I am twisting your words somewhat. I think this stems back to the disadvantage of putting economic value on the elements rather than the improvements. There is no route that was in existence 50 or 75 years ago that is not in use today.

Winfrey. — I know routes that are growing up with timber. You can't say they are all in use.

Hennes. — This is a question of fact. In my own state there are about 60,000 miles of

roads. This is about the same now as it was 60 or 70 years ago. The difference has been that as transportation developed and highways developed the need for improvement changed and some routes that got overloaded were replaced as primary routes, but they probably still are carrying as much traffic as the people conceived they would have at that time. Certainly the pavements have been worn out but this is not so much obsolescence as it is deterioration.

Finally, in your comparison between the benefit cost and the rate of return, is it a fair conclusion that in choosing alternatives the use of the total annual transportation cost would give you the correct result; and that, having chosen between alternatives by means of the total annual transportation costs, then for that particular example one could determine its justification by either benefit-cost or rate of return and get fair results?

Winfrey. — I will answer the last question first. I would say the answer is yes. If you take alternates A, B, C and D, and on a comparable basis determine the annual total costs of these highway projects, you select the one with the lowest annual transportation costs — vehicular costs, capital costs, and operating or maintenance costs — provided they are comparable in their service. You would get the same answer by selecting one which has the lowest annual cost of transportation. You get the same one by the benefit cost ratio solution and the same one by the rate of return, so you do not need to go through the other two if you pick on that basis.

Hennes. — Unless because of risk of error.

Winfrey. — Yes, but my point is they both have to deliver the same service. If one takes care of 10,000 vehicles and the other one only takes care of 8,000 vehicles, then you cannot do it because they are not comparable and annual costs will not be comparable because you are dealing with different traffic volumes.

Moskowitz. — The whole reason for making these analyses is that they do not provide the same amount of service. If they did, all you would have to know is how much service they provide, period. In answering Professor Hennes, you just stated that this method was all right provided this existed, that you did provide the same amount of service. Well, what are we here for, then?

Winfrey. — Why do we have that word "if" in our language if it is not to be used in such circumstances?

Moskowitz. — Our whole problem is to decide between alternatives which do not provide the same service.

Winfrey. — There are plenty of variations in location and design where all of the services or results are not comparable, but I will agree with you completely that in many of your highway location analyses, particularly on the Interstate System, there are proposals A, B, C and D and they do not give you the same service. Under those circumstances you cannot make the solution on the basis of strictly minimum total transportation costs because you are not comparing like things with like things.

Rothrock. — Suppose you have a corridor in which the present highways now carry a total ADT of 10,000 vehicles between two points, and plan one new location expected to divert 4,000 vehicles from the old, to compare with an alternate which will divert 6,000 vehicles; thus, leaving residual traffic on the old highways of 6,000 and 4,000 vehicles, respectively. Can't you compare the two alternates by using the costs of travel for traffic diverted to each alternate plus the cost of travel for the residual traffic for that alternate?

Winfrey. — In this case you must take the entire travel between points.

Grant. — I am on Mr. Rothrock's side on this, but I would like to make a further qualification, and that is that the interest rate used in calculating equivalent annual benefits or equivalent annual cost savings, and on capital costs on the improvement, should also be the minimum attractive rate of return. If 3 percent is enough both ways, it does not matter how you look at it, and the minimum annual cost, considering highway

costs and user costs and other costs that you are going to consider, will give a more easily interpretable solution than either incremental rates of return or incremental benefit-cost ratios. This is a way of checking, in a great many instances, whether you have loused up your incremental rates of return or incremental benefit-cost ratios.

Hennes. — In the matter of net consequences — the dollar for schools, the dollar for highways — a dollar spent for highways is not available for schools. I say this is true for a specific instance, but when we view this as a whole there are some net benefits left over because without transportation we would all be living on our own acre of ground, etc.

Lang. — I would like to speak directly to that point, the first point that Mr. Hennes made, and what I am going to say applies to the other comments made in rebuttal to Mr. Winfrey's paper. In a very real sense if you look at transportation — and I am thinking now of all transportation, including highway transportation — it does not produce except in one very restricted sort of situation that I have been able to think of. It does not produce anything that we really want, of and by itself. It only produces something which is necessary to the production of something else that we want. The only exception is the very minor one of sightseeing. In this sense transportation may have a very real value, but in all other senses, as far as I can see, transportation has no value in and of itself. The result is that in all of these economic analyses we are concerned with a conservation process. That is, we are trying to conserve resources because transportation does not produce resources of and by itself. If you think about this a little bit I think it is bound to color the way in which you approach all of these economic analysis problems.

Winfrey. — I think that is a very good observation, but we must not lose sight of the fact that if we did not have any highways, we would have something as a substitute for them (other modes of transportation) so when we are speaking of highway transportation, we must not forget that there are other modes of transportation. We have to build these highways on the justification of using them for 75 years — and that is a long, long time. In the meantime, we may have a completely different type of vehicle which requires a completely different type of highway.

Mr. Hennes made one other point that I want to answer. He spoke about the service life — the long life — but there is a decided difference between possible service life and the accepted practical life period used in economic analysis. In industry, when you do cost accounting to determine profit and loss, you use what is judged to be a reasonable economic life of the facility, that is, that period of time that you can afford to use it and make as much money as you would make if you had to substitute for it. When that point comes, we reached the end of economic life of that machine or tool or building or highway.

Now, we do our cost accounting on that basis and the profit and loss statements are on that basis; but when industrial analysts have to make an analysis of the wisdom — of the economic wisdom — of buying a machine or putting on the market a product, or any proposal of this sort, they use a comparatively short period. I say our economic justifications for proposed highway facilities should be analyzed on a short period and not on the total life of their usability. True, we can say land will be here forever but it may not actually be used for highway purposes that long.

Cherniack. — I did not want to let the assertion go by that transportation did not produce anything. Transportation adds place value. Just as manufacturing adds a value so transportation adds a value. Otherwise, we would say management adds no value and does not produce anything. I think transportation does produce values and we have to determine the values.

There is another point that I failed to mention before on this matter of net consequences. I got the implication that in most cases net consequences approach zero; that it is a mere transfer of benefits from one place to another. My studies indicate that whenever you make an improvement such that you divert traffic from one route to another, you not only divert and attract from other routes, but by the same reason, you also generate or add value, so even if you could measure such things you would find manifestations and indications that you do not have a net value close to zero. You have a net value which is usually quite positive.

SESSION TWO

Thursday, September 17, at 1:30 P.M.

CURRENT PRACTICES IN ECONOMIC ANALYSIS

FRANK E. ESTER, Presiding

Ester. — Certainly a meeting like this is something that is most valuable to anyone engaged in the practice of economic analysis. We need all the techniques, all the helpful information we can get.

For example, in Indiana we had a certain interstate project in an urban area for which we had computed, I believe, every known type of economic analysis. We submitted our report to the Bureau of Public Roads. It was approved.

In the meantime, a local pressure group had a consultant to make a new economic analysis of this same route. Their report, different from ours, finally wound up in Washington, and it was some four months before a decision was reached.

There was another project in a rural area on which the pressure group again referred their minutes to Washington. The prime statement with which they wound up their report was that they would save on their proposed location $30,000,000 in construction costs over the proposed line that we wanted to build. Well, that was remarkable, because the original estimate for this section of highway was $19,000,000.

Resume of AASHO Report on Road User Benefit Analyses

D.W. LOUTZENHEISER, W.P. WALKER and F.H. GREEN, U.S. Bureau of Public Roads

● AS EARLY as 1945, several state highway departments were using some type of formal approach in appraising the economic feasibility of proposed construction projects. Also, the same general methods were being used to determine the relative merits of two or more alternate locations or designs. It became apparent that some effort should be made to coordinate the work of these various agencies, and to establish some sort of a specific guide which would promote the use of this type of analysis in all highway departments, and encourage standardization of the procedures. Such a report, Road User Benefit Analyses for Highway Improvements, was published by AASHO in 1952.

Any economic analysis of a proposed highway improvement must include an appraisal of the expected benefits to be derived from the project, as compared to the estimated cost of the improvement. There are several means by which this comparison may be expressed. In the AASHO report, a benefit cost ratio is prescribed. This ratio represents the amount of savings to highway users for each dollar invested in the highway facility.

The basic formula calls for the computation of highway costs and road user costs, from which road user benefits can be determined.

Highway costs include both construction and maintenance. Costs for the improved facility are based upon the estimated annual amortized cost, plus annual maintenance, while for the existing highway only the annual maintenance is included. The resulting highway cost is, therefore, the increased annual cost due to the proposed improvement of the facility.

Road user costs, on an annual basis, include the actual cost of vehicle operation, plus factors indicating the value of time spent in travel, and for the less tangible advantages or disadvantages of traveling on roads with greater or less degrees of traffic service characteristics.

In the formula, road user benefits are the savings to be derived from the improvement, indicated by the difference between the road user costs on the existing and the improved facility. Other factors, including increased safety and community benefits, might also logically be included in this item if sufficient information were available for estimating the amounts.

The formula indicates a simple division, in which the estimated annual road user benefits are divided by the increased annual highway costs, to obtain a benefit cost ratio.

This method, which includes a systematic summation of estimated costs and a logical means for comparing the cost items, provides a sound approach for making a routine economic analysis of a proposed construction project. It also provides a procedure for comparing two or more alternate locations or designs for the same project, by comparing each alternate to the basic (existing) condition, using the same total traffic for purposes of comparison.

CALCULATION OF ROAD USER COSTS

The estimated costs to the road users are computed by establishing the unit costs per mile, which are multiplied by the average annual traffic volume for the analysis period and the total length of the analysis section.

Unit operating costs are affected by many factors, some of which are interrelated. For example, increased speed of operation results in increased fuel consumption and tire wear, but decreased cost of time. In the report, it was necessary to combine some of these factors, and the unit operating cost data are presented according to a selected group of specific variables. These include:

1. Type of highway design, type and condition of surface;
2. Type of traffic operation (free, normal or restricted);
3. Speed;
4. Gradients;
5. Curvature; and
6. Type of vehicle.

These variables were selected to provide a practical means of presenting unit operating costs in tabular form. They establish the amounts of the several individual items of cost, which normally are not needed as separate items in the analyses, since they are combined into a total unit cost in the tables. These specific items of expense include fuel, oil, tires, maintenance, depreciation, time, and an intangible item for "comfort and convenience." The cost tables are presented in detailed form, in order that prices may be kept current and local price situations accounted for. In the discussion of operating costs which follows, only the total costs are considered.

In presenting the unit cost data, a separate table is used for each major type of highway design and highway surface. One table lists costs for 4-lane divided highways, paved and in good condition. The second table lists paved 2-lane highways and another loose aggregate surfaces. Corrections are indicated in the text for surfaces in poor condition.

Each cost table is subdivided into three sections, one for each type of traffic operation, that is for free, normal, and restricted operation. The determination of the type of operation is based upon a comparison of the predicted traffic volumes and the practical capacity of the highway, according to information included in the text of the report.

Within the framework of each section of the tables, operating speeds form a major subdivision. Speeds are grouped in increments of 4 mph, and costs for specific estimated speeds can be interpolated.

Finally, under each classification for speed of operation, various gradients are listed in increments of 2 percent.

At this point, the analyst is able to read directly from the table an estimated unit operating cost of a passenger vehicle operating on a tangent section of a rural highway. A correction for horizontal curvature is then made by reference to a chart included in the report.

In addition to the itemized cost tables, cost charts are also presented. Total unit operating costs, in cents per vehicle-mile, for each situation or variable included in the tables, may be read from the appropriate chart.

The cost tables and charts are for passenger vehicles only. However, the method is set up to utilize similar separate and detailed unit cost tables for trucks, when sufficient information is available for their preparation. As an interim approximation, in order to account for the increased operating costs for commercial vehicles, a table is included which indicates the equivalent number of passenger cars to be substituted for each type of commercial vehicle.

The estimated cost of stops is also considered as an item of operating cost. A chart is included in the report by which the cost of each stop, according to the approach speed and the length of delay, may be read directly. The estimated number of stops per year is computed by considering the expected traffic situation at each intersection along the route. Vehicles approaching or crossing the highway under study are also included. On many rural projects, the cost of stops is not of sufficient importance to be included in the analyses.

Accident costs form a logical part of road user costs, if adequate cost data are available. If there is a significant difference in the accident potential between the existing situation and one or more alternates, or between various alternates, this item is sometimes approximated and included in the totals.

For analysis of a particular project the different sections of highways carrying traffic affected by the improvement under consideration are set up as analysis sections on which the road user costs before and after are calculated separately. Sections limits are established by major factors involved, such as points of traffic change, type of highway, number of lanes, and differences in the basic design elements. Summation of the road user costs for all sections provides the project totals.

Total road user costs are computed by using the total unit operating costs, the estimated average annual volume for the analysis period (frequently 20 years) and the length of each analysis section. It is important that the total traffic is assigned to each alternate and to the basic condition, even in situations where such an assignment of traffic to the existing facility may be somewhat unrealistic.

CALCULATION OF HIGHWAY COSTS

Highway costs are computed on an annual basis. They include the amortized annual cost of construction and annual maintenance charges.

The estimated cost of construction is amortized over a period of years which to some degree represents the expected useful life of the various elements. Right-of-way costs are therefore amortized over a longer period than the cost of less durable portions of the highway. Typically, the total estimated cost of the new work is divided into three parts — right-of-way, grading and structures, and pavement and base. A logical amortization period is assigned to each of the totals and an appropriate rate of interest is selected. Then, from an amortization table included in the report, a total annual cost may be computed.

No value is assigned for the worth of the existing facility. Annual maintenance costs are estimated.

The estimated increase in the annual highway cost is the difference between the amortized construction cost of the new facility plus maintenance less the cost of maintenance on the existing highway.

USE OF ROAD USER BENEFIT RATIO

Cost benefit ratios are used to appraise the soundness of a proposed highway investment or to aid in the selection of an alternate location or design.

In using a ratio to appraise a proposed project, a ratio of less than unity indicates a poor investment; that is, the benefits which are expected to be derived by the highway users are less than the funds to be invested in the highway. However, because of the general deficiency of highway construction funds, any proposed project normally considered for construction is likely to show a ratio of considerably more than unity. High-priority projects usually have ratios of from 3 or 4 to 10 or more.

In using the cost benefit ratio procedure for the selection of an alternate location or design, each alternate is normally compared to the basic, or existing, condition with the same total volume of traffic used in all cases. The preferred alternate, as indicated by this analysis, is the one for which the cost benefit ratio is the highest. Where several major alternates are under study, usually a second analysis should be made, using the "preferred" alternate as the base, to determine if an added increment of investment might yield a proportionately larger increase in road user savings on another alternate.

LIMITATIONS IN USE OF PROCEDURE

The procedures which are outlined in the report are intended to provide only one indication, although a very important indication, of the soundness of an investment or of the advantages of one location and design alternate over another. Other important factors, many of them intangible and difficult to include in a prescribed formula, can never be ignored.

In many situations, several routes, or section of routes, must be included in the over-all analysis of a proposed project. Since identical total traffic volumes must be assigned to these routes for each alternate proposal, predicted increases in future traffic volumes may present a distorted pattern, in which the traffic assignments may be completely unrealistic, or which may be impossible to predict.

Since arbitrary assignment of values for certain factors must be made in any analysis, there is a constant temptation for the analyst to select values which will favor a preselected project or alternate. Accordingly, complete objectivity may be difficult to achieve.

LIMITATIONS OF THE 1952 REPORT

The information contained in the 1952 report has several recognized limitations.

The cost information, except for the data on the cost of stops, was developed for operations on rural highways. Its use on urban facilities requires adjustments for the various factors for which there is a limited amount of available data.

The unit operating costs were obtained only for passenger cars. The use of passenger car equivalents for various types of commercial vehicles represents an effort to recognize this factor in the analysis, but greater refinement is needed.

Cost information for freeway operation is not completely adequate. It is especially deficient in the operation at interchanges.

Factors affecting the cost of operation are not fully representative of the operational characteristics of modern vehicles.

Unit prices which were used to establish operating costs are in need of adjustment.

PROPOSED ADJUSTMENTS IN NEW ISSUE OF REPORT

Specific changes to reflect the increases in certain unit prices since 1952 are being proposed for a current republication of the report. These changes include the following: (a) gasoline, (b) oil, (c) depreciation, (d) maintenance and repairs, and (e) time.

It was found that gasoline and oil prices have increased appreciably. Depreciation has increased 50 percent, in the same proportion as the prices of new cars. Maintenance and repair costs also have increased by 50 percent.

The value of time spent in travel was taken to be $1.35 per hr in 1952. It is proposed to increase this amount to $1.55 per hr, in the same ratio as the increase in the cost of living index, approximately 14 percent.

These proposed changes increase the cost of operation approximately 20 percent, in a typical analysis.

Although the proposed changes could be made by the analyst, within the framework of the existing cost tables, it is believed that adjustments in the printed tables will lead to more uniformity in the work. The proposed changes are intended only as an interim arrangement, until a completely revised and expanded report can be prepared. A large amount of research is under way, from which it is hoped much new information will be obtained, not only to introduce new and more accurate operational data and cost information, but to provide a more comprehensive approach to the over-all problem of economic analyses. With more expensive projects and more complex problems facing the highway engineer every year, this new information is urgently needed.

Discussion

Burch. — In the practical adaptation of the warning Mr. Walker gave that the same quantity of traffic should be assigned in each case, suppose we consider a quite usual situation: a community in which an alternate M would be located fairly close in on the one hand, and another alternate N which would be located somewhat further out on the other.

Because of the local generation, you will get more traffic on M than you would on N. There is no way to avoid it. Now, then, would you assign the same quantity of traffic to these two alternate locations?

Walker. — You would have to assign some of it back to the basic or present route. You may have a total volume of 10,000 from point A to point B located on either side of the community. On a bypass there might be 8,000 and 2,000 would continue on the present route. In your case, you might have 9,000 on route M and 1,000 on route N.

Burch. — Then you are assigning different values to these two routes, yet I believe your statement was to be careful that you assigned the same traffic.

Walker. — It is the total corridor traffic that must be the same.

Burch. — Between points A and B plus your generation which occurs on route M which does not occur on route N?

Walker. — That is one of the "limitations" pointed out. The concept doesn't provide for any generation. It assumes that all traffic that wants to go from A to B before a by-pass is built is going to get there, regardless.

Burch. — Are you concerned in comparison only with the through traffic?

Walker. — You may still have a lot of traffic in addition to the assumed 10,000 — there is still a lot of additional local traffic, but you do not include that in the analysis.

Burch. — The traffic to be included could be limited then to through traffic alone?

Walker. — Yes.

Rothrock. — We have problems like that, in which we have more traffic along the route between A and B than the through traffic alone using the corridor, and which would use the M alternate. This route would generate more traffic, and such traffic should be included in the analysis because it is benefited by a reduction in travel distance. The traffic is that which has its origin and/or destination between A and B and is probably benefited by construction of a new route such as M.

Walker. — It would benefit through relief of congestion on the existing route.

Rothrock. — The generated traffic gets on route M somewhere in the middle of the route between points A and B.

Walker. — Would that traffic currently exist? You refer to it as generated, so I assume that this traffic would not exist if the new road were not built. Is that so?

Rothrock. — It is now using the present highway.

Lochner. — Then it is not generated. It is diverted.

Moskowitz. — I think that what is troubling Mr. Burch is the word "assigned" which crept in. Walker didn't mean "assign"; he meant that you compute the cost of the total amount of travel regardless of which alternate you build.

Burch. — I see. It is cost to the the traffic in toto.

Moskowitz. — The cost to all the traffic traveling between your universe of X and Y by routes A, B, C, D, E, F, G, etc. That is what makes it difficult. We may run into 10 or 12 thousand travelers that we have to account for, all in all. It is not just the assigned traffic on a specific route.

Newcomb. — Mr. Walker, may I raise a basic question as to a reasonable approach? As economists we tend to think that the cheaper the productive process the more goods we produced. When we cut the cost of printing, we can produce a lot more newspapers, a lot more books. With the same input, we get a lot more output, because there is less friction and time loss.

With an efficient transportation system you are going to have more traffic at the same total cost. You cannot assume in a growing economy, that you are going to have the same amount of traffic on an inefficient system that you would have on an efficient system. It seems to me you are destroying your concept when you assume that without any changes and with narrow routes and with a lot of intersections, there are going to be just as many people going from A to B, and as happy and as productive when they get there, as there would be if we had an efficient system with improved routes, and with people getting there eager to work.

The two systems are totally different and the products including good transportation are going to be quite different.

Walker. — I think you are agreeing with me rather than asking me to agree with you. I believe that is substantially what I have tried to say. It is a little bit unrealistic to assume that all the traffic that would go from A to B if route N were constructed, would also find its way from A to B if route N were not constructed. However, that is the way the procedure is set up in the "informational report," and I have been saying that that is a limitation — a limitation because it does not recognize the fact of new traffic. That is to say, "generated traffic."

Moskowitz. — There may be a case for saying that it is valid to assume that all the travel will take place, regardless of whether there is room for it or not. This gives a base to measure against as to how much benefit we are providing traffic in reducing frictions and time by improvements. It is hypothetical. If we do not make the improvement, new travel will not take place, but may we assume for the purpose of considering how much good will be done that it would take place anyway?

Newcomb. — You are understating the case by this assumption.

Moskowitz. — I was afraid I would be accused of overstating the case.

Newcomb. — No, if you make improvements you are going to get new traffic. If you do not improve, then the economy becomes stagnant. You have premised that the economy doesn't become stagnant due to inefficient routes when it does. But with improvement you have enabled the economy to grow, and in the economic analysis have not given yourself credit for enabling it to grow.

Moskowitz. — Well, there is good logic for justification for improvement. California, however, does not use this economic analysis for deciding whether or not to do something. The only thing we use it for is to decide which of several alternate things to do.

Blensly. — May I say that it seems to me, as I reflect on the discussion in Session One, that if we are only considering the relative benefits of all possible alternates we do not have any problem, because we have already decided to improve the existing, or at least do something that we have decided is justified, and in analyzing all of the alternate possibilities we will be enabled to make the best choice, and thus solve our problem.

Walker. — I might say that that is the primary intent of this informational guide. It is to enable you to select the best from several alternates. It is not recommended — although it can be used for that purpose — that it be used for setting priority ratings on highways, in different areas of the state, for example.

Zettel. — I agree with Blensly that in considering all of the alternates, the most unrealistic is that you are going to do nothing. But I think sometimes we tend to underestimate on the cost of our present facilities if they are not improved.

For example, we were faced with the problem of a horseback evaluation of the proposed California freeway system. We compared the costs and benefits deriving from adding this system against the costs and benefits of not having it. I think it was suggested that the cost of the existing facility is nothing. Of course it is quite ridiculous to assume that. Either we would do a great deal of some kind of construction on the existing system, which would be a cost; or the benefits would appear to be so much greater if we did nothing, that we might do nothing with a resulting great economic stagnation.

Walker. — Of course, one alternate would be to improve the existing highway.

Zettel. — Yes, some kind of an interim improvement, rather than the alternate of not improving at all, which would be an unrealistic thing in a growing economy.

Walker. — I am not sure how far afield we are by assuming that traffic which would use an improved system is the same that would use it if it were not improved.

Grant. — Newcomb's question had to do with generated traffic. That is new traffic that might not exist with one alternate, but would with another alternate. This is a "toughy" in these economic studies. The "green book" has a line on this. The problem treated arises in relation to navigation — generated navigation traffic — and the proposed navi-

gation improvement. What they propose, in effect is, "Well, as far as assigning a benefit is concerned, let's split the difference, let's say that the advantages to this new navigation traffic, that would not move without the navigation improvement, and will move with it, are not, of course, the full savings in navigation costs; they are half the savings."

Now some such point of view might be appropriate, with some modifications, in the highway problem, with regard to generated traffic. It is not quite parallel, but it is similar.

Hennes. — Mr. Walker mentioned the increase in vehicle costs as a result of the increase in the gas tax in his remarks. Now, as to decrease in costs as a result of improved facilities, I am a little bit uncomfortable about suggesting the place of the savings, and the operating cost due to the savings in the gas tax portion of the gasoline due to highway improvement.

In the short run, there is no question about its being true that the individual driver does save gas tax resulting from a decrease in use of gas on improved facilities. In the long run, however, the sum total of all these saving is zero, because if we improve the entire road system of the country, we would of course have cut down operating costs, and certainly that part of the savings which is not gas tax charges would be saved. Yet, the total cost of highway work might remain the same (in any event it would unlikely decrease directly with operating costs), and if the cost were paid by gas taxes, we would have to raise the gas tax (on a decreased use in gas) to recover the same amount of money. In the long run, there would be no saving to the vehicle operator, due to the fact that on the gas he did not consume because of highway improvement there is still a bill for that improvement that must be paid eventually.

Walker. — I would agree with you. I think that there are two sides to the argument of how to handle gas taxes in the analysis and I believe you come out at the same place, substantially, by either including the gas tax or excluding it.

We decided that since the earlier "Informational Report" included the tax in the price of the gasoline, it should be included again, but I think our conclusion was that it would not make any substantial difference in the final outcome whether it was included or not.

Hennes. — It would make a difference in the benefit-cost ratio of specific improvements in contradistinction to an over-all economic effect?

Walker. — I believe in comparing alternates, at least, wouldn't it erase itself?

Economic Analysis of Alternate Route Locations

DAVID S. JOHNSON, Assistant Chief of Planning, Traffic and Design, Connecticut Highway Department

● THE GREATEST single, and all too often only, highway planning criterion for the comparison of alternate route locations has long been in terms of the road user benefit-cost analysis. More recently, planning engineers have begun to realize that highways cannot be located on the basis of cost to road users alone, and that there are many factors which enter into a route location. Some of these, but by no means all, are of interest to both the layman and the technician.

A few of interest to both are: (a) traffic service, (b) effect upon local planning objectives, (c) effect upon local traffic patterns and street networks, and (d) engineering —this latter only superficially to the layman.

Those of interest to technicians only are: (a) benefit-cost ratios and computations, (b) integration with "bookkeeping" type classification systems, (c) official requirements, and (d) engineering — in the exhaustive sense of the term.

In the final analysis, the actual worth of a highway facility to a community depends almost entirely upon the previously mentioned lay criteria. The professional criteria are, generally speaking, aids or tools in making a quantitative appraisal, but to place undue stress upon them against the lay criteria would be to confuse a means with an end.

Some of the difficulties in the mathematical analysis leading to the benefit-cost ratio are the many assumptions that must be made in arriving at traffic assignments. These assumptions enter into the development of diversion curves, travel times and other relevant basic data. Further assumptions are made in developing the value of the road user's time, motor vehicle operating costs and highway construction and maintenance costs. Differences in these basic assumptions may throw the final results either way, and therefore, the computations are only as good as the initial assumptions.

The difficulties with the origin-destination analysis are found in the fact that a complete analysis may not give a complete answer. Assumptions made about other routes in the area may be based on little or no actual data, and therefore, can be wrong or superficial. Screen line origins and destinations give little, or no, information on routes at right angles to the proposed new facility — yet, the new facility may have a profound effect on the existing ones.

In Connecticut, it has been concluded that the need is for an "area" approach to the traffic problem, based on land use or an equivalent method of appraisal. The gravity model method, developed by Alan M. Voorhees, may be the answer.

Presently, this method is being applied to a regional traffic problem in the Greater Hartford Area. Of the six major highway facilities, proposed for this area, three will be north-south expressways: (a) Interstate 91 through the center of the area on the west side of the Connecticut River, (b) Conn. 9 westerly of Interstate 91 to the north and overlaying it to the south, and (c) Conn. 2 on the easterly side of the river. The two east-west expressways will be (a) Interstate 84 through the center of the area and (b) US 44 northerly of Interstate 84. A circumferential, composed in part of US 44, Interstate 291 and Interstate 491 will complete the expressway system for the area. At this time, Interstate 91 northerly, and Interstate 84 easterly, from the City of Hartford are on the ground. Conn. 2 is under construction toward the south and the remaining facilities are in various stages of planning and design. So vast is the cost of this system that it is conceivable that not all of it will be completed within this generation.

In the development of this system, alternate locations were studied and traffic was assigned by standard O-D methods as the routes were proposed. Data from several roadside interview surveys were used to develop a composite traffic usage diagram of all the main streets and expressways in an attempt to determine the area-wide picture.

When assignment to the circumferential route was tried serious questions were raised, as to:

1. What traffic can be expected on the belt route?
2. What effect will the belt route have on existing streets and proposed expressways?
3. What new traffic will be induced, generated or shifted?

It was decided to use the gravity model method of analysis to resolve these questions and to check out the previously assigned traffic usage of the area network.

The advantages of the gravity model method are many, for example, speed and ease of analysis, and a more complete answer. Most important, is the fact that it is based entirely on forecasted land use, rather than traffic growth on the existing highway network. In most instances of a belt route problem, there are no existing parallel major streets or traffic arteries, and a belt route on the ground will result in an entirely new orientation of one area to another. This is why the area-wide land use approach is the only feasible applicable method to determine a properly integrated system in this area.

Highway planning is no longer a linear problem concerned with running a road from one point to another in as short a distance as possible. It is now a broader problem of finding a highway's justification in the service it provides to the area. The highway is a functional element in the area plan, and with this sort of concept, its location depends less and less upon detailing considerations of grades, alignment, mass haul diagrams and narrow economic consideration of benefit-cost ratios.

At the Sagamore Conference on Highways and Urban Development the highway officials summarized some of the factors influencing urban highway locations as follows: (a) impacts on the community, (b) present and future traffic, (c) cost of development, (d) highway user benefits, (e) effects of expressway operations on local street system, (f) compatability with local plans (g) aesthetic considerations and (h) national defense.

The city planner summarized the influencing factors also: (a) impacts on the community, (b) present and future traffic, (c) transportation costs, (d) impacts on local street pattern, (e) development of desirable land uses, (f) separation of different land uses, (g) aesthetic considerations and (h) national defense.

The basic thought for developing new highway facilities in urban areas is the keeping in mind that highway facilities find their justification, and their sole justification, in the services which they provide.

Discussion

Van Riper. — My remark is simply supplementing what Mr. Johnson had to say.

Assignment of traffic based on O and D information is a good, sound approach, but for urban expressways, the problem might arise that the feeder roads or streets and the access streets will not have the capacity to get the traffic to and from the expressway that the O and D analysis indicates the expressway would serve.

In many cases, particularly in downtown sections of cities, the streets are nearly up to capacity at the present time. In the case of an east-west expressway, it means imposing additional traffic on the northbound streets, and leads to this: After you have determined what your assignments are going to be; (that is, what volume of the traffic the expressway is to carry), may it not be necessary to take another look at your assignments, at your problems, and adjust those so as to take into consideration the capacity of the streets which are directly involved with interchanges, to bring that traffic to the expressway?

To my mind that is a realistic problem, and is a problem that you are generally going to meet in the planning of expressways and downtown sections of the metropolitan area.

Cherniack. — The reason I comment now is because the new concept has already been brought into the picture — and that is the word "land use", which is now becoming current, and it seems to be a magic word for disarming doubters, because highway engineers may not be very familiar with it, and because it is assumed implicitly that you can do a better job at estimating land use than you can highway traffic.

Now first of all — land use covers a multitude of sins — you have to group land uses into two parts. There is a residential land use and a non-residential use; the latter consists of commercial and industrial uses.

Certainly, as planners, we can take the undeveloped land that is developable, and sprinkle, as it were, residences throughout this area. With the employment of some traffic generation factors we can estimate what would arise out of those residential areas.

But when it comes to determining direction of flow we are really at sea, because who can tell where these industries and commercial establishments are going to locate.

And depending upon somebody's other than the planner's decision a radical change may evolve in the pattern of traffic from residential to non-residential areas. We cannot just implicitly assume that we have the tools for estimating that non-residential use to a greater degree than the estimating of the uses of highways insofar as we know about highway traffic services and highway services.

I want to point out that land use is a catch-all and that every time you have found some kind of factor that aids you in doing a better job in estimating residential land use, you are then on the spot to do some forecasting and estimating.

Johnson. — I would like to point out that we are ever getting closer to "land use designation," and in speaking to you, I was thinking of potential land use, not existing land use.

In Connecticut, there are 169 towns or municipalities, and of the 169, 140 have planning and/or zoning, covering 96 percent of the population and 76 percent of the land area, so we are not far from having 100 percent designation of land use in the state.

So with each little community having its own master development plan, we as highway planners must, of course, have our master plan relative to the development of the highway system, and we do. Admitting what you say, it is a guess at the moment as to what the attractiveness will be of one zone to another.

Shall I live here and work there, or vice-versa? We have to depend on a lot on Alan Voorhees'[1] analysis of the subject in guiding our analysis. We did have the incident in New Haven relative to the location of Interstate 491 in the four towns of New Haven, Hamden, North Haven and Wallingford. A few years back the legislature passed an act setting up a development corporation for those four towns, and it said that the highway department was to plan cooperatively with this commission the location of Interstate 491 as related to the development potential of the area.

Using our state-wide O-D survey we made traffic assignments to alternate locations through the valley, and the commission, through a very fine staff of technicians, used the gravity model method, with surprising closeness of results relative to the turning movements at the interchange locations.

Admittedly, they did not have the through traffic data which we had, but our turning movement volumes at the interchanges were identical or nearly identical with theirs, so we were satisfied that it was a good method, and incidentally, these results came from a method still in the process of evolution, a method that has a high potential for development.

Or course, it is not always true that you will have as good a technical staff working on such an analysis. We have to depend wholly upon the local planners to do the land-use analysis for us. In the instance of Hartford, in which the local town planners did not have this analysis completed, the planning engineer for the city took it upon himself to head up and coordinate the land-use plan for all the surrounding towns so that we would have the pattern to work with.

We have not completed this analysis, and I cannot tell you how good it is going to be, but we are faced with this problem: How do you assign traffic, circumferentially, particularly when it is intersected by as many expressway facilities as are found in a metropolitan area?

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[1] "A General Theory of Traffic Movement," Institute of Traffic Engineers, 1955.

Cherniack. — When you assign traffic by the gravity method, you make the assumption that land uses are thus and so, residences will be in certain places, and there will be certain zones that the town planning commissions have designated as locations for potential industrial development. My point simply is this: that merely in the designation of an area as an industrial or as a residential development we are not always sure that the business people who are going to develop the land either as residences or as commercial-industrial development will see eye to eye with the planners, and the gravity model merely says that if the planner is correct in his spacial distribution of residences and industrial locations, then the traffic volume will be derived by the gravity model formula. It is an answer, but it might not be the answer.

Johnson. — I think it is quite fortunate that we have an over-all expressway plan for the Hartford area that guides the planner in designating the land use of the area. They know, for example, that the Hartford Bureau Reservoir area is a "dead" area, in which there can be no development; it is all water supply system.

But for the other areas, they have got the over-all plan—each of the communities—with respect to guiding them to the designation of land use. Planning and zoning in Connecticut is not something treated lightly. There is legislation at the state level, which most towns have recognized the value of adopting. It has been tested in court and has held up in court, so that when the town does develop its master plan and says "this is an industrial area and this is a residential area" and the residential areas differ inherently from the industrial areas it is rather difficult to bring about a zone change, because an industry wanting to locate there is not going to get in without a court case.

The court invariably upholds the planning and zoning master plan, so that there is good assurance of foreseeable use of land-use planning in Connecticut.

Moskowitz. — I think there is an area of agreement here, but what is bothering Cherniack is that regardless of what legal designation you put on a given piece of land, there is no assurance that this is going to be filled up. In other words, somebody has to guess what is going to happen in the future. Whether they guess the total amount of traffic that this road will develop or whether they guess that there will be so many thousand employees of a certain type of industry, you are still guessing something that is going to happen in the future.

Zettel. — Mr. Johnson indicated the land-use planners were working from the transportation system you have laid out, whereas, frequently the land-use planners like to go around the other way. Of course, this is an interrelated thing.

Now, you lay out your transportation system and that controls your land use. I submit that this is what you are suggesting: You have laid out a transportation system which will have a very important bearing on the land uses. One wonders then, if you laid this out before you had the land-use information?

Johnson. — Well, the system was laid out cooperatively with the community on the basis of the O-D analysis, which we have completed, and now, of course, we are concerned with lane use, not land — how many lanes in this particular vicinity.

Zettel. — That is, now you have your system laid out, and now you are speculating as to the land use for the design of the system.

Ester. — I was particularly interested in Mr. Johnson's reference to right angle traffic, or it might be feeder roads, or cross-road traffic into your main arteries.

We are finding in Indiana, due to the large mileage in our interstate system, that it appears likely that the future right angle traffic to this interstate system might develop a program practically as large as our present interstate system. Certainly, this feature of knowing what cross traffic is going to be like is vitally important.

Special Problems in the Analysis of Urban Expressway Projects

KARL MOSKOWITZ, Assistant Traffic Engineer, California Division of Highways

● THE FACT that theory is sometimes hard to apply does not lessen its validity. It would be useful to provide some practical examples of some of the difficulties that can arise in applying theory to actual reality.

Problems that are always present include:

1. The problem of predicting future events; that is, growth of travel and shifts in land use (including shifts that are a direct result of the expressway construction).
2. Accurate determination of existing trip desires, including the selection of zone centroids that will be correct enough to distinguish differences between desires that can be affected by small shifts in route location and geometrics, including the possibility that ramps may have to be shifted several blocks during the design stage which comes after the economic analysis.
3. A sure method of assignment of traffic to a proposed facility, taking into account different speeds at different times of the day.
4. Prolixity of the calculations, even assuming that everything else is known accurately.
5. Stage construction. It is known that no metropolitan network is going to be built in a day and the annual benefits will continually change during the assumed amortization period, but the complexity of trying to calculate the benefits during all of these stages makes it almost impossible to do.
6. The main reason for building a freeway network in an urban area is to provide added travel room for future growth of traffic in the community. In many communities, if nothing is done, the travel will remain practically the same as it is now because the existing street network has almost reached capacity. In computing the benefits of building an expressway, the cost of future (doubled) travel cannot be compared against the cost of present (single) travel; therefore, it is necessary to assume that the future travel will be equal whether the network is built or not. This, of course, is hypothetical but probably valid. There must be a datum to work from. It cannot be considered economic for people to stay rooted to one spot, even though it may "cost" less. A corollary to this problem is that (if time savings are considered a benefit), it is known that if no expressways are built, the travel time for a given trip will tend to become larger and larger during future years. The amount by which it will become larger is almost indeterminate, and, in truth, what might happen instead of the time per trip becoming larger, is that there will be fewer trips without the expressway.

All of the preceding problems have occurred to one and all. There is one other general problem that should be discussed:

7. A principal reason for urban freeways is to relieve congestion. The numerical units of measurement of this relief seem to be time units, and therefore a value has been placed on time, which at best must be partly arbitrary.

When traffic is assigned to the freeway, all the formulas utilize time savings as a criterion for deciding what percentage to assign.

Figure 1 shows the California assignment curves, and Figure 2 shows the original Trueblood curve, assuming that average speed via the freeway is 48 mph and average speed via the surface street route is 24 mph (it is necessary to assume some average speed in order to plot the Trueblood curve on time-distance axes, for example, 48 and 24 were chosen for convenience, not because they are typical).

Using the California values of 4.6 cents per mi and 2.6 cents per min, an "equal cost" line has been drawn in Figure 1; using the AASHO values of 4.5 cents per mi and 2.25 cents per min, an "equal cost" line, has been drawn on the AASHO curve. The shaded area to the left of this line is the area of "money-losing users". The remainder of the area, to the right of the "equal cost" line, is the area of "money-losing non-users". For example, the freeway route between a given pair of zone centroids is 3 mi longer than the surface street route, but saves 2 min of time. Everybody who uses the freeway loses 13.5 cents in extra mileage, and gains time valued at 4.5 cents by AASHO and at 5.2 cents by California. If there are 1,000 daily trips making this move, the AASHO chart would show that 740 of them would use the freeway route, and thereby lose

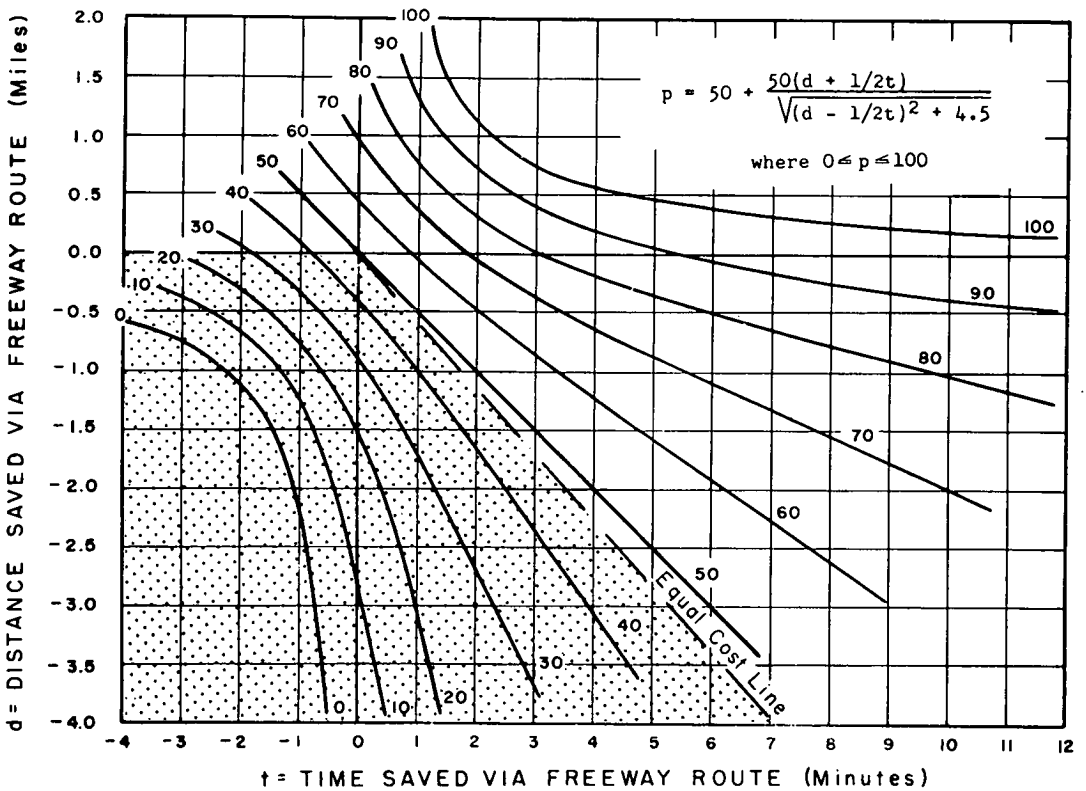


Figure 1. Percent of traffic diversion to Freeway in relation to time and distance saved.

$100 per day in mileage costs, while gaining time valued at $33. The economic analysis would show that this interzone movement would result in a "loss" of $487,000 in 20 yr. Using the California chart and time value, 280 daily trips would use the freeway at a "loss" of 8.3 cents each, or $170,000 in 20 yr.

(Note: "cost" or "loss" are always enclosed in quotation marks when those terms include time value. Nevertheless, time value shows on the same side of the ledger as trip cost.)

These "money-losing" trips tend to becloud the issue of how much benefit can be derived from a given freeway alternate, although when comparing one alternate with another it seems reasonable that an alternate located so as to minimize the "loss" as well as to maximize the benefit should be preferred.

The answer to this problem is that time is valued differently by different persons. It would be nice to have a sliding scale of values, on the assumption that time is worth at least as much to any individual as it costs him to gain it. If a mathematician could furnish this scale, it would be given serious consideration. One ramification this mathematician must face is that if Alternate A is so located that it calls for 40 percent users between a given pair of zones and it takes a time value of 4.5 cents a min to offset the loss in distance for these users (Fig. 1 at 0.8 min saved vs 0.8 mi lost), and Alternate B is located so that it will attract 80 percent of the same interzone transfer, which would only call for a time value of 0 cents to offset the mileage loss (Fig. 3), the sliding scale must be such that at least one-half of the 80 percent is credited with

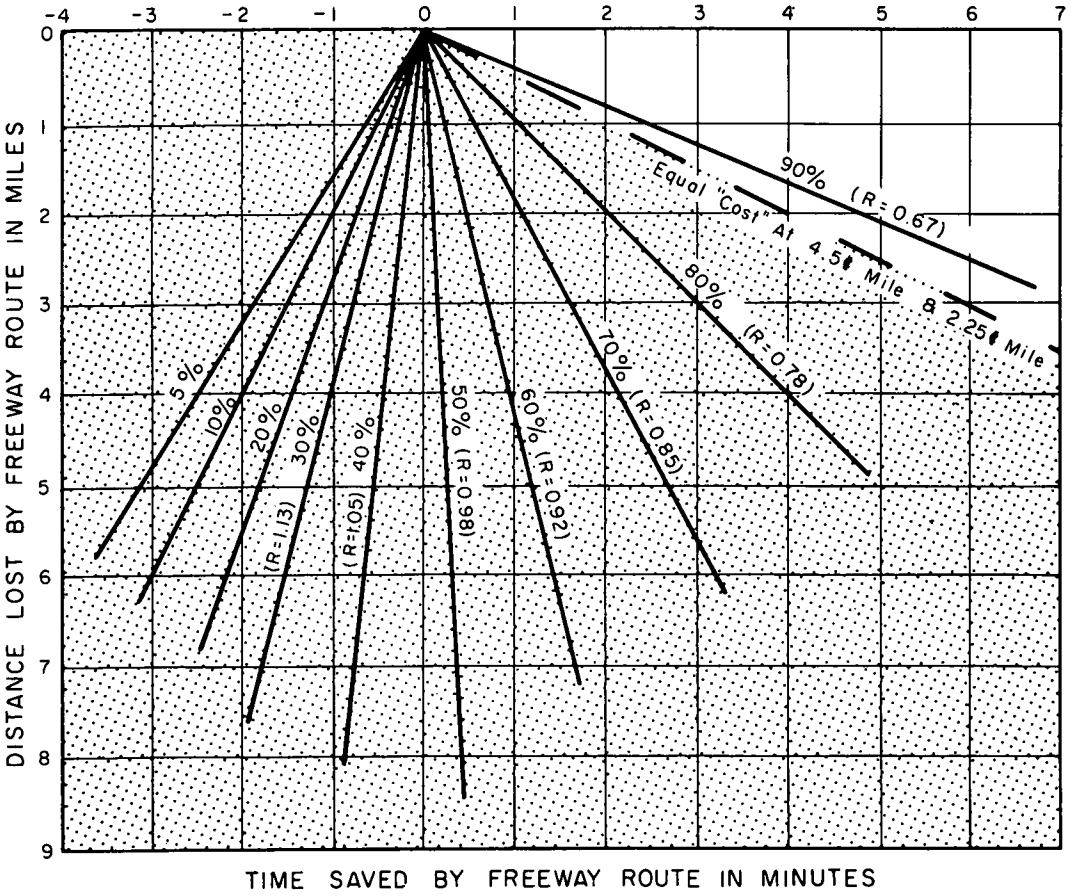


Figure 2. Trueblood assignment curve when average speed via freeway = 48 mph and average speed via street = 24 mph.

a time value of 4.5 cents, because these are the same people that constituted the 40 percent in Alternate A. Also, the mathematician must assign time value to the non-users' time: with Alternate A, 60 percent are non-users who presumably value time at less than 4.5 cents per min.

In other words, the problem is still present if all the alternates call for more than 50 percent users, which on the California scale means that the users "save" money. Using a fixed value for time, it is now found that the non-users lose money more on some alternates than others.

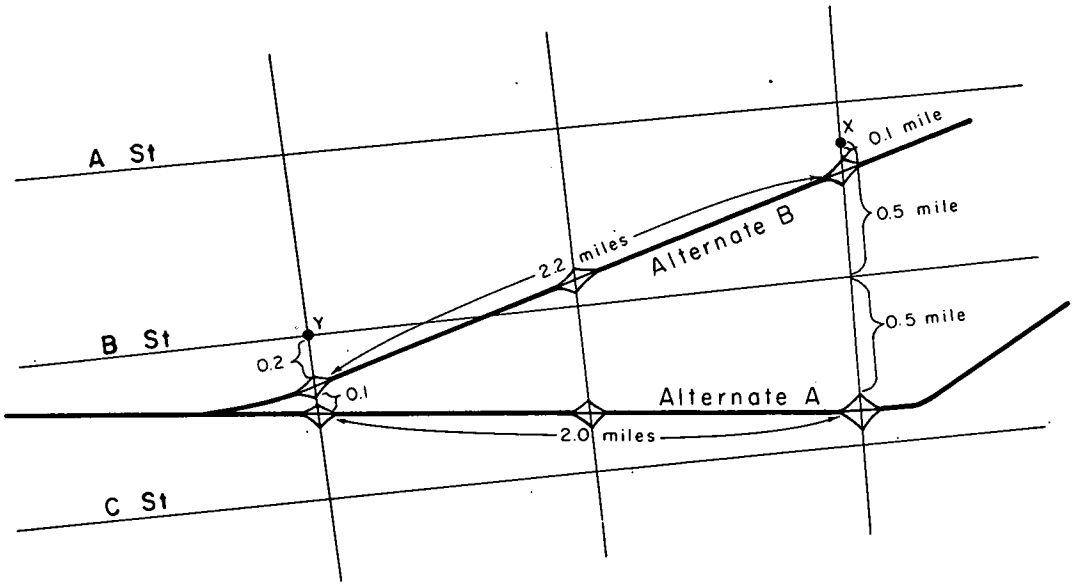
Five randomly selected cases will be cited in which pure theory did not necessarily

give the right answer as to what to do. The Division of Highways does not employ economic analyses for the purposes of deciding (a) whether to build a project at all, or (b) when to build it. The economic analysis is used only to compare alternates; in other words, to decide how to do it.

CASE I

The most frequently encountered practical problem is deciding how much of the difference in user benefits between alternates is owing to the real difference between the alternates in traffic service, and how much of it is owing to the unavoidable error of estimate.

Figures 4 through 8 show the layouts of five alternate freeway systems in a metropolitan



Via Streets, x-y = 2.5 miles, 6.25 minutes

Via Alt. A 1.0 @ 24 mph = 2.50 min
2.0 @ 54 " = 2.22
0.3 @ 24 " = 0.75
Total 3.3 miles 5.47 min

d = 3.3 - 2.5 = 0.8 mile lost
t = 6.25 - 5.47 = 0.8 min gained
p = 40 %

Via Alt. B 0.1 @ 24, 0.2 @ 24 } 0.75 min
2.2 @ 54 = 2.45 min
2.5 3.2

d = 0, t = 3.05
p = 80 %

Trueblood Alt A $\frac{5.47}{6.25}$ = 0.88, or p = 66 %. Alt. B 100 %

Figure 3. Showing "money-losing" users (Alt. A) and "money-losing" non-users (Alt. B).

area of about 150,000 population. For comparing these alternates, the total travel within this area was estimated for a 20-yr period (for this purpose the system was assumed to exist full-blown at the beginning year of the amortization period). The sum of user cost and time value of all the trips analyzed is estimated at $2.6 billion during the period, provided that travel conditions remain constant, that is, if no freeways are built, but

a hypothetical condition is conceived that will allow all of the predicted travel to take place at present travel speeds.

Table 1 shows the comparative economics of these five systems, including a variation in Plan A (Fig. 4). The difference between Plan A and Plan A-1 is $17 million. It is easy to see that this is real and is in the right order of magnitude because almost all of the $2.5 billion worth of travel is identical and the difference is composed of large differences for relatively few trips in the area where the two systems deviate from each other. On the other hand, an inspection of the map and detailed study of the individual trip movements fail to reveal any real reason why the benefits of Plan B (Fig. 5) should be so much less than either Plan C (Fig. 6) or Plan A. The difference here apparently is in the order of $40 million and is probably less than the error of estimate in calculating the $2.5 billion. Plan D (Fig. 7) shows benefits of only $32 million, or about $80 million less than Plan A, and here it is reasonable because Plan D completely omits one route and provides 13 mi less freeway than Plan A-1.

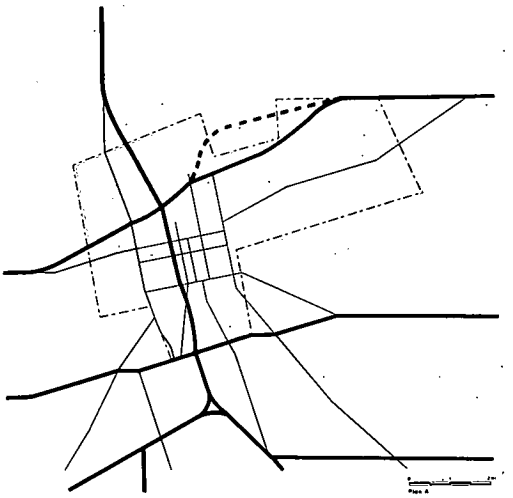


Figure 4.

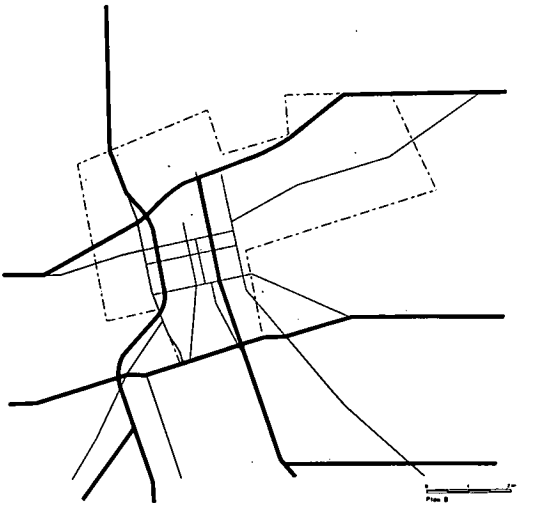


Figure 5.

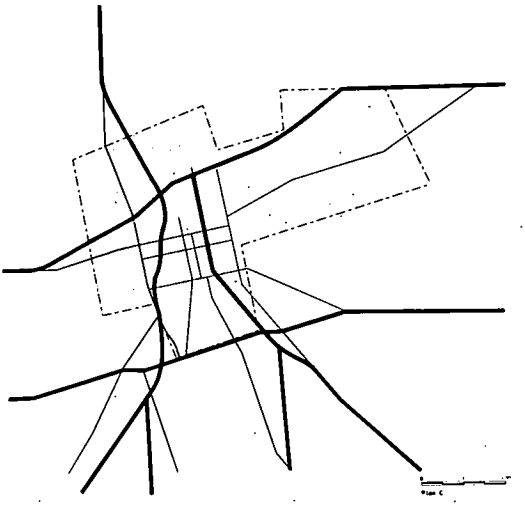


Figure 6.

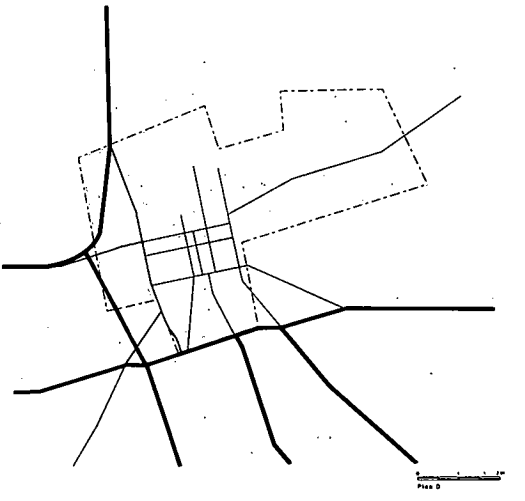


Figure 7.

The dilemma is that Plans A, B and C are approximately equal in savings; that Plan A is definitely $17 million more beneficial than Plan A-1, and that Plan D is definitely less beneficial than any of the others. But the fact that the computed figure for Plan B comes out so much less than that for either A or C makes it questionable whether it can be decided how much less good Plan D will do and whether the difference between A and A-1 is significant though real.

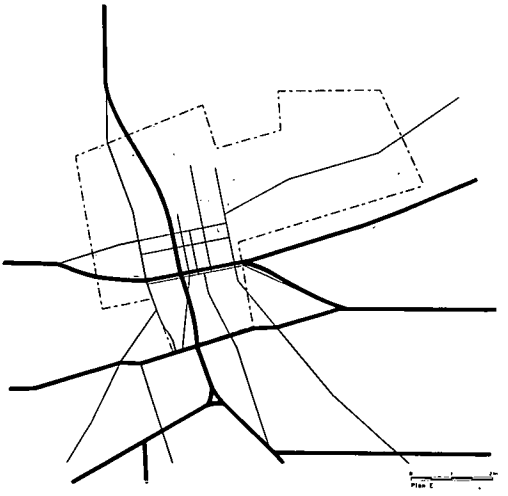


Figure 8.

CASE II

This case is cited to show the hazards of using the "benefit ratio" as a criterion. Figure 9 shows a metropolitan area of about 100,000 population and five alternate locations for one segment of the freeway system. Two freeways have been fixed. These are marked Routes 1 and 2. The route under consideration is Route 3.

Table 2 shows the user benefits of Route 3, Route 1 and the combination of Routes 1 and 3, assuming that Route 2 is already built. When Route 3 is analyzed separately, Alternates A and B are clearly superior to Alternates C, D, and especially E. However, normally it is not possible to separate the benefits of one route from another because many of the trips in the universe will use portions of both routes and the benefits of Route 1 will be changed, depending on which alternate for Route 2 is selected. Normally it is necessary to compute the benefits for the whole system. As shown in the lower section of Table 2, when Routes 1 and 3 are combined, although the total benefits of Alternate E are considerably less than A or C, the benefit ratio is higher. To illustrate the pitfall that could result from using a benefit ratio, a sixth alternate has been included in Table 2, that is, Alternate PG. Alternate PG for Route 3 consists of

TABLE 1

ECONOMIC COMPARISON OF PLANS SHOWN IN FIGURES 4 - 8[1]

Item	Existing System	Plan A	Plan A-1	Plan B	Plan C	Plan D	Plan E
Miles of freeway	—	54.41	54.80	59.20	61.32	41.96	56.10
1. Mileage, or distance costs	1,629	1,591	1,601	1,626	1,600	1,628	1,597
2. Time value, autos	957	875	882	881	869	926	890
3. Sub-total, Items 1 and 2	2,586	2,466	2,483	2,507	2,469	2,554	2,487
4. Savings in costs	—	38	28	3	29	1	32
5. Value of time savings	—	82	75	76	88	31	67
Benefits, sum of items 4 and 5	—	120	103	79	117	32	99

[1]In millions of dollars for 20-yr accounting life of project.

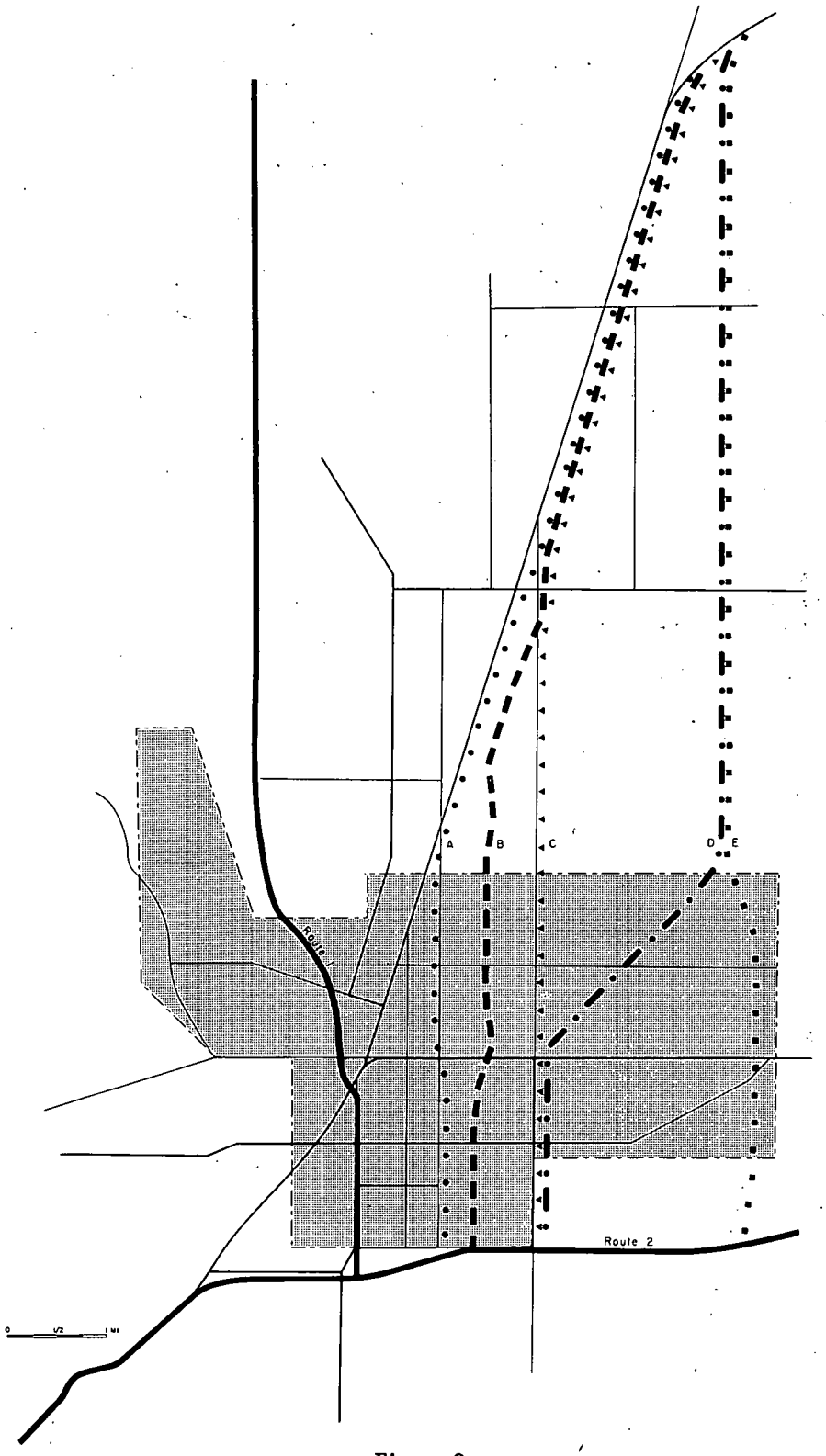


Figure 9.

TABLE 2

BENEFITS AND COSTS[1] FOR PLANS SHOWN IN FIGURE 9

Routes	A	B	C	D	E	P.G.
Route 3						
User benefits	40,770	31,070	21,880	21,471	8,674	0
Construction cost	24,370	19,641	16,794	16,457	10,950	1,000
Benefit ratio	1.67	1.58	1.30	1.30	0.79	0
Route 1						
User benefits	94,980	97,830	97,730	96,332	96,332	97,800
Construction cost	22,558	22,558	22,558	22,558	22,558	22,558
Benefit ratio	4.21	4.34	4.33	4.16	4.16	4.34
Route 1 and 3						
User benefits	135,750	128,900	119,610	117,803	105,006	97,800
Construction cost	46,928	42,199	39,352	39,015	33,508	23,558
Benefit ratio	2.89	3.05	3.04	3.02	3.13	4.14

[1]In thousands of dollars.

a "pot of gold" containing $1 million, which is buried in the ground. The benefits realized from the $1 million are zero, but the benefit ratio of the combined system is far higher than any of the benefit ratios of the practical systems. It was necessary to use this device to show some skeptics why Plan A was better than Plan E, although the benefit ratio was lower.

CASE III

Figure 10 shows several alternate lines in a city of 150,000 population that forms

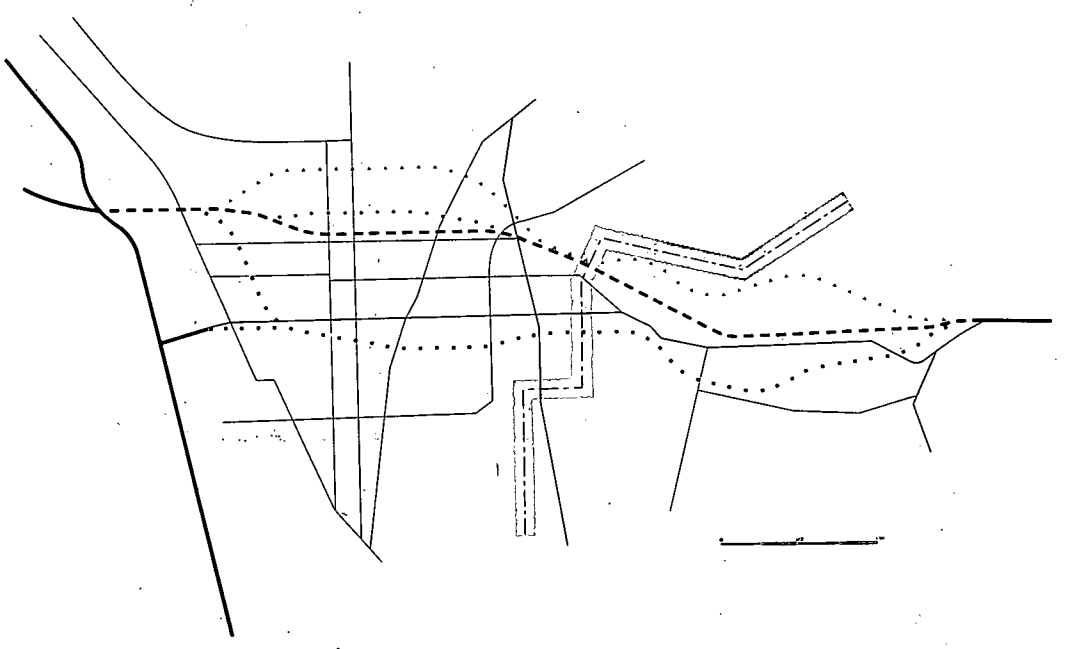


Figure 10.

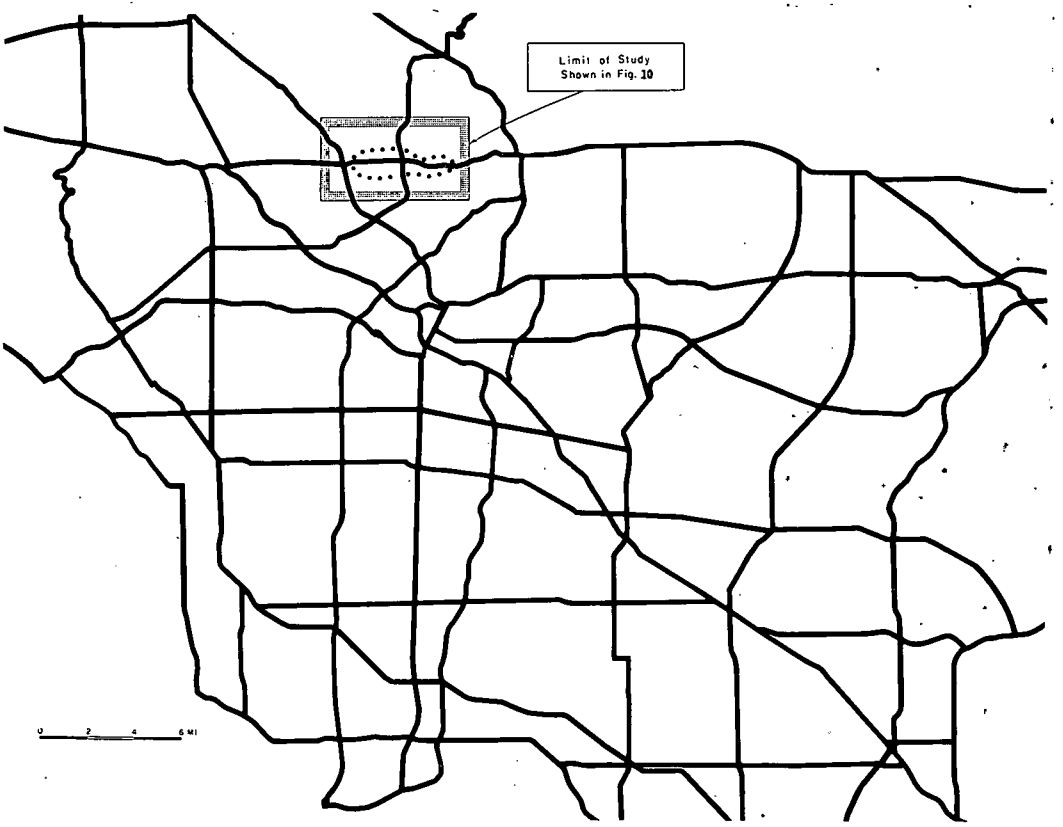


Figure 11.

a portion of a metropolitan area of about 4,000,000. It will be noted that the northernmost and southernmost of these alternates are separated by more than a mile, and the difference in traffic service to this community should be noticeable. However, in addition to the difficulties outlined in Case I, there are two additional difficulties: (1) There is no accurate origin and destination survey or zonal expansion system, and (2) because of the fact that this is a small segment in a large network of roads extending beyond the boundary of Figure 10, it is necessary to arrive at a common traffic volume at the limits of the segment shown here for all alternates. If a different traffic volume were assigned to Alternate A than to Alternate B, it would affect the traffic volumes on all the rest of the network, at least within 10 mi of this location. These traffic volumes have been carefully balanced in an over-all picture. In this case, it was decided that the difference between the alternates was not calculable. Figure 11 shows that this is probably a reasonable assumption because on this scale it is apparent that it will not make much difference which alternate is chosen — the system will work fairly well either way.

CASE IV

Figure 12 shows five alternates in another section of a very large metropolitan community. Four of these alternates approximate the alignment of the existing highway, but the fifth one creates a new diagonal. The diagonal line shows considerably more benefits than the ones which more-or-less parallel the existing main highway. This is because a new route is provided for some classifications of trip desires and these classifications are bound to save distance and time by virtue of the diagonal. In other

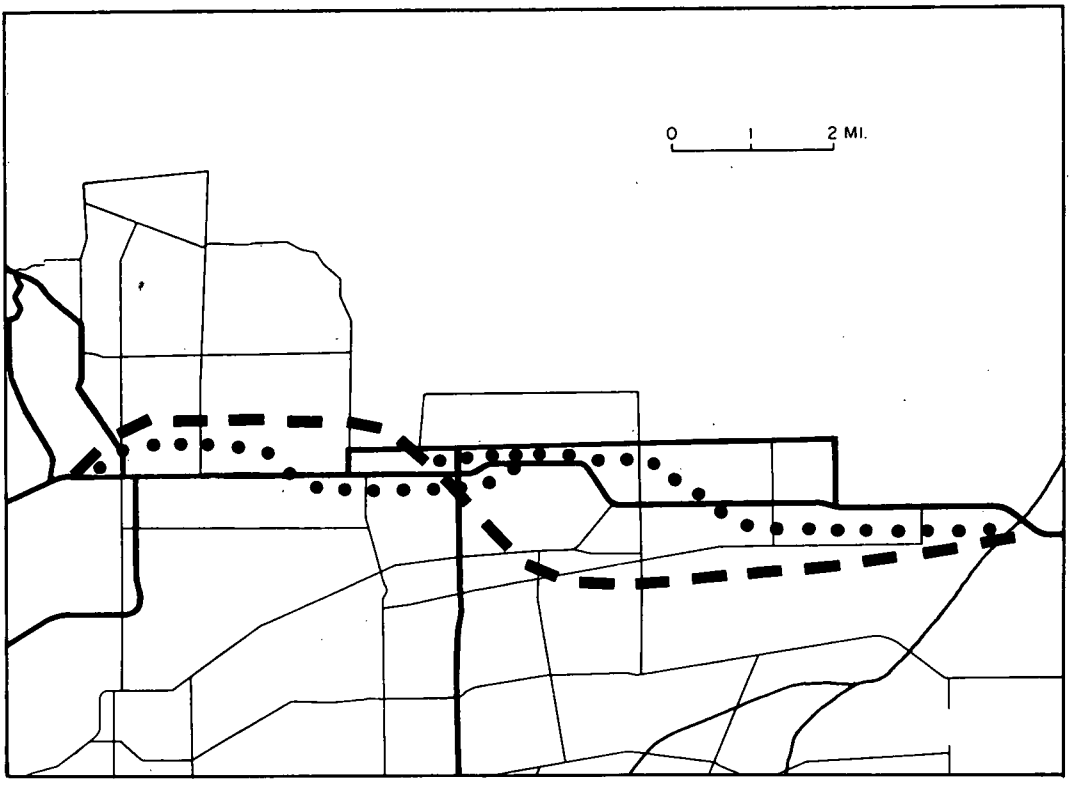


Figure 12.

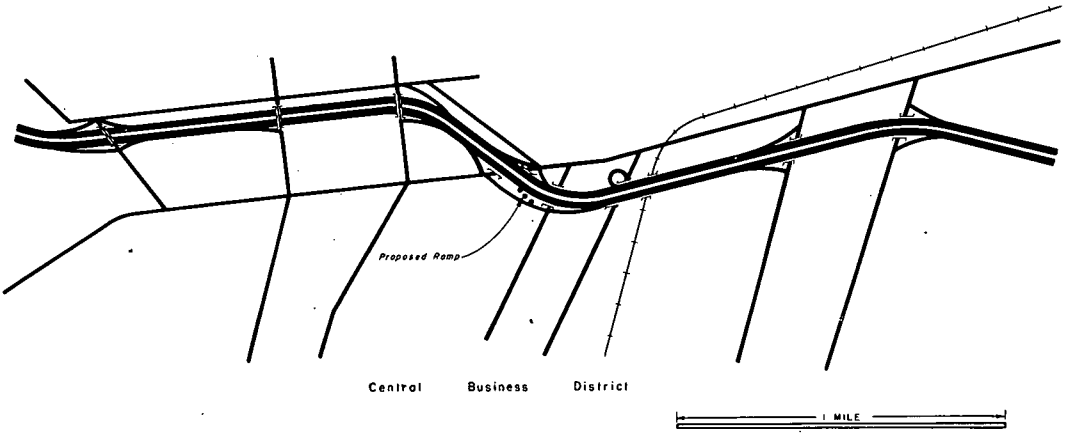


Figure 13.

words, any time a diagonal is imposed on a grid network, it will shorten the distance for many users of the facility without lengthening the distance for the non-users. The ultimate result of this kind of reasoning might possibly show that a zigzag line always at 45 deg to the existing rectangular network would show greater benefits than a straight line parallel to the existing network. Of course, this would be absurd.

CASE V

Figure 13 shows a segment of existing freeway and its connections to the city street system. An investigation was made of the value of providing one additional off-ramp as shown by the dotted line. Because of the additional freeway travel and the small amount of distance savings that would be afforded to about 5,000 cars a day, it was found that this additional ramp would provide approximately $1 million worth of benefits in a 20-yr period. The existing ramps are already less than 1 mi apart. There is a controversy among design and planning engineers throughout the country regarding the spacing of ramps (this paper does not argue the pros and cons of this controversy) but it is easily seen that if benefits are computed on the basis of time and distance savings for road users, there would be almost no limit to the number of ramps that should be provided.

Discussion

Lochner. — You referred to the the fact that people are or are not taking an expressway and either losing money or gaining money. I wonder if they know it is costing them more money to avoid such intangibles as the loss of composure and nerves and so forth?

Moskowitz. — The only measure that we can make of these intangibles, as far as road users are concerned, and I am probably getting into the field of land development, is time units, and so we have assigned a value to time.

The point that I was trying to make is that when I say "money losing", it is in quotation marks, and when I say "cost", it is also in quotation marks, because it includes the cost and also the value placed on these intangible things.

Lochner. — In other words you are saying in the establishment of money values, you have attempted to allow for these intangibles, is that it?

Moskowitz. — Well, no, what I am saying is that in our traffic assignment as established by our diversion curves, after assigning of value to time, it turns out that we find people using the freeway, where the value assigned to time is not enough to make up the additional cost of making the trip by that longer distance although shorter time; and I also said that I know what the answer is.

The answer is that we haven't assigned enough value to that particular person's time, or convenience, or whatever else you want to call it, but which we have to measure in units of time.

Jorgensen. — Isn't there another point to that, too, in that you have to end up with an average, because you cannot check these people out individually? I think there are a lot of people who drive their automobiles in varying ways from that which would be ideally economic, for you certainly get tremendous variations.

Berry. — Mr. Moskowitz, I would like to ask a question in the matter of total 20-yr benefits. When you speak of the problem of the ramp, where you could save the million dollars, did you take total 20-yr benefits and establish the total 20-yr cost?

Where did the cost picture come in? I mean the highway cost, not road use cost, but — rather, the capital cost of building that ramp?

Moskowitz. — Well, the capital cost of building the ramp was about $100,000, which was not a substantial cost as related to benefits.

Berry. — What if it was a $5,000,000 interchange? You do not take the capital cost into account at all in making your comparisons?

Moskowitz. — In order to compute whether or not it would be a worthwhile thing to build the ramp, we computed the total costs of travel for approximately 5,000 cars a day.

Either they slow down way back and get off of the freeway, and then wait at a signal and make a left turn and a right turn and go on along the road and then make another right turn farther on, say point T or else they start at the same place, still on the

freeway, and they do not slow down until they get to the clover-leaf deceleration lane. They save a little distance in the total trip.

The distance saving alone, rubber and gasoline, was $150,000, due to either going around that corner (and that did not include the cost of a stop) or else staying on the freeway, and then, of course, at two and six-tenths cents a minute, because they went faster, it took them a few cents less in time value to get there.

Incidentally, I wanted to comment on something Mr. Winfrey brought up in Session One, as to whether 1 min saved twenty times is any different from 20 min saved one time.

We have a 4-lane road from Sacramento to Los Angeles, and you can make reasonably good time on it, but you still must go through about five or six cities.

The only thing we can measure that is going to be better about this road, when we get a real freeway all the way from Sacramento to Los Angeles, is going to be a couple of minutes here and a minute there and three minutes some place else. But I think the people that are putting up the money for these highway improvements know what they want, and they want a freeway that goes through all these little cities.

You will certainly notice the difference on that 400-mi trip, even though you save maybe a grand total of only 15 min on the trip.

Cherniack. — On this question of the value of time, you come to the conclusion that it is as if certain motorists were irrational in their usage of the freeways, they use it despite its being uneconomical to them.

I would suggest this: That we have two kinds of time, first, the kind of time that we have speaking of here, a clock time, as so many 5 min or 10 min differences on the clock, with the motorist placing a value upon that kind of time. He can get to work 15 min earlier; he can sleep a little longer; that is clock value of time. Then there is another kind of time, the kind of time which is composed of stopping and starting, stopping and starting, then that kind of time, or that difference in time, is not really a measure of time; it is an indicator of the annoyances and irritations, the wear and tear on the body. So we could statistically measure time value in two ways.

I can bring out an analogy, for example, in temperature differentials. Consider the difference between 84 deg and 90 deg. It becomes 6 deg more uncomfortable at 90. Now, if you go from 98.6 to 104 in body temperature you are really in trouble. Similarly, you have two kinds of time, just as you have two kinds of temperature differences. If you worked the problem backwards to find out what is the value that you really ought to place upon time, in order to get a proper and reasonable value, you find that that time value is pretty high, do you not?

Instead of evaluating time in over-all time, you can actually and statistically divide the time up between the usual running time that it takes (or that the freeway may reduce the travel time) and the portion of the time which could be used as an indicator of the things we do not have a measure for.

Grant. — Mr. Moskowitz when you take these 20-yr benefits, at zero interest rate, you add in the twenty as if it were right now. You have considered your increase in traffic, maybe three to one in 20 yr and the savings in 1979 are used in the numerator, and the investment in 1959 is used in the denominator; that is correct, isn't it?

Moskowitz. — Except that we do not use the benefit ratio for reasons that I explained.

Grant. — You do not use the ratio, but you compare the $1,200,000?

Moskowitz. — The total savings during the 20 yr, against how much it would cost to build alternate A, and then we take the total savings in 20 yr of alternate B, and compare that against how much it would now cost to build alternate B.

Grant. — I am just trying to make it clear that you are using all the 20 yr added together with no discount factor or anything.

I think I must have misunderstood you when you said — well, looking at this additional access setup, and you had all of these savings, and not too much extra cost, and then, I thought, you went on to say, and this proves or demonstrates that it really does not pay to make an economic analysis of design problems. Did you really say that?

Moskowitz. — First of all, I have no quarrel with the idea that you should use interest. It is just that we do not. I am sure, though, that it does not matter, when we use it for comparing one alternate line against another line between the same two points. Then we are going to get the same answer as to which alternate line will do the most good for the money, whether we put the interest in or not.

In other words, I would feel perfectly justified in taking this 1959 cost and putting it in the denominator, if you want to call it that, although it is not a denominator. We subtract one denominator from the other and compare this difference against the new rate. We do not divide it up and call it a ratio, but I would be perfectly satisfied to call it 27 yr at 3 percent.

Wouldn't I still get the same annual cost then as I would without including interest?

Grant. — Not if you discounted your benefit at 3 percent.

Moskowitz. — Well, how do you compute the annual benefit? If you haven't an assumed amortization period, how do you compute the annual benefit?

Grant. — You compute the present worth. There is a formula for it. I guess that is the easy way to say it.

Moskowitz. — Suppose these benefits ultimately return some money at the end of the year. This can happen, can't it?

Suppose I built an alternate which saved somebody some money, which we call a benefit, in the first year, and I put it in the bank?

Grant. — Well, it does not assume that necessarily. You just say a dollar 20 years hence is not as valuable as the dollar today. A dollar saved in 20 years is not as valuable as a dollar today, because it is considerably less than the dollar now. It will get you a dollar in 20 years.

Fritts. — We are talking in this conference about economic analysis, and primarily, we have been talking about route analysis, so far.

Mr. Johnson, I assume that in laying out those radial routes you have in the Hartford Master Plan, you actually have made an economic analysis of routes, but when you get to the outer belt, we are into another field. How do we get back now to route analysis of the outer belt?

Johnson. — That is the problem we are faced with and we do not know the answer. On this particular route we had no less than twelve or fourteen alternates. To arrive at the proper one is the problem we are faced with.

How do you make an economic analysis of that sort of thing? We have two bridges built, so we have two controls, but that is all we have, and how to arrive at the number of lanes required for the facility is the problem.

Fritts. — How many are economically justified?

Johnson. — We know that the traffic now at this bridge backs up some distance, and that some of it might soon start on the circumferential to find another avenue of entrance, but what avenue of entrance are they going to use? This we don't know.

Fritts. — That is why you are going to a gravity model, to get some justification for a potential design for this facility?

Johnson. — That is correct.

Fritts. — I think we may have to recognize that, as Mr. Cherniack said, there may be some errors in this business, nevertheless I believe it is better for a reasonable estimation to be made rather than to have none at all.

Johnson. — Yes, we have got to assume that the arterials are going to serve the through traffic. If they do not become bogged down because of a bad guess on our part, all we have remaining is the traffic that is going to serve the area and use the subject facility, but we fear that somewhere along the line, these things are perhaps not going to be as good as they should be, and there will be a shifting. There is no way of changing it.

Levin. — Would it assist in economic analysis if you had a master plan for that area?

Johnson. — You are correct, but the Bureau does not recognize a master plan. I say that because a master plan has to be based on some design year so far into the future that it is beyond 1975, but the plan we have presented here has to be to 1975 standards.

Applications of Economic Analysis to Highway Systems and Programs

R. C. BLENSLY, Planning Survey Engineer, Oregon State Highway Department

● SEVERAL PROBLEMS are continuing to confront highway administrators, and it is desirable that some tool be available to assist them in making proper decisions. Among these many problems are the ones resulting from:

1. Additions to the highway system;
2. Transfers from one system classification to another; and
3. Selection of alternate projects and route locations.

The questions arise, "Can economic analysis be utilized to assist highway administrators in making the decisions confronting them?" and "Can the application of economic analysis develop a rather simple method of determining relative priorities which can be used for selecting additions to the highway system, changes in system classification, and the selection of proper alternate routes or locations?"

As early as 1937 the Oregon State Highway Department published a technical bulletin (1) which was a complete treatise on this subject. The problem at that time was no different from the problem today. It is extremely important that some means be available to evaluate properly changes in the highway system, whether they be additions to the system, transfers from one system classification to another, or for the selection of proper routes for relocation and improvement. It was determined that there were three main factors which should be considered in this type of analysis: costs, revenues, and benefits. It was felt that the proper correlation of these factors would give a sound basis for the engineers' decisions.

The three factors utilized in the analysis were all resolved to an annual value so that they could be related on a common basis. The problem in using these factors was a need for finding some means of combining them to develop a composite measure. The first step in this combination was the development of the ratio of annual revenue and cost which was termed "solvency quotient." The solvency quotient provided a measure as to whether the project was economically sound or not. If the solvency quotient is less than unity, the project cannot be financed from revenue derived from the traffic using the facility unless there exists another source of revenue. If, on the other hand, the solvency quotient exceeds unity, then additional money is available for expansion or improvement of the highway system.

The application of the solvency quotient to systems requires the computation of a solvency quotient for the existing system as well as the contemplated system. If the existing system is not solvent within itself, it must obtain support from another area in order to make expansions or improvements economically sound. On the other hand, if the existing system is solvent and thus has a surplus of revenue, then it may be meritorious to expand the system or improve it. The use of the solvency quotient alone does not take into consideration the savings which may be accruing to the motor vehicle users through the improvement of highway routes or the establishment of new routes; therefore, the solvency quotient alone will not provide the complete answer necessary for administrative decisions. The savings to the motor vehicle user (benefits) can be combined with the annual costs to provide a ratio commonly called "benefit quotient."

The next step in the development of a composite measure is the proper combination of the solvency and benefit quotients. Clearly, these two values cannot be added directly as a scalar value. One cannot add horses and cows and arrive at a result in composite units. Neither does the multiplication yield results which have much logic to defend them. It therefore appears that the component quotients could be combined by a process

of vector or geometric addition which would have a certain degree of logical significance. The procedure of vector addition presented in the Oregon study (1) is quite complicated and will not be outlined herein. This vector addition of solvency and benefit quotients provides a measure which can be used for the purposes outlined above.

McCullough and Beakey (1) brought out that the selection of highway improvements is not a problem susceptible to exact mathematical solution, and that the final selection must be tempered by knowledge of individual conditions and needs. The most that can be expected from mathematical measurement is the development of a somewhat crude measuring stick or method which will indicate interrelations of the factors considered.

In the development or the use of the solvency quotient or the benefit quotient, it must be kept in mind that the revenue developed by a highway is based on tax rates which are normally based on arbitrary decisions of the proper level of taxation by the legislatures. Similarly, the level of design and the resulting highway costs may be based on an arbitrary decision of the engineers. The adjustment of either one of these items taking into account economic considerations could conceivably give answers entirely different; therefore, unless the level of taxation and design standards are developed to provide the maximum economic returns, considerable caution must be exercised in using these measurements.

The objective of the foregoing procedure was to develop a mathematical evaluation whereby the earning capacity and the benefits from the project could be combined and evaluated in relation to the cost, thus providing the measure of a composite desirability of the project. The procedure, though well documented, was very complex, and its complexity and the long period of time required to carry out the analysis discouraged wide spread usage. As a result, those portions of the procedure dealing only with benefits and costs were extracted to put into everyday use and the resulting ratio of these two items, the benefit quotient, gained widespread popularity. On the other hand, the portion of the analysis dealing with the solvency quotient has become almost unknown except on a systemwide basis. The question arises as to why the composite quotient was not used to any large extent. Was it due only to the complexities of the computation, or was it due to a possible misunderstanding of the intent in meaning of the quotient because of the complex method by which it was put together. As near as can be determined, the composite quotient was lost in the normal succession of personnel, and the portion of the computation for the benefit quotient only has been retained. Not only has this become the popular method of analysis within the State of Oregon, it has also been recommended by the Committee on Planning and Design Policy, of the Association of State Highway Officials (2).

A measure to be used as a tool in selecting highway improvements must be somewhat easy to compute, but more important it must be of such a nature that it is easily understood, not only by the engineer using the tool but the layman who often will need more of an explanation and more justification for the priority than the engineer does. The composite benefit quotient was apparently too complex to meet these needs. The question then arises, how can or how should the benefit analysis be utilized in making system studies or developing programs for highway improvements?

Experience has indicated that there are certain inherent deficiencies in the benefit quotient; therefore, they will not in themselves provide this index for priority. The present benefit analysis reflects primarily a savings to the motor vehicle users through improved alignment resulting in fuel and time savings. These are direct benefits. On the other hand there are indirect benefits such as ease and comfort of driving congestion-free facilities that are not adequately measured in a benefit analysis. These factors should be given consideration in programming future developments. The existing method of computing the benefit quotient does not give any indication as to whether or not the proposal is solvent. The benefits could greatly exceed the costs, yet it is conceivable that such an improvement would not be solvent because there would not be sufficient excess revenue to provide for this improvement. It has been indicated in the AASHO Report that the present method is not suitable for use on an area-wide or statewide basis, because the results cannot be compared if they are based on dissimilar routes, traffic patterns, terrain, or design standards. The present method apparently does not provide a measure of need in addition to a measure of benefits. It provides an

aid in selecting the best alternate route for improvement only; therefore, there remains the problem of finding some measure of need which, when used in conjunction with a benefit analysis, will assist in the assignment of priorities.

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2. American Association of State Highway Officials, "Road User Benefit Analyses for Highway Improvements. Pt. 1 - Passenger Cars in Rural Area." Informational Report by Committee on Planning and Design Policies (1952).

Discussion

Campbell. — Concerning vector analysis you have said that when one has quantities of unrelated and non-compatible units to measure and place a value upon and to add together he cannot combine them into a total of homogeneous units by the ordinary mathematical procedures of arithmetic addition, but that he can resort to vector analysis. But is it not true that as soon as one arbitrarily sets the scalar values for each vector and artibrarily sets the angle between the vectors that he arbitrarily does establish a mathematical relation between the two supposedly different kinds of units which we said in the beginning are not compatible?

Is there any relationship between solvency and benefit? Can you simplify for us the logic of adapting vector analysis to this problem? Would you say that my statements with respect to vector analysis are correct?

Blensly. — I think you are correct. I hope I did not mislead. I do not think it was intended that there was any implication that vector addition was the answer. It was just felt that it was possibly a logical way of doing it. There was a little logic to it; in it was some means of combining the two, and you couldn't add them directly; it didn't make very good sense to multiply them; vector addition seems to be a little more logical mathematically.

It may not be correct, because one is still trying to add horses and cows to get an answer, but it is probably better than direct addition or direct multiplication or any direct method of combining.

Campbell. — Let me pursue some further this subject of combining the solvency and benefit quotients in order to obtain a resultant quotient useful in priority rating. These quotients can be combined, properly or improperly in several ways. One way would be that of computing the net gain or loss shown by each quotient (subtracting unity from the quotient) and then adding algebraically for each project its net gain or loss in solvency to its net gain or loss in benefit. This would give a composite number representing total gain or loss. If the solvency component is regarded as of unequal weight with the user benefit, it can be weighted before combining.

I do not recommend this method because I do not know how to interpret the resultant composite number. For use in priority determination I would set the solvency quotient opposite the benefit quotient for each project in tabular form. This will show the negative and positive values (unity plus or unity minus). Beyond this, judgment of surrounding circumstance is necessary I believe to rank the projects in priority.

St. Clair. — I do not think that user tax revenues or earnings can be added to highway benefits either directly or by vectors. Furthermore, I do not think that government revenues can be classed in the category of benefits. Benefits to the government should be of the same sort as benefits appearing in the private sector of the economy. They include, for example, savings in transportation cost, including time costs, in the use of governmental vehicles, aid in the national defense, and aid in the carrying of the mails.

User-tax payments have their most direct relation to user benefits in the following manner. They reduce the effect of the benefits on the user who pays them. If the user

tax were exactly equal to the benefits, they would net out to zero. If this were the case there would be no separate benefits left over to be transferred to other sectors of the economy, to the consumer in the case of a commercial vehicle and to the land in the case of improvement in automobile transportation. In any complete treatment of benefits and costs the payment of the tax must be reckoned in as a negative term in the equation.

This does not say that solvency calculations have no legitimate standing. They should in the first instance be considered as an independent calculation, made for the purpose of determining whether the particular road improvement pays for itself or needs subsidy from other parts of the system.

There is, I think, another way in which the solvency calculation can come into the analysis of benefits. The fact that the users are willing to pay the tax needed to support the facility is positive evidence that they receive a benefit at least equal to the tax payment. This is very plainly to be seen on a toll facility, and the toll authority can maximize its revenues by a delicate adjustment of the tolls on different classes of vehicles (this would not of course maximize the benefit received by the public from the toll road). In the case of user taxes the evidence is not so direct, but the point can be established by a study of the earnings of a road or of a road system, over a period of years.

Campbell. — The subject of length of project has been raised more than once, and we have seen that if the study area is confined, for example to the length of a bridge — and a bridge is usually a very expensive thing to build — that the bridge project will in a good many instances not have a benefit quotient as great as or greater than unity. This can easily happen if one does not study the economic consequences deriving from the total change in traffic pattern affected by the project.

Isn't it better then that we consider as the study area of a project, whether short or long, the whole length of trips between origins and destinations of all the traffic that used that particular bridge or that particular project, rather than considering only that length (with vehicle-miles) which lies nicely between the immediate ends of the new construction project? Does not a piece of highway anywhere on a trip affect the convenience and economy of the total trip, and affect the choice of route? In other words, will we not find a higher B/C ratio in our analysis if we spread the benefits and costs over the entire trip length, or at least for enough to include total length of local trips (say 5 miles or so each way from center) whose benefits from the project as related to trip length are proportionately greater than for long distance trips?

Blensly. — I don't know that I have got the answer for you. I do know that you do not have to confine it to the length of a bridge. We have situations where we make a benefit analysis on a fairly long piece of highway, where there may be a situation where the new road may cross the existing road two or three times. Now, we could take any one of these several portions of the new road which are severed by the existing highway and run a separate analysis on each of them as separate entities or in a series of different combinations of the several parts, or of the whole project as one integrated whole.

In many cases, the alternate route may be such that you could have several pairs of alternates; you will get different answers with each one.

I personally feel that the proper procedure is to take the over-all project from origin to destination of trips assigned to it for study, rather than a small section in the middle.

Winfrey. — I think you can make a reasonable approach to determination of proper project length by analyzing the problem on an incremental basis. In other words, you start from some point, be it the middle or either end, then keep adding increments of length, and taking different lengths of construction, analyze each of them. Take 2, 4, 6, 8, and 10 miles and so forth on an incremental basis, and soon you will find that it may not be economical at all to build 4 miles, but it is economical to build 10 miles, because of the greater use of the facility that you may get out of that additional length with its additional attraction to traffic, and at the same time its possible lower unit cost per mile.

I think we also can analyze bridges and get ratios greater than one, because you

have there the problem of either to do without or to do with, and if there is no bridge there at all, where is the value of the bridge? What will it mean? What will people pay for a bridge?

I think you can quickly prove that the bridge is highly desirable for the general economy and for the general welfare.

Blensly. — I might use an illustration of a point where I feel that the benefit analysis falls down for a priority system of accounts.

We had a certain case of analyzing alternate routes between two points, and it was one that could logically be considered in these two elements, a northern improvement, or a southern improvement.

In one of the particular alternates, the northern improvement provided what we felt was needed to relieve congestion in the outskirts of an urban area, and it would have helped the motorists considerably. The highway was old and needed improvement, but there would be no substantial time saving nor distance saving afforded by the improvement. That is, there was a little time saving; you would increase the speed during the peak hour, but the southern half would save about 2 ½ miles in some 10 or 12 miles. It would afford a substantial mileage savings, when you considered the over-all project. It had a high benefit quotient.

The northern half, which we felt was the portion that was actually needed, had a very low benefit quotient, something less than one; whereas the southern half had the much higher mathematical rating.

There was the question: How do you use this rating for priority purposes then, if you feel in your own mind that, other things considered, the northern half is the important one, and the southern half you will not need for twenty years? How do you evaluate these factors? What procedure do you use to take judgment into consideration?

St. Clair. — I would like to return to the use of the economic analysis in priorities. In fact, I would like to reopen, really, the subject of the relation between comparing a heavy traffic route and a country road with respect to their benefit-cost analyses.

Well, if you took them in the raw, so to speak, you would never build any country roads, and I believe Moskowitz pointed out that if you do not have the origins of traffic, you would not have any traffic or need any roads. But the question I will pose grows out of what we all agree to be the logical conflict that seems to be present. It is quite obvious that regardless of anything in the way of political decision, you do need the light traffic roads.

You do not necessarily need them improved to a high quality, but you need them, and you might decide from a social point of view that there was a greater priority at some time in a program of light traffic roads.

How then, in face of this logic, would you set up an economic analysis on a system basis that would solve this problem mathematically, so to speak, rather than judgmatically?

Grant. — I think this is discussed in a paper by Professor Lang, concerning the use of digital computers.

St. Clair. — What I mean is that sufficiency ratings actually take that consideration into account. To be specific, sufficiency ratings do not always suggest that you improve the heaviest traffic road, but that you improve on the basis of the total program. Maybe the economic analysis is not fitted to cope with that problem, but programming simply is not all politics; it is common sense, for one thing.

Gardner. — With respect to a low volume traffic road, is it necessary to improve that low traffic volume road, or should we maintain it in kind as it now stands, and let it, shall we say, perpetuate itself?

Secondly, can we apply benefit-cost analyses to priorities? In a paper which I am preparing, congestion delay is computed for all the highways on the whole system by reason of capacity and other items.

The congestion delay is a tremendously large factor in the benefit-cost analysis, and in the broad picture, if we rate all of our highways on just this item, we are almost

getting 100 percent confirmation that the highest congestion is going to be the highest benefit.

When we relieve that high congestion, we are getting the highest benefit. I might be anticipating one of the papers. It would be impossible, I confess, to do such a job without the electronic data processing system. But that is what Pennsylvania's approach will probably be to this priority problem. The benefit that derived from decreasing the congestion divided by the cost of the project will give what I have termed a "modified benefit-cost ratio" and sequential, descending values of that benefit-cost ratio will provide priority ratings.

Of course, after it has been decided that a certain project recieves top priority, it will be analyzed for alternate routes. It will be looked into as to whether it will stay on the existing location or be changed in basic location, or in what respects we will do something about it.

But that is a supplemental problem arising after determining the priority.

Moskowitz. — Mr. St. Clair, I see nothing wrong with the thought that you presented, but you are going to have this problem: there are going to be an awful lot of roads that do not have any congestion on them which you still want to improve.

Suppose we did this in California. I guess the worst congestion in California is on the Bay Shore Freeway, which was built about five years ago. What should we do, make it 16 lanes?

In other words, suppose it came out that we should improve this Freeway first, when actually, it is one of the projects that we have just finished improving. On the other hand, you are going to find that there are some country roads that are on some local system, but I think that we have only got one highway system, and that includes all the roads that are public roads. I do not think there should be any relation between the amount of money that a road gets and what system it happens to be on. I think that the amount of money that a particular segment of road ought to get should be based on first, solvency, and second, how much money it gets should be based on traffic and engineering reasons, rather than what system it happens to be on.

I am beginning to question the whole theory of different design standards for different systems.

Johnson. — I would like to say, Mr. Moskowitz, that I for one agree with you that there is one system, that the automobile does not recognize differences between interstate, primary, secondary, urban, rural, and local roads, and we approach the problem that way in Connecticut.

Also, in this problem of design, we feel that recognition must now be given to land use, to prevent in the future some of the problems that we are now faced with in the drainage program that is astounding dollar-wise, due to the fact that land development has taken place and made useless the existing drainage facilities.

So the design department of the Connecticut Highway Division is presently determining a factor of land use potential, so that they might install appropriate drainage in the initial improvements, to take care of the drainage at the time the land does develop.

Burch. — I think in the last 10 or 15 minutes we have opened up a Pandora's box. We have been talking about state highways. Now if we acquiesce to the concepts expressed by Mr. Gardner and by Mr. Moskowitz — that there probably should be nothing such as highway systems — that a road is a road — I am afraid we could not live with that.

North Carolina is one of the few states where the state has all of the roads (the counties and townships have nothing to do with them). The state has 70,000 miles of road, varying from little pigtrack trails up to the expressway-freeway type. The people just won't let you consider all those as being the same, the differences being the differences between land services—not land use, but land service performed.

In the case of local roads where land use and geography are paramount, we can admit that there is no traffic or practically none, but yet the road must be there ready to serve.

The other consideration is the human voter reaction. If you don't give those roads a reasonable level of traffic service, then the people who live on or near them, few

though they be, will say, "We are becoming or have become second class citizens," and that won't do, either.

Newcomb. — May I suggest that the problem is a problem only if you consider highways as in a vacuum. In other words, people do not travel over highways to burn gasoline and time; they go because the value of the goods at the end of the trip is greater than the value of the goods at the starting point.

A ton of lettuce, grown in Norfolk or North Carolina, is valueless on the farm, but that lettuce in a Pittsburgh market has a high value, so we see that these highways are here not alone to save money in the form of less expenditure for gas or tires, but to add value, add space value. When you put the total economy into your formula, then Blensly's problem becomes quite soluble. The southern route may add much less to the economy of the community than the northern route, though it does add more to the saving of gas and rubber. Let's start looking at the impact of the highway on the total economy; it might make poor formulas, I think it makes good sense.

Blensly. — I think such a concept would require a revision of what is called "benefit analysis." Our present procedures are very inadequate.

Newcomb. — I think so, and I hope that we can get a revision of our thinking to put the total economy into our formula.

Lang. — I would certainly agree 100 percent with what Mr. Newcomb said, and it is my impression (in connection with this matter of minor roads where there is little or no traffic) that we become confused and say, "well, because there is no traffic on these, an economic analysis of their value to us does not make any sense."

I think this assumption is quite incorrect. What we are doing is failing to take account of all of the economic consequences of not building the road or of building the road. If we did take account of all the economic consequences, we would find an economic analysis is just as applicable to this type of road as it is to a freeway.

Winfrey. — Mr. Blensly, you asked a question a moment ago about whether you should build a certain project now or some 20 years in the future, in speaking about the priority between a northern or southern improvement. Am I correct in that?

Blensly. — The southern improvement shows the high benefit quotient and is the one that you do not need for possibly 10 or 20 years, while the northern improvement shows, I believe, a very low benefit quotient, yet it is felt that there is a need there, maybe because of congestion, or for other considerations.

Winfrey. — It seems rather an unusual result to get such a high economic value out of something which is not needed, so I would first suggest reviewing the analysis and see why that happens, or, if it does happen. If you want to know how much you should build today for a benefit which does not come about for some time in the future, then you have the simple problem of comparing values and cost and benefits at a common time value.

If a piece of today's construction will not be used for 20 years, then in 20 years its equivalent cost is the present cost compounded at the proper interest rate for the 20-yr period.

Likewise, if you are considering today a benefit which is not going to materialize for 20 years, as indicated a moment ago, then you have to discount it from 20 years hence down to today, by defining its present worth value.

That is a standard type of application we make with the compound interest theory, in order to get things at a common point in time, and it is the only way that you can compare it. You cannot at all compare a dollar today with a dollar 10 years from today, even assuming a stable economy, without bringing them to the same time point, which means compounding one or "present worthing" the other.

Blensly. — I think possibly you misunderstood me. I was not implying that it would not be used today; what I was implying was that the traffic was such that there would not be sufficient traffic to require it for another 20 years.

In other words, the existing facility could handle the traffic for maybe another 20 years, and at that time, there would be congestion and you would need the other facility.

This example shows the fallacy of our existing method of computing benefit analyses, in that it is based almost entirely on savings in time and distance, or the combination of the two.

Here is a substantial savings in distance. If you have any traffic at all — and you will have some trips — it is a benefit to that traffic. If it does not cost much — in this instance, it does go through virgin territory and is rather cheap construction — you can build it cheaply, and you will have a good benefit-cost ratio.

Moskowitz. — I hate to monopolize so much time, but I have a good example to illustrate Mr. Blensly's point.

In Arizona twelve years ago, US 66 was an old 18-ft wide oil cake, and some of it was not even paved, and it dipped in and out of all the drainage channels.

Even then, it was carrying two or three thousand cars a day. People drove 60 and 70 mph, and our present methods of just taking time and distance would not have shown much benefit in converting that route to modern standards.

I am not talking about a 4-lane freeway now; I am just talking about building what they called their standard road at that time, which would have been 36 ft wide for two lanes, including the shoulder.

On the other hand, there was a proposed route from Kingman to Winkelman, which for the few people that would have used it would have saved over 100 miles, one of the most fantastic cases you will run into anywhere. Serving a very few hundred cars a day, it would cost around a hundred million dollars to build this road; yet, the rate of return method or any other method of analysis would show that you should build this shortcut, and that you should build it before you should improve the road which served several thousand cars a day.

Here is where we have to get into the solvency aspect of the problem. Is it right to spend so much highway revenue on what would be an extremely "insolvent" project so that somebody can reap some high benefits along this shortcut that saves a hundred miles?

In other words, this shortcut is quite similar in character to the one that Mr. Blensly thinks can be put off for 20 years. When he says that, of course, he is applying an economic evaluation that has not yet been formalized.

Grant. — My comments are in further answer to Mr. St. Clair, and to point out that everybody really has been answering him — particularly Professor Lang, who phrased it concisely, that is "we must take account of all economic consequences in our analysis." The rest have all been saying the same thing, which is that if the formal analysis for a basis of decision gives one conclusion, and your intuition gives a completely different conclusion, either your intuition is wrong, or you need to improve, to sharpen up, your techniques of formal analysis.

Research in Economic Analysis at M.I.T.

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● RESEARCH in the economic analysis of highway improvements currently under way in the Department of Civil and Sanitary Engineering at M. I. T. is the outgrowth of studies originally directed at some of the strictly technical problems involved in current highway design. This development has been a strictly logical one, inasmuch as economic considerations must inevitably play a large part in any complex engineering work.

About three years ago the photogrammetry laboratory under the direction of Prof. C. L. Miller began a series of studies aimed at the integration of modern photogrammetric and electronic computing equipment into an efficient system for the location and geometric design of highways. These inquiries led to the development of the so-called Digital Terrain Model (DTM) system and a number of associated instruction programs for an IBM 650 electronic computer. Basically, the DTM system involves the collection of topographic data in digital rather than analog or map form. These data, when combined properly with a mathematical description of a trial highway alignment, can be operated upon by a computer so as to produce complete information on the geometry of the alignment and the associated earthwork quantities.

The most significant characteristic of this system lies in the fact that the topographic data are all referenced to a generalized coordinate system rather than to some particular alignment under study. This permits the engineer to analyze a large number of alignments extremely rapidly and with only a small additional expenditure over that required to analyze but one alignment. As a result of this analysis the engineer has, moreover, a complete set of geometrical information upon which to base quantity estimates for such things as pavement, drainage structures, and fencing, as well as earthwork. Yet, these items when costed out do not tell the whole economic story by any means.

A consideration of the advantages of the DTM system for the determination of these particular components of construction cost led to the realization that the current reluctance on the part of practicing highway engineers to undertake really thorough economic studies was due in large measure to the relative inability to handle the large amounts of data involved. These "data engineering" problems seemed, in fact, to call for the same sort of approach that was taken in the development of the DTM system. Thus, it was decided to broaden activities to include such other parts of the total problem of the economic analysis of highway improvements as might be amenable to the data engineering approach.

One outgrowth of this effort has been the development of a method (still in the testing stage) of estimating the land costs associated with alternatives in alignment. This method involves making an approximate assessment of land costs, probably directly from aerial photographs, for the entire section of terrain through which alternative alignments for a highway might be expected to pass. The area of interest is marked off into zones on a map overlay and the cost per sq ft or per acre shown on each zone. The map overlay is then sectioned off by rectangular coordinates and the data on the location, size, and cost of each zone are punched on cards in a fashion similar to that in which data are handled for the DTM system. These data, together with the geometric description of right-of-way limits as determined by the DTM programs, are then fed into a computer with the EA-2 instruction program. The computer outputs land cost for that alignment by station.

It will be recognized that this technique is not sufficiently accurate for use at the stage where detailed attention to individual parcels or improvements becomes necessary. It is, rather, strictly intended for use in the reconnaissance or preliminary location

phases of highway design. Where the locating engineer is interested, however, in analyzing a large number of alternative alignments in order most nearly to optimize his final location from an economic standpoint, this gives him a rapid and inexpensive way to determine land costs. The objective here is the same as that of the DTM system of computing geometry and earthwork; namely, to put within reach of the practicing engineer a means whereby he can do a thorough job of highway design with a minimum of time and expense.

The second effort in the direction of simplifying the over-all problem of making economic analyses of highway improvements actually antedates this somewhat simpler land cost problem. This is a technique for computing vehicle operating costs and travel time requirements for alternative highway alignments.

The technique of computing vehicle costs is somewhat different from those previously mentioned, inasmuch as it works directly with annual costs rather than with first or capital costs. The heart of the technique is a computer program which will simulate the operating performance of any sample vehicle over an alignment as specified by the locating engineer. Using the vehicle speeds and energy requirements thus determined, the computer is able to output the various vehicle operating cost factors. It is also able to output total travel time for the alignment in question, which can then be costed out by the locating engineer at the figure which he deems appropriate. The sum total of these costs for the sample vehicle or vehicles can then be extended to cover the entire vehicle population on the basis of traffic estimates made for the highway under study.

An experimental instruction program, the EA-1 Vehicle Operating Cost Program, has been written to perform the type of computations outlined above. It should be emphasized, however, that while this program has been coded and debugged, it is definitely nothing more than an experimental effort at the present time. A large number of difficult problems, some of which will be mentioned, still remain to be solved. In particular, major revisions in program logic will probably be necessary before we can claim to have a practicable technique whereby the locating engineer can determine the effect of alternatives in alignment on this most critical cost component.

Despite the fact that the work is still in a somewhat imperfect state, it is of interest to follow through the logic of this EA-1 program. Basically the program works with three sets of input data. The first of these describes the horizontal and vertical alignment of the highway under study, as well as the maximum speeds at which an operator can be expected to drive his vehicle over various sections of that alignment. The alignment data can be taken directly from the output of the DTM geometric programs, while the speed restriction data must be compiled separately by the locating engineer.

A second set of input data defines the sample vehicle. These data include such things as vehicle weight, engine horsepower characteristics, gear ratios, air and rolling resistance parameters, fuel and oil consumption parameters, and parameters to describe tire wear and maintenance cost. These data also include the maximum acceleration and deceleration rates which the driver can be expected to use. The third set of input information is of an administrative nature, including such things as the station at which computations are to begin and end, the initial speed of the vehicle as it enters the section of alignment under study, and the interval at which speeds and costs are to be computed and punched out.

The program is then designed to output vehicle speed at each computing station, cumulative running time including stops, cumulative fuel consumption, oil consumption, tire wear, and maintenance cost. In addition, it is possible to amend the program output so as to include such things as fuel efficiency in miles per gallon, average running speed, or energy consumed in braking.

Figure 1 is a logical flow diagram showing in simplified form the general sequence of computational steps through which the computer goes at each computation station.

Present thinking is that computational runs in both the forward and reverse directions would be made for each of three classes of vehicles (automobiles, single unit trucks, and combination trucks) over each alternative alignment under study. The somewhat different driving habits for each of these vehicle classes would be simulated through

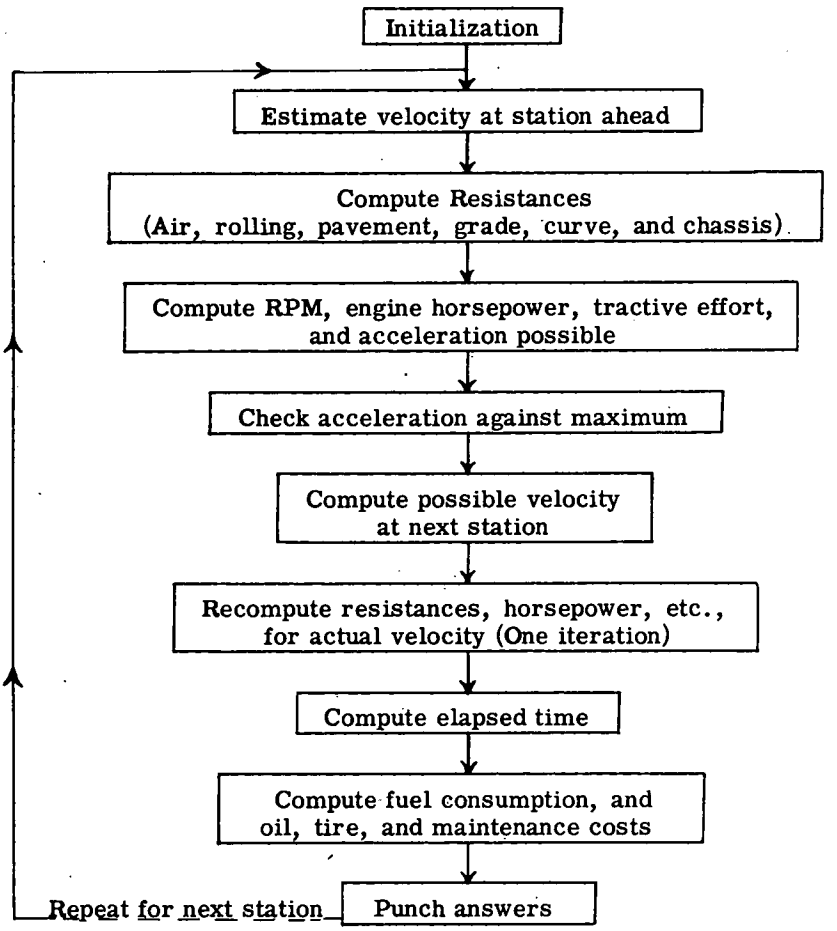

Figure 1. Flow diagram.

the maximum speed restrictions and acceleration and deceleration rates imposed by the locating engineer. These values would be representative of average driver performance, and would not necessarily correspond to either posted or design speeds. The input parameters describing each sample vehicle would be determined in advance on the basis of the composition of the existing vehicle fleet.

Current research efforts in connection with this computer program and its use are centered around three major problem areas. The first of these is concerned with the simplification and modification of existing program logic so as to produce acceptable answers at a smaller expense in computer time. The present program is thought to be too slow to enjoy widespread use by practicing engineering offices. The second problem area concerns the selection of sample vehicles which will be truly representative of the very large and diverse fleet of vehicles which can be expected to use any highway over even as little as a year's time. The third problem is that of testing computed results to determine how closely they would conform with actual vehicle performance. In each of these problem areas the research group has enlisted the assistance of various members of the staff of the Bureau of Public Roads, and the prospects for an early solution to many of the present difficulties seem good.

The EA-1 program as originally conceived was designed principally to handle the problem of alternatives in route location of high-type, intercity highways. It has been recognized, however, that this is only one type of problem -- though perhaps the most

important type at the present time — which such a computer program might be able to handle. Among other possibilities are the following problems: the analysis of at-grade versus grade-separated intersections; the determination of optimum interchange spacing; the determination of limiting grades for design standards; design of passing lanes on upgrades; or determination for tax-allocation purposes of the benefits accruing to various classes of vehicles.

There is, unfortunately, one major difficulty involved in handling many of these problems. This stems from the fact that the ability of even an improved instruction program to produce answers which will be accurate for widely varying types of alignment and for a wide range of vehicles may be too limited. This does not, however, rule out the possibility of preparing additional instruction programs designed specifically to handle some or all of the design situations mentioned above. It is also thought of prime importance that some effort be made to take account, either in the existing program or in some future program, of the effect of traffic congestion on vehicle performance. To date we have been unable to develop any promising ideas on this aspect of the over-all problem.

Regardless of the deficiencies in the present EA-1 program and of the difficulties involved in its improvement, we cannot help but feel that the sort of information which it can furnish the locating engineer would permit him to do an incomparably better job of economic analysis than is currently within his reach. The important thing in this connection is that it is a long way from the solution of the conceptual problems associated with the economic analysis of highway improvements to the implementation at a practical engineering level of the complete economic decision-making process.

Thus, the objective is the development of systems and methods of analysis which will permit the engineer to put into practice on a day-to-day basis the principles of engineering economics which others in attendance at this conference are working so hard to develop for highway engineering problems.

Discussion

Blensly. — My concept of the present method of economic analysis and its use is generally at the very preliminary stage of the discussion of a route or an alternate route, possibly before we even have a definite line; maybe in the reconnaissance stage.

It seems to me you are developing a procedure which will provide an economic analysis but at the time you are just getting around to comparing design features. At that time, one already has to have his design made, so of what benefit is your economic analysis when you have gone so far that you can't go back?

Lang. — It is true that I may want to consider vehicle operating costs, in the reconnaissance of location stage where you are not describing in any great accuracy the vehicle alignment. I question whether any state highway department or anyone else is actually making accurate computations of vehicle operating costs at this stage.

We are not trying to produce in this technique something to replace reconnaissance techniques, but rather a means of evaluating alternate design possibilities to determine cost components entering into economic analysis. It is hoped that this technique will be usable for both the preliminary and the final design stage, and in a large measure in the preliminary design stage, where you do actually establish curves, for example, both horizontal and vertical, and you do try out various curves for fit, and economy. In other words you have specified your alignment.

Let me refer again to the DTM techniques to help place this new technique in perspective. One of the principal things that the DTM system for determining the geometrics of alignment tries to overcome is this: with existing techniques of analyzing data it was expensive to analyze more than one or two alignments in detail, and the engineer was not getting anywhere near what might be considered an optimum conclusion, because the initial choice of an alignment is largely on a guesswork basis, and there is every reason to believe that if the engineer developed and analyzed 6 trial alignments, rather than two, he would on the average be bound to find one of those

extra four that would be better than the two first ones that he tried. But he does not do it now, because it is too expensive.

As far as the geometric computations and the earthwork computations are concerned, with the DTM system, the engineer can analyze 6 or 12 or maybe even 20 alignments for what it costs him to analyze 2 by the old techniques.

Now this seems far-fetched, but as the Ohio Department and some of the other departments who have looked into this system have vouched for, this is literally the case, because what the DTM system does is to eliminate the need for taking the basic topographical data more than once, which in the old system had to be done.

Well, we are trying to do the same thing with this vehicle operating cost program, which is to make the actual job of determining vehicle operating costs so easy for the engineer that he will analyze 6 or 8 or 10 alignments in this fashion. Once you have the basic data for this type of a system, it becomes very cheap to analyze about as many alignments as you wish.

This system might have limited usefulness where you are trying to determine whether or not or where to locate the components of an over-all network. This is a different sort of problem, but even though you are working with an entire highway network, you still have to have some idea of vehicle operating cost. This system may give you the means of determining these so rapidly that you won't shy away from it, and this will permit you to fill in one more cog, at least, in the over-all economic analysis.

But of course it should be recognized that when you have got capital costs and vehicle operating costs, you still haven't got all the associated costs. Actually what we hope to do is to see whether or not we can determine some of the other cost components in the total economic cost picture, feeling that the experience gained in what we have done so far may be useful in attacking some of the other problems.

But we are interested in the implementation of economic analysis at the day-to-day level.

Berry. — I would assume that this method would apply particularly to mountainous terrain, or in areas where there is quite a high percentage of trucks, because it is in the truck that you get a differential in time due to grade; whereas, with a high percentage of passenger cars the operating cost and the travel time to not, perhaps, change as much in alignment for grade.

I would assume, also, that you would build into this a feedback so that as traffic volume increases it would have its effect in travel time and that would be priced along with the operating costs, but it looks like it certainly has possibilities if you are able to overcome some of the difficulties brought out by Mr. Blensly.

Lang. — Well, I hope someone will give us some ideas as to how to take account of congestion and its effect on the actual operation of the vehicle.

Our feeling is that one of the biggest shortcomings of the present technique is that we are unable to take any account of congestion, but we have given it some thought. This is one of the problems that will have to be overcome before this whole system will reach its maximum usefulness.

Rothrock. — Mr. Lang, we are using the digital terrain model in Ohio in several jobs. We like it especially in rough terrain. In some of the flatter parts of the country we do not think that it is particularly useful.

This program that you are working on is simply vehicle operating costs and time. Are you going to extend the program to include the computation of the benefit-cost ratio or probable rate of return?

Lang. — No. We definitely have no intention whatsoever of trying to compute benefit-cost ratios or rates of return directly. To attempt to systematize this area or this part of the economic analysis would so obscure the refinements and the difficult problems and judgment decisions that are inherent in this final process of the over-all economic analysis that it would be much more of a detriment than a help, and in any case, the actual mechanics of these computations are so simple that there does not seem to be any particular justification for putting them on a computer.

Rothrock. —Then your technique is used to produce comparative data useful to the engineer in evolving analysis and design and for making decisions.

Lang. —That is right. We are not even trying to compute final costs. We are outputing them, and then it is up to the engineer to assign some proper unit cost to this.

Burch. —In reply to the question about the effects of congestion, it may be of interest to you to know that North Carolina State College we have a research project under way now, on a mathematical model, using a 650 computer and simulating the actual movements of vehicles and their interrelationship on a highway.

This is not an intersection study; there has been a lot done on that in cities, already; this is a typical rural highway.

Rothrock. —In your technique of computing the motor vehicle cost, or cost of operation over a given length, if you want to compare this with the present corridor, or operation on the present corridor [Ed. Note: This could be used to formulate for the present indexes for adequacy ratings for geometrics.] then you must put in the geometric data for the present highway (and any other highways which are in the corridor) also, which has to be determined?

Lang. —That is correct, yes.

Rothrock. —And what you come out with is simply a unit cost per vehicle.

Baker. —I have gotten the opinion that these economic analyses are not as accurate as they might be, not so much because we do not know curvature and so on, but because we do not have certain basic information such as fuel consumption under given situations. Isn't it true that we need a great deal of research in certain areas before you can make maximum use of the techniques you are developing?

Lang. —We really do not have good unit cost figures, nor do we have good information on the nature (mathematical nature is what we are specifically interested in) of the cost functions that we are working with.

But there is every reason to believe that as more data are accumulated and more sophisticated statistical analyses of that data are carried out, we will begin to get unit cost figures and basic characteristics of cost functions which will permit us to do a good job.

It is admittedly crude now, but you have got to admit that it is still better than nothing, and nothing is substantially what we are working with now.

SESSION THREE

Thursday, September 17, at 7:30 P.M.
THE DETERMINATION AND MEASUREMENT OF HIGHWAY COSTS
ROBLEY WINFREY, Bureau of Public Roads, Presiding

Cost Elements in Economic Analysis of Highway Programming, Location and Design

CLAUDE A. ROTHROCK, Engineer of Preliminary Location and Design, Ohio Department of Highways

● THE MAIN PURPOSE of an economic analysis of a proposed expenditure for a highway facility is to determine: (a) whether the investment is justified by the calculated benefit-cost ratio, or the prospective rate of return; and (b) as between alternates being considered which is the best economically.

The term "costs" as associated with the analysis consists generally of the same items of expenditures considered in determining the probable merit of any other investments. Principal of these is the periodical charge necessary to return interest on the capital invested and secure eventual recovery of the capital amount. The term for this charge is amortization, or capital costs.

Another primary item of cost to be considered is the aggregate of expenditure for physical maintenance and upkeep, and for operation of the plant, or operating costs. There may be other items, such as overhead and general supervision, but generally capital costs and operating costs are the principal factors of cost in the determination of the economic worth of a proposed highway investment, having the greatest effect upon the result.

By the benefit-cost ratio method of analysis, as outlined in the AASHO Report, amortization of the investment is the result of applying the capital recovery factor for a pre-chosen rate of interest, at estimated service lives, for the calculation of captial recovery costs during a given period of study.

All three variables (interest rate, period of study, and service lives) are functions of the annual capital cost; not only in the computation of the benefit-cost ratio, but also in any other analysis requiring a calculation of capital recovery.

In the AASHO proposed method of analysis the method and rate of depreciation, and consequent salvage value, are undetermined and, as such, are not preliminary factors of the problem. The estimated service life, or lives, fixes the capital recovery factor at the assumed rate of interest. The depreciation may, or may not, be equal to the amount of capital recovered, and the salvage value also may, or may not, be the amount of the investment unamortized. Only if the interest rate chosen happens to coincide with the rate of return on the investment does the unamortized capital at the end of the period equal the salvage value. Otherwise, the ratio found is only an index by which to

compare a proposed investment with other investments for which an index has been similarly calculated using the same assumptions as to rate of interest and service lives.

By the usual method of calculating a prospective rate of return, that is, determining the rate at which the sum of the present worths of a series of net receipts and the salvage value will equal the original investment, it becomes necessary to introduce the probable salvage value at the end of the time period of study as a factor of the computation. For this purpose, it is necessary to select a definite method and rate of depreciation, or probably better, a realistic estimate of the salvage value at the end of the study period regardless of the times and rates by which the depreciation occurred, but based upon a value determined by past experiences and observations of similar cases.

Some questions concerning determination of capital costs as they are, or should be, applied to highway economic analysis are as follows:

1. Is a 20-yr study period a proper one to use in all cases? This period has been generally used, probably because it appears to be advised as the maximum period for reliable projection of traffic growth. Traffic predictors seem to be dubious of making forecasts beyond 20 years. But if traffic beyond the 20-yr period should be thought to be stable at the maximum attained at the 20th year, or possibly to grow even at a lesser rate, another 5 or 10 yr added to the period would add appreciably to the average annual benefit.
2. Are the estimates of service lives of the component items of construction (as generally used because of their introduction in the AASHO report; namely, 20 yr for pavement, 40 yr for grading, drainage and structures, and 100 yr for right-of-way) or in line with best practice for economic analysis in light of knowledge gained from studies of actual service lives; especially for pavements? What changes are recommended?

It may be that the 3 classifications are too broad and restrictive. For instance there are many items which probably should be segregated for more rapid depreciation, such as signs, signals, and guardrails. Where the cost of right-of-way includes damages such as for loss of access, or buildings or structures to be removed, or such items as utility changes, having no salvageable intrinsic value, it appears that their costs should be segregated for a write-off period not greater than the period of the study. Like treatment may be given to the contract item for maintenance of traffic during construction.

3. How will an appraisal of salvage value be anticipated 20 years in advance?
4. For use in the computation of a benefit-cost ratio, why not account for the salvage value by applying the capital recovery factor only to the amount to be depreciated (original investment less the estimated salvage at the end of the period) during the period of study, and add annual interest on the unamortized balance (salvage value)?
5. In a calculation of the benefit-cost ratio, what criteria should be applied in selecting an interest rate? Opinions by those responsible for such analyses vary from the extremes of no interest to a rate approximating the yield on capital borrowed by private indivuals, or a rate selected as the minimum desirable return. It is recommended by some that the rate be used that is paid for interest on road bond borrowing. Such rates vary, and the trend at the present time is higher rates. Regardless of the varying bond rate, should not studies of different proposals made for the same authority at different times be at the same rate to indicate the relative merit?
6. It may be suggested that the charges for right-of-way, considering the worth of land only without improvements, be made as rental on a permanent investment, and thus chargeable as a current expense deductible from current income (benefits). This concept would need exploration, and it may be found that with the use of a 100-yr life for amortization, the difference in charges would not be of consequence. The effect of the reduction of amortizable investment, compared to a probably similar relative reduction in net benefits, would be toward a larger rate of return. It may be doubted that the relative standing of alternates would be affected.

Thus far, nothing has been said about other annual costs, such as overhead, general supervision, maintenance and the type that generally can be lumped as operating costs.

It would appear that for those that can be readily determined or estimated there is not much uncertainty about their place in the analysis. In the benefit-cost analysis it would appear that they should be reduced to a probable annual average figure and added to the annual capital cost to appear in the denominator of the ratio. In a calculation of the prospective rate of return, the figure should be deducted from the average annual benefits to determine a figure analogous to net profits of a business enterprise.

Discussion

Winfrey. —In connection with right-of-way, many analysts in the state and consulting engineering offices may use a 100-yr period in the calculation of the annual capital cost of right-of-way. In their initial right-of-way cost they include the full expenditure for such items as land, severance costs, damages, buildings that they buy and tear down, and all other costs directly associated with acquiring title to the property.

If I were to use—and I say "were" because I am not inclined to do so—a long period, even more than 50 yr, for right-of-way, I would be inclined to separate the land value from damages, severances, and buildings. These items have no value whatsoever to the highway after the land is obtained. Certainly in the long run they have no value.

Another way of handling right-of-way, would be, as Rothrock suggests with other items, to set up a salvage value for the land. Certainly the only salvage value to right-of-way would be the value of the land.

Rothrock. —The possibility, of considering salvage was offered to me by a lawyer. In Ohio, they have the right to borrow money from certain state funds to made advance purchases of right-of-way. It appears that such purchases might be made by a separate authority who would charge the State Highway Department rent on the land and whereby they could issue revenue bonds or some sort of bond which would stand good for the payment to the purchaser of the bond. It would introduce the business rental concept into that particular element (land) of cost. I do not know whether it would stand up or not. The plan would probably need some exploration if it has any merit.

St. Clair. —If you have $100,000 in right-of-way, of which $40,000 is in these items other than the market value of the land, how would you treat that $40,000?

Rothrock. —My opinion is that it should be written off as rapidly as you can, at least within the period of the study. These damage items have no salvable value, nothing intrinsic about them at all.

Winfrey. —Certainly not longer than the first cycle of payment.

St. Clair. —On the other hand, it is an expense you will never have again on that road.

Gardner. —So long as the original acquisition is the only amount of right-of-way you are going to have for 100 yr. The probability, however, is that you are going to widen your highway some day and take more right-of-way and then have these same elements of costs associated with the new improvement. I agree with the immediate write-off.

Grant. —How good are the maintenance costs with regard to types of pavement? Clark Oglesby was a part time consultant for Stanford Research Institute in connection with the economics on a flood control project. One of the bits of information that was important had to do with the flooding of certain roads. He thought he could get from the county engineer information about maintenance costs, so he asked the question, "How about maintenance costs on your highway system." The county engineer said, "Oh we are clean, we can account for every nickel." But when it came to finding out how much had been spent on any particular highway there was no information, whatsoever. They knew they spent about $2,000,000 a year, that on the average they worked on about half of the mileage of the county system, and this was all they knew.

Are the state maintenance costs in better shape than those of this particular county? Is that a uniquely bad example, or is it a common example ?

Rothrock. —I think it is very common. The accounting of maintenance costs in the states that I have any knowledge of is very poor. As an example, I have seen work being done on one system, say the secondary system, but charged to the money which

was available on the primary system. They just used available money to switch around as they pleased, charging work to any section that was convenient. Maintenance cost is very poorly kept as a general rule. We get our maintenance costs, or an approximation of them (the ones that are used in our studies) from our maintenance department and just take their word for the costs.

Jorgensen. —For the purposes of this kind of an analysis, don't you think that the average values you get for maintenance are really reasonable... are a reasonable approximation of what you are going to have? They are not a seriously weak spot in this kind of analysis.

One should not get the wrong impression from the fact that there may be some discrepancies in the way things are charged, for in total I think our maintenance charges are reasonably representative and valid for this kind of analysis.

Rothrock. —The maintenance costs generally are a small part of the annual costs as compared to the amortization costs... a rather small percentage, so they don't make a lot of difference.

Fritts. —If we will take a look at the statutes in each state we will find that there are legal requirements about the reporting of expenditures of highway funds. I think we can all agree that even when the highway department reports its expenditures on maintenance, for instance, they have to be reported as maintenance expenditures. I know that one maintenance foreman may charge something to one section that should be charged to another, but even if it comes to the county, the county has to report legally certain expenditures.

These things are fairly accurately presented, so I don't think we have any bear by the tail in this situation.

Rothrock. —Maintenance is not a large percentage of total annual cost and you can be off on your maintenance costs 50 percent and still not be too far off in your total costs.

Burch. —In answer to what is maintenance cost, this kind of reply is often made: "How much does it cost to maintain a son in college?" The answer is, "All you have." That is about the way that total highway maintenance expenditures have been determined. It is how much you have available to spend. I don't mean to imply the existence of waste. The states, counties, and cities have a great pride in trying to do the best they can in maintaining their roads in as good condition as they can, but the limit they can go depends on how much money is available.

The second point on maintenance cost is how do you define it? Is it the amount necessary, or is it the amount expended? There is, as you know, quite a difference between cost, properly defined, and expenditure, on the other hand. Some accountants will say there is no difference, what you spend is what it costs, but that is not necessarily true. Ed. Note: Universal Standards for maintenance have not been defined. The 100 percent level has not been set.

As to record keeping I agree that there is no use to worry about it. Cost records undoubtedly are not kept in detailed form, road by road, section by section, as well as they might be. If you were to ask the ordinary housekeeper, "How much do you spend for salt, for sugar, for coffee, for lard, etc," you could probably get an excellent accounting of how much it costs to run the kitchen, but no breakdown on itemization. We have to fall back on what I call experienced appraisal. Experienced judgment and the composite of the experience of many maintenance people over many years comes up with figures which to me have great stability and are acceptable.

Rothrock. —This question of maintenance costs chargeable in an economic analysis is not too important. If you use a figure, you are estimating for the future anyway. You are not going to the past except to get a basis of projection. If you use a figure which appears reasonable in the light of the knowledge that you have about the past, you cannot be very far off. The principal item of financial charges is the amortization costs and the recovery of capital. These costs may vary considerably, depending upon the interest rate.

Shall we take an entrepreneur's point of view of depreciation and salvage, or realistic value based upon our experience? For instance, a man going into business will

recover his capital as rapidly as the Government will allow him to recover. Should we do that, or be more realistic and make our probable salvage equal exactly to what we think it will be? The business man looks for a quick return of his capital even at the expense of reportable profits now, in the hope he will make profits later.

How about an average life calibrated by dollar weighting of each component?

Zettel. —I would make one amendment, that no business man can recover his capital over what the Government will allow. You have to add one other factor. That is competition and what will the market allow, which is more important than what the Government will allow. You don't go into any business assuming a complete monopoly and that you are going to recover your investment with only the restrictions that Government imposes in income tax returns. You have to consider the market situation. I interpose the statement that Government is not the control on how fast you recover. The market is the thing we are talking about. My point is that it is not a matter of what the Government will allow, but the market.

Rothrock. —That is a matter of accounting.

Zettel. —It is only a matter of how you can price your product.

Rothrock. —Yes, but that is for accounting purposes only. We are making a projection of something else.

Zettel. —But he is projecting what he can sell his product for.

Rothrock. —We are not governed by that. What shall we do?

Fritts. —That is our difficulty. We are not governed by what the market says you can do, we are governed by what the Government says you can do.

Rothrock. —I mean that the highway analyst is not governed in setting his rate of depreciation by any figures the Government gives him; whereas the business man is limited.

Zettel. —This isn't the basic determination. The basic determination is that the Government derives its regulations not from an accountant saying, "I am going to allow so much," but on some kind of judgment, the same kind of judgment we are involved in here.

Rothrock. —The question is, what is the best method or rate of derpeciation to use in our analysis, or what service lives?

Winfrey. —There are two concepts for us to follow. One is, we can make our economic analysis on the basis of our best judgments as to the ultimate number of years of service of the facility in its total, or by component parts, including the best estimate of the salvage value at the end of those service lives. Second, we can make our analysis over some shorter period which I choose to call the analysis period, in which, for economic analysis only, we do not need to pay attention to service lives, except that our analysis period must not exceed the period of useful service of the facility.

I prefer the latter, that is, using an analysis period. This plan is universally used in industry in economic analyses. This economic analysis is not to be confused in any way whatsoever with cost accounting to determine a profit and loss in business, not to determine the annual cost of owning and operating a highway system. When we do that we come over and must use our best judgment as to service lives and salvage values.

Ed. Note: Salvency quotients on the other hand should be based on cost of owning and operating.

In either case, however, it seems an economist and business manager and financier must be on the conservative side. It is only good judgment to use low salvage values in connection with long lives because the risk factor is so much greater. We don't know what will happen 100, 75, or 50 years from today. We are more apt to know what is going to happen 20 years from today, so if I use 20 years, I use a more liberal salvage value than if I use 75, 50 or 100 years.

But I want us to remember that there are two separate things we are discussing—cost accounting and economic analysis. They are not the same.

Rothrock. —In my paper I said that net benefits, after taking the summation of the consequences, would be analogous to gross return to a business, after deducting the annual costs of operation, to get the net returns. Is that proper, in order to determine the rate of return?

Winfrey. —It is the way I would do it, and therein, gentlemen, is something which was not mentioned previously. Annual maintenance cost is more critical than you may think, particularly if it is high with respect to benefits, or if it is high or extremely low with respect to capital cost. The ratio of maintenance cost to investment will alter the rate of return that you will calculate. The rate of return solution is sensitive to the relationship of annual maintenance cost to capital cost.

Rothrock. —How does one handle the annual costs and financial costs on a project constructed by stages?

Make the assumption, for instance, that 2 lanes are built now to satisfy the traffic demand for the next 10 years. Ten years from now an additional 2 lanes are constructed. The difference in costs is that you add presumably double your initial cost at the end of half of the 20-yr study period. To get an average cost over the 20-yr period my solution was to charge capital recovery on the first $100,000, through the whole 20-yr period and also charge through the whole 20-yr period a sinking fund charge to create the $100,000 at the end of 10 years.

Winfrey. —Were you interested in determining economic analysis or highway costs?

Rothrock. —The financial costs for the 20-yr period, as an average over the 20-yr period.

Ross. —In response to the question relative to the forecasting of traffic for a 20-yr period and then the use of a different period possibly for computing road user benefits, in Idaho we are using a 15-yr period for a computation of our road user benefits, even though we project traffic for a 20-yr period.

Rothrock. —You are using the traffic you expect in 15 years as an average over the time, not a straightline growth of traffic?

Ross. —We feel it is more realistic than the 20-yr design.

Rothrock. —The question I meant to ask was, supposing there is something like a straightline growth of traffic during the period. Why not use a 25-yr period instead of a 20-yr period if you think the growth continues on at the end of the 20-yr period for another 5 years.

The reason is, we have always used 20 years for the design year. Why do we need to use the design year? Is it desirable to use the average of the design year and the first year as the mid-point or the average traffic over the period? Whereas another few years added to the period of analysis would add a little something more to the average traffic.

We are dealing with averages here. Of course, that is not true, either, because the income benefits on the lower amount of traffic the first year is nothing like the benefits to double that amount of traffic in the 20th year. However, I have determined that that does not make a lof of difference. In some rates of amortization the average does not make a lot of difference as compared to a straightline individual present worth of each year.

Ross. —We were looking for traffic to justify these routes, particularly Interstate, and therefore, whereas the Bureau requests that we take a design period of 25 years, we feel we are much more justified in taking a mid-point of 15 years or making the total period of 30 years.

Winfrey. —I can give you a simple solution, one which I have recently read in a report from one of the states. They made an analysis of their annual benefits as of the present time, using present day traffic. Then they said in the next 40 years these benefits will double, so they just doubled the benefits, did not take the present worth of these distant benefits and came out with a very nice answer. Very simple!

Fritts. —I know in some of the states like Idaho, Montana, and South Dakota, they are troubled with this economic problem. On the Interstate System, for instance, where today the traffic is 1,200, 1,500 ADT, they anticipate the traffic to 1975 or some period beyond. There is an economic problem whether to build 2 or 4 lanes. There is, in my judgment, some confusion in the minds of the men out there about the economic justification of building 4 lanes now, or building 2 lanes and then maybe it will cost them a little more 15 years from now to build the other 2 lanes. What is the economic justification? I don't know what the answer is. I wonder if our economic analysis provides a good answer to that kind of problem.

Ross. —I would like to point out further with respect to Idaho that you can oftentimes justify 4 lanes in the beginning by virtue of your sight distance restriction that you are building into a 2-lane versus a 4-lane highway, plus the operational problems you encounter at your interchanges.

Zettel. —I don't mean to be facetious, but when we talk about the Interstate System state-by-state we are going to have differences of approach to these problems, and differences in factors. If you were going to establish priorities for the Interstate System you would have to look at it on a nationwide basis.

Interest and the Rate of Return on Investments

EUGENE L. GRANT, Professor of Economics of Engineering,
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● FOR MANY YEARS the interest rates used in most economy studies for highways and other public works have been quite low. In its Manual of Instructions, the California Division of Highways uses 0 percent. In its 1951 report, the AASHO Committee on Planning and Design Policies used rates from 1½ percent to 3½ percent in its examples. Recent studies of the economy of alternate highway locations made by a number of state agencies have used 3 percent and 3½ percent. A recent rate for evaluation of Federal water projects has been 2½ percent; this rate was furnished to the various agencies by the Bureau of the Budget under the provisions of Circular No. A-47, December 31, 1952.

The discussion of "Interest and Discount Rates and Risk Allowances" in the 1958 revision of the "Green Book" (Proposed Practices for Economic Analysis of River Basin Projects—Report to the Inter-Agency Committee on Water Resources by the Subcommittee on Evaluation Standards) includes the following:

> ...the minimum interest rate appropriate for use in project evaluation for converting estimates of benefits and costs to a common time basis is the risk-free return expected to be realized on capital invested in alternative uses. At a given time this rate is the projected average rate of return; i.e., yield, expected to prevail over the period of analysis, in the absence of inflationary or deflationary changes in the general price level, on such relatively risk-free investments as long-term Government bonds. ... Use of the minimum risk-free rate assumes that risk elements have been adequately accounted for in the calculations of benefits and costs.

The viewpoint herein is that in many cases the public interest requires the use of substantially higher interest rates in economy studies for public works—particularly in economy studies for highways.

On first impression, it might seem that September 1959 is an unusually favorable time to present a case for the adoption of higher interest rates in economy studies for public works. Interest rates on borrowing by local and national governments have not been so high for a long time. The interest ceiling of 4¼ percent on debt maturing in more than five years presently makes it impossible for the United States Government to do any long-term borrowing; a recent short-term borrowing was at 4¾ percent. The Canadian Government is currently paying more than 6 percent for short-term money. Many recent tax-exempt state and municipal borrowings in the United States have been at interest rates of 4 percent or more.

But the case for higher interest rates in economy studies for public works was a valid one even when Federal and local governments borrowed at much lower interest rates than at present.

Either in private enterprise or in public works, the issue in the selection of an interest rate for use in economy studies that are made to evaluate proposed investments in physical plant may be phrased as follows: "What is the lowest possible rate of return, all things considered, that is deemed sufficiently attractive to justify the proposed investments?"

In such investment decisions in competitive industry or by individuals two relevant questions to consider are as follows: "What investment opportunities, if any, are likely to be foregone as a result of a decision favorable to a particular investment in physical plant?" and "What is the cost of money, all things considered?" In general,

the minimum attractive rate of return should never be less than the cost of money. Often, however, the minimum attractive rate of return should be considerably higher than the cost of money because of considerations related to the investment opportunities foregone. In the language of the professional economist, the concept of "opportunity cost" is applicable to the selection of the interest rate to be used in economy studies.

In a business enterprise, the investment opportunity foregone may be either within the enterprise or outside of it. In modern industrial society, many proposals are often made for investment in new physical assets. In competitive industry, the usual condition is that the proposals at any time are, in total, considerably more than it is practicable to finance.

Whenever I meet anyone engaged in the preparation or review of capital budgets in competitive industry, I ask him, "What is the minimum attractive rate of return in your company?" The first answer is often "Well, it depends." (This seems to mean it depends in considerable measure on management's judgment of the relative risk in different investment proposals.) But by further questioning, I usually discover that proposals having prospective rates of return of less than 10 percent after income taxes are rarely, if ever, approved; many types of proposals will be rejected if the prospective rate of return is less than 15 percent after income taxes; some will be rejected if it is less than 20 percent. One large integrated oil company requires 10 percent after income taxes for proposals in the transportation and marketing divisions, 14 percent in the refining division, and 18 percent in the production division.

I get the impression that in competitive industry, the usual controlling element in setting a minimum attractive rate of return is the relationship betweeen the internal opportunities for investment and the available investment funds. For example, in preparing the capital budget for a manufacturing enterprise, it is determined that $200,000 is the largest amount that can be made available for plant investment during the coming year. This includes funds from all sources including capital recovered through the depreciation element in pricing, retained earnings, long-term borrowing, and new equity funds. Assume that a number of proposals for new plant investments are made and that the aggregate of the proposals is $500,000. Careful estimates are made of the consequences of each proposed investment and prospective rates of return after income taxes are computed for each. Assume that these rates range from 35 percent down to 8 percent. Assume that when the proposals are arrayed in decreasing order of rate of return, it is evident that the available $200,000 will be exhausted by proposals that have prospective rates of return of 17 percent or more. If all proposals are deemed to have equal risk, the minimum attractive rate of return is 17 percent because the approval of any proposal yielding less than 17 percent will cause the manufacturer to forego the opportunity to earn 17 percent or more from some other proposal.

It is my impression that such conditions of capital rationing are the exception rather than the rule in regulated public utilities and that the controlling element is the over-all cost of capital, considering both borrowed capital and equity capital. A common rate used in economy studies for public utilities is 7 percent after income taxes.

Economy studies comparing alternate proposals for investment may be made by any one of several different methods. One method is to compute the prospective rate of return for each proposal and to judge proposals in relation to one another or in relation to some stipulated minimum attractive rate of return. Other methods, applicable to certain types of alternatives, are to convert alternatives to equivalent uniform annual costs or to present worths. In evaluating proposed public works, the most common method is to compare benefits with costs; benefits and costs may be expressed either as equivalent uniform annual figures or as present worths.

It is essential to recognize that the issue or what ought to be the minimum attractive rate of return, all things considered, is still present when decision making is based on comparisons of annual costs, comparisons of present worths, or on an analysis of benefits and costs. These methods all require the use of an interest rate for conversion of non-uniform money series to equivalent uniform annual figures or to present worths. The operational effect of using a particular interest rate in calculation of annual costs, present worths, or benefits and costs, is to adopt that interest rate as the minimum attractive rate of return. For example, if 3 percent is used as the interest rate in computing benefits and costs and if any proposal for which the computed benefits exceed

the computed costs is deemed to be justified, the effect of this procedure is to justify any proposed investment that will yield more than 3 percent.

Although the foregoing point should be self-evident, I am sure that it is not really understood by many of the persons who use benefit-cost techniques in the analysis of proposals for public works. It is my view that the widespread failure of analysts, legislators, and administrators to understand this point is a serious weakness of the benefit-cost technique as it is now commonly used with interest rates from 0 percent to 3½ percent.

What are the considerations that ought to enter into the selection of a minimum attractive rate of return in the evaluation of any proposed investment in highways? I believe that proposed highway investments are similar to proposed investments in competitive enterprise in that the controlling element in selecting a minimum attractive rate of return usually should be the investment opportunity foregone. In judging what investment opportunities are being foregone, it is necessary to look at such opportunities within the highway program and also to look at the investment opportunities available if highway construction taxes are reduced. It is likely that the first look would result in a figure much higher than 3½ percent and feel sure that the second look would also give a figure more than 3½ percent.

In most states it is a common condition for the highway improvements scheduled for any given year to be only a small fraction of those improvements that, on intuitive grounds, are believed to be badly needed. Just as in competitive private industry, each year many proposals are competing for limited investment funds. Suppose that prospective rates of return should be computed for each proposal and that all proposals should be listed in order of rate of return. Such an array would show that the available funds would be exhausted by projects having relatively high rates of return. Moreover, just as a similar analysis year after year for capital budgeting in private industry continues to show a high minimum attractive rate of return because of continued technological progress, population growth and growth in the standard of living, the same factors would continue to cause highway funds to be exhausted by projects having high prospective rates of return.

Now, consider the investment opportunities foregone by the taxpayers who provide the funds for investment in highways. For the many taxpayers who have to borrow money for one purpose or another, a gilt-edge risk-free investment is to borrow less money or, in most cases, to reduce the amount of an outstanding loan. For those taxpayers who borrow to finance homes, this risk-free investment will yield 6 percent more or less (often considerably more if it is necessary to finance with a second mortgage). For those numerous taxpayers (all of them highway users) who borrow to finance automobiles, this risk-free investment will often yield 12 percent or more. For taxpayers engaged in competitive industry, we have already noted that minimum attractive rates of return for proposed plant investments are often 10 percent or more after income taxes. An after-tax rate of return of 10 percent corresponds to a considerably higher rate before taxes; for instance, if the applicable tax rate is 50 percent, an after-tax yield of 10 percent requires a before-tax yield of 20 percent with the return from the investment divided equally between the investor and the government. Such industrial investments are far from risk-free, there always is risk that an analyst's most careful estimates will turn out to be incorrect. But it should be pointed out that neither are highway investments risk-free; in fact it seems to me inherently more difficult to make a reliable economic analysis of a proposed highway improvement than to make one of a proposed investment in industrial plant.

The yields on investment opportunities outside of the highway field seem to be clearly relevant in setting a minimum attractive rate of return for proposed highway improvements. For the past decade in the United States, we have had a steady increase in highway user taxation, both on the state and national levels. The primary purpose of these tax increases has been to make more funds available for investment in highway plant. I personally believe that an economic analysis would indicate that, all things considered, these tax increases have been justified. But the economic grouds for justification should be based in large measure on a showing that the highway agencies can invest these funds as productively as could the taxpayers. To the extent that highway agencies consider increments of investment to be justifiable on the basis of rates of return of from

0 percent to 3½ percent, the agencies are not in fact investing a part of the funds as well as the taxpayers might have done if the taxes had not been collected.

It seems to me that the case for higher minimum attractive rates of return in economy studies for proposed highways should be based primarily on the foregoing considerations relative to opportunity cost—giving weight both to the prospective yield from alternative highway investments that would be displaced by a proposed investment and to the prospective yield from taxpayers' investments that are, in effect, displaced by all highway investments. But there are several other aspects of this topic, as follows:

1. The consideration, if any, that should be given to risk in selecting a minimum attractive rate of return for proposed highway investments.
2. The sensitivity of decisions to distant forecasts in cases where a low minimum attractive rate of return is used.
3. The point that the cost of money borrowed by governments often is somewhat greater than it appears to be.
4. The relationship between the selection of a minimum attractive rate of return and the uneven distribution of the favorable and unfavorable consequences of many public works.
5. The relative merits of the rate-of-return technique and the benefit-cost technique for evaluation of proposed highway improvements.

The quotation from the "Green Book" indicated that the authors believe it is possible to make estimates of the future in a way that eliminates the element of risk. I personally question whether anyone has an efficient enough crystal ball to accomplish this desirable result. Moreover, if analysts make their best possible forecasts regarding a diverse group of investment proposals, the likelihood that forecasts will turn out to be incorrect will be greater for some proposals than for others. My example of the oil company that used different minimum attractive rates of return in different divisions illustrated how a company management recognized different degrees of risk associated with investment proposals in marketing and transportation on the one hand and refining and production on the other.

When an analyst attempts the difficult task of placing money valuation on consequences to whomsoever they may accrue, it seems to me that there are obvious risks that his estimates will turn out to be incorrect. In fact, I beleive that differences in risk for estimates of the consequences of different types of highway investment are so great that highway administrators might reasonably use different minimum attractive rates of return for different types of investment. For example, an investment intended to decrease maintenance costs might be acceptable with a lesser return than an investment to save time for highway users.

I am sure we would all agree, at least on intuitive grounds, that the risk of incorrect estimates of the distant future is considerably higher than the risk of incorrect estimates of the near future. It is common for economy studies for alternate highway locations to be based on forecasts of substantial traffic growth; it is not uncommon for an analyst to forecast that traffic will triple during a 20-yr study period. With low interest rates used in compound interest conversions, the conclusion of the economy study is extremely sensitive to the distant estimates. At 0 percent (the interest rate used in studies in California) a dollar saving 20 years hence is given the same weight as a dollar saving today. At 3 percent a dollar in 20 years is like 55 cents today. In contrast at, say, 7 percent a dollar in 20 years is equivalent to only 26 cents today. A characteristic of economy studies is that the higher the interest rate used, the lower the sensitivity of the decision the estimates of distant future consequences.

Because so many analysts base their selection of an interest rate on the borrowing rate by the particular public agency undertaking the proposed construction, it is worth while to mention the point that the interest rate does not always provide a full measure of the adverse consequences of a particular public borrowing. For example, increased Federal borrowing contributes to inflation. State and municipal borrowings in the United States have a concealed subsidy because of the exemption from Federal income taxes of the interest on the debt. A large issure of general obligation bonds of a state may have the effect of increasing future interest rates to be paid by cities, school districts, and other civil subdivisions of the state.

If proposed public works should be analyzed on the basis of expected consequences "to whomsoever they may accrue," we should also recognize that such consequences are sometimes distributed quite unevenly among the population. Certain persons may be affected extremely favorably; an example is a person who owns land that will increase in value because a particular project is undertaken. Other persons will not be affected at all. Still other persons will be adversely affected; an example is a person whose business will be damaged by the construction of a freeway. This uneven distribution of consequences of certain public works is a reason why such works should not be deemed to be justified unless their prospective rate of return is fairly high.

Professor Oglesby and I have previously advocated the use of the rate-of-return technique for the economic analysis of proposed highway investments. It seemed to us that a major advantage of this technique is that its use avoids the confusion and argument over setting an appropriate interest rate. In addition, the conclusions of a rate-of-return analysis are easier to understand then the conclusions of a conventional benefit-cost analysis.

Both in private industry and in public works, objections have been voiced to rate-of-return techniques on the grounds that the techniques are unduly complicated and time-consuming because it sometimes is necessary to use trial-and-error solutions for unknown rates of return. This objection seems to have little merit. Even where such trial-and-error solutions are necessary they usually add only a few minutes of computational time to an economic analysis that may have taken many man-days. Moreover, it is possible to prepare tables and diagrams that greatly simplify rate-of-return calculations in the majority of cases.

However, if the administrators of highway agencies feel that it is essential to use benefit-cost techniques in highway economy studies, I hope that higher interest rates will be used than the ones presently employed. To be specific, I suggest the use of a 7 percent figure; as already mentioned, this is the figure currently used in many economy studies for regulated public utilities throughout the United States.

Discussion

Moskowitz. —I still think that we are exaggerating minutia when we talk about the details of the theory of the analysis. There are many broad things that we have no answers for and which I hope to get partial answers for. How can we justify the standards? How can we justify systems at all?

The California Division of Highways does use zero percent interest rate. Almost all your arguments are directed to whether we should do the project at all, or which project we should do first. In those cases the use of the time value of money is much more important than it is when you are talking about which alternate between two fixed terminals.

Grant. —I think interest is important in all cases, and I do believe it is important in location studies as well as the other things you mentioned.

Moskowitz. —But less important, isn't it?

Grant. —Not when there is no difference in investment, the bigger the difference in investment the more sensitive the answer is to the interest rate. This I will agree to.

Moskowitz. —In view of some of the problems, we prefer to use zero interest. One problem is that of explaining why we set a given interest rate when we do not pay interest. This is one reason why we don't think it is terribly important. I wish to make it clear that the California Division of Highways is not against the use of interest as a matter of principle.

Zettel. —On most of the California cases on highway location that I have examined I would agree with Moskowitz. Location and economic justification are separable problems. I agree however, that it would be just as easy to use interest all the time if you could explain to the public, and I believe you should.

On the other hand, on the kinds of decisions you are making about alternates, there are so many other things of much greater importance. Such things as community values

and esthestics and the like which we can't value are so important that I have not been tremendously disturbed, in considering alternates between points A and B, whether the highway should go down Ashby Avenue or go down Dwight Way, I don't think there is much to be concerned with when interest is omitted. Not that I condone at any time leaving out interest, but I don't think omitting it gets you very far off base.

Given the income available and given the legislative formulas that allocate this income in this area, interest does not make much difference, when you are working within a very narrow range of alternatives. Usually you are not considering whether you should build, but whether you should build a freeway in Alameda County or Santa Clara County.

Moskowitz. —I would like to get straightened out on two things. The first is a question about the assumption of whether you are going to have a straightline growth of benefits resulting from traffic growth.

Historically, AASHO has shown that the total travel in a state like California has a fairly uniform rate of growth. But whenever we have built a project, especially an expressway project, the growth line goes up. Actually we hope that this particular highway first might level off early so it will get closer to capacity.

This area of estimating is so much larger than guessing what period of amortization and rate of interest, that I cannot attach much importance to using interest in comparing alternates.

You mention present worth, and also mention interest on the capital investment. If you obtain the present worth of future benefits, then you have the benefits for alternate A and alternate B reduced down to 1959.

Now we have the construction cost in 1959. Isn't it fair to take this present worth of benefits against the construction cost? I mean, you don't add interest to the cost do you, if you have already brought the benefits down to 1959.

Grant. —You could add the present worth of the maintenance costs in the study period.

Moskowitz. —But that is the only extra highway expense that you put in.

Grant. —Your outlay is the present worth, unless you have a stepped plan as Mr. Rothrock was suggesting, two lanes now and two more later—something like that.

Moskowitz. —Yes, it seemed several times as though someone was adding the interest to the construction cost in order to figure out how much it is going to cost for 20 years. It isn't necessary to take the benefits and bring them down to the present, is it? You don't do both?

Grant. —If you convert the initial investment to an annual equivalent cost, you ought to convert the benefits to an equivalent annual benefits at that interest rate. The equivalent annual benefits will be less if you have increasing benefits. The equivalent annual figure will be less than the average at any interest rate above zero.

Moskowitz. —I have read about the big "Time" and "Life" building. Do they make a real economic analysis? Do they know they will get enough new subscribers or new advertising, or something to justify the expenditure for this type of space to do business in?

Grant. —There are more arguments among professionals in industry than we have among the highway engineers. There is great diversity of practice, in other words.

Gardner. —Don't we have two kinds of money? The money that a man earns through his labors, and, then by reason of not having spent that money, the money that he puts in the bank as savings, or puts into corporations as an investment. Following that thought, we have been considering what private industry does. Are we on the same plane as private industry? Isn't private industry managing capital, the savings that you and I put in the bank above what we immediately need? I can't quite reconcile interest rates in view of the fact that we are buying in roads a perishable commodity just as we buy eggs, and we certainly wouldn't put an interest rate on the money that we spend for eggs. I would like clarification on that interpretation.

Grant. —It seems to me that the roads are more like the machine tools or the buildings of industry than they are like eggs, which are consumed quickly or they get rotten, unless they are refrigerated. We have been talking about 20-yr or 30-yr periods with regard to roads. With regard to investments in industry you may think of machinery in the industrial plant as having lives of 25 years not too different from the assumed lives of your highways. I don't see that the egg analogy is relevant.

Gardner. —If there is to be a road at my house, and I decide I want to do it with modern equipment so I will save some time and I go out and borrow money, I should be the one paying the interest on it. I can't quite reconcile this picture.

Grant. —As I take it, the economy study is to determine decisions among highway alternatives, where you are going to put this road, what kind of structure you are going to have, how big you are going to build this culvert, whether you will have a dirt surface or a gravel surface or a more permanent surface, what kind of interchange structures, if any, you are going to use, and what kind of traffic control devices to use. These are decisions among alternate capital investments. There is also a decision as to the general level of capital investments. These are what we are talking about.

Zettel. —We can also answer Mr. Gardner in terms of his analogy. If he built that road in front of his house, he figures he is going to use that house. But if he should sell that house he would expect compensation for the road too. You see you have made an investment that is not a dozen eggs but something that has added to the capital value of your home. The driveway to your garage is part of the whole investment in your house, it is a capital investment that has a life longer than the life of a dozen eggs.

Fritts. —What I have to say is that my point of interest does not necessarily go to the determination of whether route A or B or C in this particular complex is the thing to build because I think the decision belongs with the engineers. I think they ought to have the mechanics where they can calculate the value of the proposals. Our interest is a little broader than that. Our interest is in the necessity of saying to the people of America that there is economic justification of a highway system. I am not arguing with whether we divide it into three or four component parts which make a transportation system as a whole, but our big problem has been (and I am speaking now from the ASF point of view because we have worked with people all over the country) in trying to portray to the people of a given state what is a desirable highway plant for that state, divided into systems, if you will, because we logically divide it into systems for certain basic reasons.

The one big essential is to be able to say to the people that this system will provide this kind of service. What does this system produce for you? What does this produce for you in the return of various classes of benefits? The direct returns that we have been talking about today are very limited.

We talk about the economic studies. You put the value on time and operating costs, etc., but these items are minimal amounts of return to the people of the state. We have that problem today and we are having probably the biggest year in our history working with states, even in spite of the accelerated program. Our problem is to determine what the state ought to do in terms of its program. What should its future program be? How should we readjust that program to provide for the people in that given state a desirable economical highway plant? There are dislocations that come from the Federal highway program, dislocations in the allocation of revenue, and many other things. That is the cause for this re-examination of the whole highway program.

We need to set some economic guides which are not concerned about the route from A to C but are concerned about systems, about the economics of a highway plant itself in given categories. What do these mean to the people? What are the economics of this thing? And I for one will tell you that it is perfectly logical to separate economic evaluation of systems or of a system from financing. But the finance men pick it up from that point, have to back up against this economic analysis and say, "Well, the economy of the situation is such, therefore the tax should be such." The Automotive Safety Foundation for one doesn't go into the tax matter.

We have worked on the basic principle we stated this morning. The concept is, you separate the economics from the taxes and you separate it also from the finances.

Now, what I hope will come out of this conference is that we don't just get down to the business of moving a highway from this point five miles over to another point. We want to talk in a broader concept about what is the economic justification of improvement. How do you justify it in toto? What does it mean? What does it mean to you, to me and everybody else, as an individual highway user?

I am not going to discuss interest. I only know this, when you talk to the state legislatures they say, "What are you talking about, interest? You want us to borrow money?" We don't know. We say only that this is the kind of system of highways that will provide the service that is needed justifiably for your traffic. We don't get into interest at all. Generally speaking throughout this country (and even in the Federal Highway Act) what one can do is predicated on a system of highway taxation dedicated to highway purposes. There is no other tax in this country dedicated as the highway tax is.

So I think we need accepted principles of how do we support the highway program in this country, and not tie it to public utilities or anything else. Tie it to an accepted principle in this country that the highway situation is a situation in itself.

Pendleton. —Regarding the basic question of interest calculations and allowances in highway planning, I don't think Professor Grant was really suggesting that we who use the highways and pay for them necessarily pay an interest charge on the investment. He says, rather, that we should be sure that when our money is spent that it is spent in as productive a way as would provide not only a return of principal but also a rate of return, an interest rate. It is a distinction between the financing problem and the project formulation problem. We don't necessarily have to pay the interest but we ought at least to get the interest worth out of our highway investment.

Lang. —I certainly am in violent disagreement with Mr. Fritts and in complete and utter disagreement (and I was long before I ever came here) with Professor Grant and Mr. Zettel.

My principal quarrel with Mr. Fritts is, if I read his meaning correctly, that we might very well be trapped into building highways when in fact highways was not the best thing for us to be building. This is nothing more or less than what you are trying to get at when you include interest charges in your economic analysis.

The fact of the matter is that being more or less of a dyed-in-the-wool railroad man I have long suspected that our investment in highways might be a little more than it should be, and I think that a case can be made in this for specific instances although I am afraid in the aggregate I agree with Professor Grant in saying that if we actually analyzed the investment we are making in highway facilities we would find that the return was adequate to justify the expenditure.

Lindman. —If interest is included in the presentation of a program to the legislature, it is very confusing to say the least and the legislators ask what you are going to borrow money for. I would also say that when you allocate taxes among different taxpayers, they can't see any sense in having the interest charged in that computation.

So here are two applications which may not be—but I think under some considerations might be—called economic analyses. These particular analyses fall outside of the use of interest and amortization.

Do you think that the interest rate should vary from time to time when the Federal Reserve Bank changes its rate of interest?

What do you do when you get into an undeveloped country, for example Paraguay, where the interest rate was 4 percent a month for the commercial rate? It seems to me it distorts highway planning if you try to use such a high rate of interest for such a long term investment.

Grant. —Suppose AASHO, the state division of highways, or somebody reviewing highway needs, looked at prospective rates of return on proposed projects and said to the legislature—not using interest as a cost—"Here are these projects and we are sacrificing 12 percent return or a 15 percent return by not financing the projects." Could the

legislature understand this? I shouldn't be surprised if they could. This, is my general answer to both of you. I have met legislatures, too. They aren't so dumb.

The problem of the underdeveloped country is a tough one and of course you are in an entirely different league—just as you are in different leagues in industry and in government. You are in a different league in Paraguay and in the United States with regard to minimum attractive rates of return. But the situation in the underdeveloped country is not unlike the situation of the business enterprise that does not have enough capital.

I had a friend who went into a reasonably successful business. He needed more capital to put into it. He was, as small business men are, short of cash, so he said to me, "I can't make any investment unless it will pay for itself in three months." This was a very realistic viewpoint, this was capital rationing with a vengeance and this is what I think you have in underdeveloped countries.

Highway Costs as a Factor in Engineering Needs Estimates

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● HIGHWAY NEEDS studies include an analysis of the physical requirements for construction and maintenance of highway systems over a period of future years. Their common denominator is cost in dollars. Thus, "highway costs" are the major factor in engineering needs estimates. There is hardly a conceivable kind of cost relating to highway transportation that is not a factor in these studies. All costs of all kinds are involved one way or another.

Needs studies are used for a variety of purposes and the cost factors are more important in some uses than in others. In broad terms, needs studies have four major uses, as follows:

1. They provide the basis for determining the revenue requirements for the highway network, methods of financing including taxing and equity determinations, and methods for allocating funds between the various governmental units and the various road and street systems.
2. They set forth, for specific planning purposes, the physical requirements (the standards) of the road and street plant, both in terms of construction and of maintenance needed to provide the desired level of traffic service over a period of years.
3. They provide a factual basis for the scheduling of work so that projects can be undertaken to meet first needs first and to permit orderly long range development of the highway system.
4. They provide an almost inexhaustible source of data for research and analysis in areas such as investment requirements, finance policy, cost-benefit studies and systematic programming.

To a considerable degree the use to be made of the study will dictate the type of cost analysis required as part of the study. In the conduct of needs studies it has continually been attempted to refine the engineering base and to improve the cost estimates so that they will be applicable for all of the purposes cited.

DIRECT COST ELEMENTS

There are six classes of costs that enter directly into highway engineering needs estimates. They can be listed as follows:

1. Costs for constructing the necessary improvements, including right-of-way, at identifiable locations and to specified standards, considering the status of the existing system.
2. Future replacement requirements must be estimated in order to derive the long-term total needs. Most of these replacements cannot be determined precisely as to exact location or nature of the work to be done. The road life studies, reflecting the experience of all highway agencies, prove that the job of building and re-building highways is never ending; therefore, the replacement requirements (over and above those which can be identified in the particular period under study) must be determined by statistical means.
3. So-called "stop-gap" needs also should be incorporated into the total costs. The stop-gap needs are temporary capital expenditures designed merely to hold the existing facility in service until the proper type of necessary improvement can be constructed. The amount of such stop-gaps depends greatly on the speed with which the program is

prosecuted. If available funds are limited in relation to the total needs then, unfortunately, it will be necessary to spend greater amounts in stop-gapping. It is possible to detail such work, project by project, for varying rates of financing—but that job is very complex. Study of various samples and historical analysis of past expenditures lends considerable validity to a statistical approach for such work which ordinarily is only a small percentage of the total needs.

4. The total financial requirements would not be complete without as detailed knowledge as possible of maintenance needs. This area of operations is the most difficult to pin down with as much accuracy as might be desirable. Various methods are used, depending on the available information and the circumstances.

5. Engineering costs are a substantial element that must not be neglected. Here, too, it is not possible to estimate in detail the precise engineering costs for separate projects, many of which may not be built for 10 to 20 years. Past relationships to the total programs, coupled with consideration of future efficiencies in engineering methods, seem to be the best guides.

6. Finally, administrative costs must be added to complete the total needs picture. Again, like engineering costs, these must be evaluated in terms of the extent and amount of the total program requirements.

ECONOMIC RELATIONS

When it comes to determining the type of facility to be constructed and the level of traffic service to be provided, the engineer has to take into account many things which have an important bearing on costs. Basically, he estimates the probable benefits, including intangibles, of a certain type of improvement, measures those benefits against the prospective cost, and accordingly determines whether the proposed improvement is economically justified.

For example, even if money were no object, there are many types of improvements that are economically unsound. Despite the many known advantages of freeway design, building freeways to serve localized light traffic in sparsely populated rural areas, would not be considered or would building high type facilities simply to provide access to private residences. But there are many situations where a decision cannot be easily made.

It is well known that adequate shoulders add to the safety of a highway. Before specifying shoulder standards for any given highway mileage the engineer needs to analyze all costs related to shoulders of varying widths, study the benefits to be derived from each type, and then decide accordingly.

For complete safety and convenience all highway-rail crossings should be separated. But is the heavy expense of a grade separation structure justified in the case of a crossing that is passed by just one freight train a week, and only a few dozen vehicles a day? If not, what are the justifiable limits?

Vehicle operating costs admittedly are higher on gravel roads than on paved ones. Yet, gravel roads are less expensive to construct. At what point do the savings to highway users, computed over a period of years, make the paving of a particular highway a sound investment of public funds?

There are many situations, especially in urban areas, in which deferring needed improvements will tend to increase motor vehicle operating and accident costs, may result in higher right-of-way costs in the future, and may hamper economic development of the area. On the other hand, speeding up the improvement program may require extra costs for interest, divert scarce resources which might be used more effectively otherwise, require excessive amounts of engineering and other services to take care of big loads, and result in earlier obsolescence of facilities.

The balancing of these considerations requires the maximum of adequate, accurate cost data not only for the direct highway system costs, but for the indirect user and public costs just mentioned.

METHODS OF ESTIMATING

Where actual observation of work requirements is possible, the "identifiable" costs can be determined. When detailed plans and quantity estimates are available, the proper application of current unit prices should produce cost estimates reasonably close to the ultimate contract price. This is the ideal way of estimating costs and should be utilized whenever possible.

In most needs studies, however, the entire mileage of a highway system is included and has to be reviewed and estimated. This precludes the detailed kind of job which would take years to complete. So, other methods have to be employed, except for those relatively few locations for which detailed plans are ready.

Through proper analysis of past costs (classified by the various types of work, the standards utilized, the terrain, and the several regions of the state) it has been possible to produce average quantities and costs per mile, which when adjusted for price differentials, can be applied to comparable proposed work in each region.

Engineers also must consider other adjustments, some of which may partially compensate for upward movements in prices. For example, despite the general post-war price increases, earth excavation is being done today for unit prices not much different from those of pre-war times and considerably lower than those of the early 1920's. This has come about solely through the development of bigger and better machines.

Using the methods just mentioned, field engineers of some experience have been able to do a remarkably accurate job of estimating costs at current price levels, as reflected in actual contract awards.

Estimating Replacement Costs

Replacement costs which can be identified as stage construction can be handled by methods similar to those just described. The majority of replacement costs, however, must be dealt with on a statistical basis. The key to this problem is adequate road life data.

Usually, needs studies have dealt with the physical side of estimating future replacements by analysis of the life history of existing roads classified by surface types. It is recognized that a road is reconstructed or replaced for structural deterioration or functional obsolescence or both. Data are not available to segregate the importance of these two factors.

Road life data provide averages, indicating the mileage of the total construction in any year which is likely to be replaced. Thus, for 100 mi of highway built in a given year, the first few years show only a very few miles that would require any work. On the other hand, in 30 or 40 years there may still be a few other miles of the original 100 on which no work (other than maintenance) had been necessary. Meanwhile, all of the remainder will have been rebuilt or resurfaced. Road life studies provide the basis for such estimates but they have to be used with understanding, modification and judgment of the nature of the replacement work. Moreover, even the matter of definition must be carefully considered as to whether the work would be classed as maintenance or construction.

The next problem is to establish the unit costs of the probable required work. With modern design it is anticipated that the majority of future replacement would involve simply heavy re-surfacing but with some reconstruction and, occasionally, some new construction to take care of obsolescence which must be anticipated.

The unit costs are ordinarily derived from the detailed studies of the identifiable projects. These are then applied to the estimated mileage of each type of replacement need.

Local Road and Street Estimates

For most purposes, it is important to obtain good estimates of the total needs for the great mileages of local rural roads and local city streets. In many cases, however, it is impractical, because of insufficient manpower and money, to attempt a section-by-section analysis of the detailed costs involved. Sampling procedures and other statistical devices can provide satisfactory estimates for most purposes. This is

especially true since the majority of such roads would be developed to similar low cost standards—the greatest differential involving consideration of the current state of development of such systems in each of the many local jurisdictions involved.

Estimating Maintenance Costs

Maintenance cost records are notoriously poor for needs study purposes, especially in local governmental jurisdictions. There have been many problems of proper definition and accounting practice. Moreover, there appears to be a lot of freedom granted within the budgeting process to switch from construction to maintenance accounts or vice versa. Nevertheless, the historical record represents the first step in proper analysis of maintenance costs. Wherever possible, these are classified by surface types over a number of years, so that the changing nature of the highway system may be properly accounted for.

One of the most difficult areas of proper estimation involves the establishment of proper standards of maintenance performance. Past practice has been to limit artificially the total amount of the maintenance budget, and the maintenance engineer does the best he can, up to any given amount. As a result, maintenance may be quite inadequate in some areas and occasionally overdone in others. Accordingly, it is important that a good objective analysis of the proper work load should be made, either in total or by sampling methods.

The work required then should be priced in terms of labor, equipment and materials, and the results applied to the type of highway system which will be developed by the anticipated program growing out of the construction needs studies.

Engineering and Administrative Cost Estimating

These costs are related to the size and scope of construction and maintenance. Therefore, a review of the historical record provides the chief data on which to base future costs. They are usually taken as a percentage of the total program requirements with consideration given to possible efficiencies in future operations, as well as the scope of the administrative responsibilities.

The latter frequently involve administering grants or subsidies and dealing with local governments in carrying out their own programs. Most needs studies have provided 10 percent for engineering and about 6 percent for administrative costs of state highways. More detailed analyses of these requirements would be desirable.

CONCLUSIONS

In all highway cost elements, both direct and indirect, general economic conditions play an important part. The price levels of the future will have an effect—especially on long-range financing plans—which must be taken into account. For engineering studies, however, current levels are generally used, permitting direct adjustment of direct costs as the future unfolds.

A safeguard in the estimating process is a system of checks against various indices relating costs to travel, population, etc., and a comparison of the averaged costs with the classified historical data. Dependent on the purposes for which the costs are to be used, in the final analysis the grand totals should average out within reasonable limits of accuracy. One job may be over-estimated and the next under-estimated, but if this averaging is carried too far, the usefulness of the data is impaired for economic analysis of alternative locations, for priority and programming purposes and for the detailed study of standards. To the extent that emphasis can be placed on these important matters, engineering needs estimates should be improved through a greater amount of advance planning which will provide more exact basic plans on which to make more accurate quantity estimates.

Continued research is vital to the many problems of refinement of estimates, to means of testing their validity, to study of the economic relations and cost-benefit analyses which are essential to establishment of standards of maintenance, location and design and, finally, to the equity of finance policy necessary to develop future highway programs.

Discussion

Baker. —Mr. Buckley, in a previous reference to maintenance costs, it was mentioned that the amount spent was how much you have. How do you recommend getting at the "proper" level of maintenance in any study?

Buckley. —We have tried a number of methods and we are not satisfied with any of them, but we have tried to approach it on a basis of square yards of pavement to be maintained, miles of shoulders, miles of ditches and so on, plus, to the extent possible, per-mile costs where there are valid estimates of these unit costs. It depends so much on the type of data available that I could not give any formula for it.

Baker. —I think principally you hit on states where the level of maintenance is quite low. Do you ever encounter conditions like this, or is it normal to merely extrapolate the maintenance?

Buckley. —No, we have found those conditons and it is quite true that the normal maintenance budget is an arbitrary figure, arrived at by a compromise. We find that the level is low by observation. The engineers involved, in one manner or another, try to determine what a proper level is. You don't add two and two and get four, believe me.

Jorgensen. —In line with the thought about trying to get something in the way of economic measure against the total system improvement, would it be practical and effective to compute rate of return on a sampling of these projects to go into a needs estimate, whether it be a 10 percent sample or a 2 percent sample. And then to express this in the form of economic justification, for example, by the rate of return. It could be done by the primary system, secondary system, etc. For this purpose I think the average of this sample, or maybe the range of this sample, would be getting close to what you express as the minimum rate of return. As far as the sample is concerned we would have more than we have now. Would it be practical of accomplishment?

Buckley. —I can't answer the question, but I do agree with Mr. Fritts that is has been one of the greatest deficiencies of these needs studies, the total benefit to the economy of the state. We say if you spend X billion dollars you will take care of some vehicle-miles of travel much faster, but what does it do to the over-all economy? I think we can reasonably demonstrate the benefits of convenience, and safety and all the other user items, but it is the broader aspect that we have never been able to grasp.

Hennes. —It seems to me these last two papers bring up some of the same questions. The costs that are used for the needs study could require the interest to be included if you were going to do it on a justification basis. This is one of the two purposes of a needs and costs study—to determine whether this total investment is justified. But the other use is to determine the amount of revenue that has to be raised and I think this conflict or the danger of its being misused is a real one. I noticed that Professor Grant did not put out the warning that his remarks on interest were confined to comparison and justification studies.

In cost allocation studies interest cannot be included as something to be recovered from the investors because the taxpayers are actually the investors who forego the interest. The foregone interest is the interest I forego when I pay the gas tax. If I were charged twice, once for the interest I myself had foregone.

The second point is that the investor in these justification projects is the taxpayer. He is on a pay-as-you-go plan and on the basis of earmarked funds. If this is part of the general picture, then the foregone interest is the interest that this taxpayer could get with his $50 a year, because approximately 65 percent of the funds come from private automobiles and 35 percent from commercial vehicles. We have to consider whether the interest that he foregoes is comparable to these larger sums that might be available to the larger investors.

The use of Grant's example in that case of the man who purchases the automobile on time is not quite a fair one, because he in general does not have this as a choice—of paying this $50 a year in user taxes and buying his automobile for cash or paying for it

on time, because the sums are too disparate. There is no real economic choice between the two, so the alternate investments he has are the rates that are available to the average citizen (4 or 5 percent) except for this matter of risk. And the risk that is involved here, of course, is on the forecast. The basis for determining the evaluation of that is quite difficult. About the only way we can judge the figure is to go in the past and look at the record as to whether the forecasts of traffic over the past years have been pessimistic or optimistic.

In viewing the consequences of the error of neglecting interest in these justification and comparison studies, I think that it would be interesting to know what is in general the lowest ordinary benefit-cost ratio for which projects are actually approved and investments made. If the cutoff point is quite high, then although the error might be quite real, its consequences are not so real.

Rothrock. —The problem generally is the choice between two or more alternates as presented to me. We compare them with the present situation as it is. Quite frequently on some of these particular projects we find that the benefit-cost ration is less than one or approximately one.

Now, at the interest rate you use, if that is a satisfactory term and the calculation is right, a benefit-cost ratio of one is satisfactory. We recently had a case where there were three alternates that were compared by the benefit-cost ratio, and one gave 0.96, another one gave 1.1 and the third gave a trifle more than 1.1. We recommended any of them, because to carry that thing out to the second decimal point was rather foolish.

Berry. —Were these projects with very low benefit ratios on the Interstate System where you are really designing to high standards?

Rothrock. —That is what happened in this case. We were using extremely high standards. We used the consultant 's estimate of costs and traffic because we were told that we did not have time to go into our own estimates. We were told later, however, after we came up with these ratios, that they thought the estimates of traffic were too low. Probably in that particular case traffic would be about three and a half times the volume used. On the basis of that we told the administrator that any of the three projects were comparable. We could find no appreciable difference. The high standards and the 4 percent interest rate we use, do cause benefit-cost ratios of somewhat less than 2.0 on the Interstate projects.

Zettel. —I am sure Professor Grant will rebut some of the things that Professor Hennes said. I do not think that the interest rate for the highway user he is talking about is relevant to the problem at all, but if it were, I suggest that there are a lot of highway users that are paying 1½ to 3 percent a month interest rate to finance companies. If you want to use the average interest rate of the highway user you will find it very high, rather than low.

But that is not what we are talking about. We are talking about the return on alternative investments, not from the point of view of the individual, but from the point of view of the economy which is what we are interested in after all.

There is this distinction between financing of a growing program and what Professor Grant is talking about. Professor Grant is saying that the needs estimates that ASF would turn up with is possibly something other than what they are. And I think Professor Grant would say, "I don't know whether these are the needs until I have evaluated them in these terms." You are saying that we are going to finance what ASF says are the needs, and Professor Grant is questioning whether they are the exact needs until he knows the interest rate and how it has been used.

Grant. —On the interest paid by the highway user who finances his automobile, I am not really advocating 12 percent or 15 percent as the rate that should be used in economy studies for highways. I am simply pointing out that in many studies we draw inferences about the values that highway users put on such things as time and comfort and convenience by their actions. The highway user who is willing to buy a new car and pay 12 or 15 percent is in effect deciding that the services of that new automobile are such

that he is willing to pay a 15 percent interest rate. If he did not have so much taxes to pay he could do either of two things. He could spend it for consumption or he could use it to increase his down payment on the car so he would not have to pay so much interest. Therefore, he would in effect invest it at 15 percent, or if he spends it for a vacation he is saying in effect, this vacation is worth more to me—the consumption expenditure is worth more to me—than the 15 percent.

But don't think that I am advocating this rate in our analyses. I am pointing out an inconsistency in that the economic analysts for highways look at the actions of highway users. They analyze them carefully when it is to their interest to justify more highways. But let me say cynically, they do not analyze them when it is not to their interest.

I am just not close enough to the highway needs studies to have any respectable opinion about them. I would think it would be clearly impracticable, within the time and staff and other restrictions, for an outside group such as ASF to look at prospective rates of return for all of the program of the state.

But Mr. Jorgensen's suggestion that this might be done on a sampling basis, if you started with a stratified sample, and then randomized within that stratified sample, certainly sounds to me as if it would be interesting.

After all, the effects of the highway needs studies are generally good. But one effect, as was the case in 1946 in California, was to increase the gas tax and this is always lurking in the background.

Well, is this really a justifiable expenditure? You do not have much objective evidence if you just say, well, we are short of good highways and we have lots of traffic. Maybe this could be improved, on a sampling basis.

Buckley. —That might be applicable to the higher volume roads, but in the lower volume roads we cannot prove economic benefits even excluding interest.

On roads of 25 or 50 vehicles a day, you compute the cost of even a very low type surfacing and it runs up to vehicle-mile costs that you cannot justify in time savings or vehicle operating savings, or anything else.

However, we are certain that there are intangible benefits which in the limits of our knowledge today we cannot measure in dollars and cents. Therefore, adding interest, or not adding it, in the 75 percent of the mileage, I don't think would make a bit of difference.

Rothrock. —The sampling could be done to include a weighted part of the lesser highways. That would have to be the sort that would be the average, representative of all the highways. But the benefit, or the computation of the benefit, would be based on an expenditure of the entire amount, half a billion, or a billion dollars immediately.

Buckley. —It probably could, because the profit-making roads are now subsidizing these other roads that I am talking about.

Rothrock. —You could take the subsidization and still get a net benefit. But would that be a fair analysis, to say that if we spend a billion dollars now we will get a certain benefit ratio out of it, and then come up with a 15-yr program of expenditure rather than an immediate program?

Fritts. —You won't do it if you are just going to measure the vehicle saving. You are going to have to put in the general economic justifications, what are called consequences today. The consequences are going to have to be measured, and those consequences—not just the user benefits—are going to justify a total system.

Rothrock.—I say the net consequences which result in benefits. I don't mean user benefits strictly, any benefits to whomever they occur.

Buckley. —We have always been accused of coming up with fantastic costs and now you people are trying to make them bigger.

Zettel. —We may reduce them. Concerning this land-use aspect, I think it is a matter on which we can't have a way of measuring the user benefits.

Buckley. —I think they are there but you can't measure them in dollars and cents.

Zettel. —In any methods of measuring user benefits that we know about you would say the driveway to my garage is not justified. I insist that the driveway to my garage is just as much a user benefit as it is a property benefit, except that I put it in as a property owner. I bought it as a property owner, but it is as important to me as a user as it is as a property owner. We just don't know how to evaluate that kind of benefit to me as a driver of an automobile.

Berry. —Mr. Blensly previously said that research has not been used in priority determination. Professor Grant has really thrown out a challenge, and we ought to start doing more research, possibly even to the extent of having a subcommittee of this group prepare a prospectus and get it under way. Also on benefit-cost versus rate of return. We have done a little on that at Northwestern, but I think a lot more needs to be done.

Winfrey. —Gentlemen, as we come to the end of this session, Mr. Rothrock has an announcement.

Rothrock. —Professor Grant spoke of the use of tables or charts for determining rate of return. In Ohio we have prepared a set of tables and charts for determining rate of return, present worth, etc. (Appendix B.)

SESSION FOUR

Friday, September 18, at 9:00 A. M.

THE DETERMINATION AND MEASUREMENT OF USER BENEFITS

JAMES S. BURCH, North Carolina Highway Commission, Presiding

Effects of Travel Impedance Costs

NATHAN CHERNIACK, Economist, The Port of New York Authority

● BEGINNING in 1924, the author was involved in several types of traffic and revenue studies. One type had to do with the actual determination of the probable redistribution of vehicular traffic among existing ferries or free bridges and proposed toll crossings. Another type had to do with the determination of the probable traffic volumes that would be "generated" by the proposed crossing, in addition to the anticipated annual organic growth of vehicular traffic. A third type of study was to demonstrate through statistical research the fact that a proposed crossing, by reducing travel impedance costs and despite the levying of a toll or a higher toll than on existing crossings, would actually stimulate cross-river trips. A fourth type of study was to demonstrate through research that, despite differences in the toll cost between a cheaper competitive ferry or an alternate free bridge, the proposed toll crossing would actually divert sufficient traffic from cheaper ferries or free crossings to be competitive with them and thus prove to be economically feasible.

In a 1940 paper (1) several hypotheses on traffic distribution and generation were brought together. The author set forth equations and determinants of generation of vehicular trip volumes, distribution among alternate routes, and organic growth, on the basis of types of data then available for such trip determinations.

In 1945 the author set forth two hypotheses: one on traffic distribution and the other on traffic generation.

The traffic distribution hypothesis, expressed mathematically, stated that equal numerical differences in impedance costs between a selected standard and any other existing alternate route, are associated with equal percentage differences, in the opposite direction, in the quality ratings of the existing alternate routes.

The traffic generation hypothesis, expressed mathematically, stated that the differences in trips between any pair of zones (one a residence and the other a non-residence zone) and a standard pair of corresponding zones, are (a) proportional to the differences in auto registrations in the two resident zones, (b) proportional to the

differences in the indexes of "attraction" in the non-resident or purpose zones, and (c) inversely proportional to a function of the differences in impedance costs between the given pair of residence and non-residence zones and the corresponding standard zones. The inverse mathematical functional relation between trip differences and impedance cost differences (between any pair of zones and a standard pair) was an exponential function and not a power function, like the so-called gravity model.

G. P. St. Clair put these two hypotheses and their corresponding series of equations through thorough and rigorous mathematical tests. In connection with the author's traffic distribution hypothesis, he suggested an alternate hypothesis which might briefly be stated as follows: "all alternate routes have equal impedance costs." In this connection, he also suggested that a relationship would have to be established between running and waiting time impedances and the traffic volume flowing along alternate routes. This would provide another basis for determining redistributions of traffic among existing and proposed alternate routes.

In connection with the author's traffic generation hypothesis, St. Clair agreed that the mass product of (a) auto registrations in the resident zones and (b) indicators of attraction in the non-residence zones, were partial determinants of inter-zonal trips. He also agreed to the idea that impedances and impedance costs presented real possibilities for the relative economic evaluation of proposed highways.

In addition, St. Clair derived from the author's exponential functions, by the method of the calculus, an exponential-type-skewed function and normal-type-skewed function. The designations of functions sound like formidable mathematical challenges. Though they may appear complex, they seem to be realistic reflections of both traffic generation and the types of linkages that appear to exist between homes and sites of economic activities. The author has discovered data which not only points to the realism of these mathematical functions but also to the fact that some of the corollary "constants", which they would yield, would be quite meaningful and valuable in real life if determined from certain types of data.

These analyses and the extended reciprocal correspondence between the author and St. Clair were not published at the time (in 1946). The author felt that the data that would be forthcoming from the "home interview" O-D studies, then newly developed by the Bureau of Public Roads, might yield the very types of trip volume data, in sufficient quantities, together with correlative determinant factors that might be assembled simultaneously, to test scientifically, the validity of the author's trip-impedance cost hypotheses. These data might also provide the data necessary to test the validity of the mathematical functions suggested by the author as well as those derived by St. Clair.

The author has since found that the data summarized from the "home interview" method of assembling O-D data had serious defects for use in research, particularly for testing the validity of these hypotheses. For one thing, the data on trips to and from given O-D zones were usually mixtures of primary trips, some originating or destined for residences in the zones, and other trips originating or destined for non-residence sites in the same zones. As a result of these trip mixtures, correlations between trips into and out of zones, with autos domiciled in these zones, could not possibly yield satisfactory correlations. It was essential therefore that this "chemical mixture" of trip data be broken down first. By going back to the original schedules and obtaining pure "elemental" trips to and from zones originating and destined for exclusively in residences in those zones, meaningful correlations could then be established.

Every O-D zone is not only a residence zone but also a non-residence zone. The same type of "chemical breakdown" is required to obtain trips to and from every O-D zone as a non-residence zone. If such breakdowns could be made, then such data could be correlated with data on gainfully employed for journey-to-work trips, with floor space in commercial buildings for business trips, floor space in retail establishments for shipping trips, and floor space in other buildings for amusement and recreation trips, etc. These types of land use data for non-residence zones have since become available, but only very recently.

Bringing together some 35 years of continuing studies, bearing on generation of traffic, distribution among alternate routes and modes of travel, and organic annual growth in vehicular traffic volumes, present knowledge and understanding suggests these types of future studies.

To arrive at the minimum number of fundamental determinants of vehicular and person trip generation as well as their distribution among routes and modes of travel, the first essentials of course, are data on vehicle and person trips between as large a number of pairs of zones as possible in study areas. In one of the pairs of zones, the trip ends must be exclusively at residences or "residence zones." In the other of the pairs of zones, the trip ends must be exclusively at non-residences where the purpose of the trip was satisfied or in "zones of purpose." Such zones of purpose are: employment zones, retail shopping zones, commercial or amusement and recreation zones. Vehicle and person trip data should therefore be assembled on the basis of several significantly different purposes but also by modes of travel such as by auto, bus, rapid transit and via commuter rails.

However, supplemental data on fundamental traffic determinants are equally essential. Such data must be assembled for small areas—like census tracts, postal zones or O-D zones. Such data consist of population, households, auto ownership, numbers of gainfully employed at sites of zones of employment, net residential acreages, floor space at retail establishments, at all other commercial establishments and at amusement and recreation sites.

Equally essential data that must be assembled, if possible, simultaneously with trip and land use data, are those obtained through test runs between every pair of zones in the study area and along various routes made with autos, by riding buses, and railroads. These test run data consist of the following: distances, travel time, both running, stopping and waiting times; auto operating costs; tolls at bridges, tunnels and highways; parking fees in non-residence zones; vehicle volumes along all major arterials and well-traveled routes, and notations of annoying and irritating potential hazardous aspects of routes, like left turns, parked cars, pedestrian crossings and so forth.

With such trip volume and supplemental fundamental data at hand, trip data may be correlated with the above fundamental determinants, and excellent results anticipated. Trips for any given period of time and for one or more purposes, to and from zones with trip ends exclusively at residences would yield excellent correlations with auto ownerships in those zones. In turn, densities of auto ownerships (expressed in cars per acre) would be correlated quite closely with household densities (expressed in households per acre).

Thus, auto ownership densities appear to increase in proportion to household densities up to about 10 to 15 households per acre; after that, auto densities do not increase as fast as household densities. Auto ownerships per household, on the other hand, decrease as household densities increase. Thus, there are more cars per acre in Manhattan (about 21 cars per acre) than in Westchester County (about 5 cars per acre). On the other hand, on Manhattan there are only about 40 cars per 100 households compared to about 120 cars per 100 households in Westchester County (in 1955). In the author's opinion, household densities (households per acre), are far more stable indicators of auto ownerships in small areas than are, for example, such indicators as distances of zones from CBD's, or income per household.

Similarly, trips for any given period of time and for any given purpose—such as journey to work, to and from the same zones but with trip ends now exclusively at sites which satisfy the purpose (such as at sites of employment or retail establishments)—will correlate with indicators of the purpose, such as number of gainfully employed or sales volume or floor space, in these non-residence zones.

Trips between pairs of zones, one a residence and the other a non-residence zone, made for one or more purposes, will thus correlate closely with the product of (a) auto ownership in the residence zone and (b) indicators of the purposes satisfied in the non-residence or purpose zone. The mass product influence on trips between pairs of zones may thus be "filtered out" by dividing trips by the product of auto ownership and the purpose indicator, to yield a very significant series of auto or person trip ratios, for each of the zones in the study area. It is these auto or person trip ratios, for each of the zones, which are inversely related to travel impedance costs, between pairs of zones.

It is usually exceedingly difficult to establish, from non-physical statistical data, the precise mathematical functions connecting trips with their correlative determinants,

because any one of several families of inverse functions will usually yield equally good statistical correlations, and closeness of fit of any curve, is the only statistical test for choice of the precise function. However, in the opinion of this researcher, the so-called gravity formula, which states that trips vary inversely as some power of distance or time, does not appear to be the mathematical function best suited to express the inverse relationship between trips and impedance costs. The gravity formula being a power function states, in effect, that a one percent increase in distance or time produces an x percent decrease in trips. The type of mathematical function that best expresses the inverse relationship between trips and impedance costs is an inverse exponential type function. An inverse exponential trip-versus-impedance-cost function postulates that a numerical difference in determinants like distance (miles), running or waiting time (minutes), tolls (in cents) or parking fees and one or more forms of usually unmeasurable types of impedance which produce irritations, annoyances and potential hazards to travel, or numerical differences in unit costs of these impedances will produce percentage differences in trips, in the opposite direction.

These mathematical functions also postulate that motorists in the study area, place average unit values on the differences in each type of impedance, between any given pair and that for the standard pair of zones. Thus, motorists place an average unit cost on every mile more or less than the distance between the standard pair of zones or on the differnce of every minute of running or waiting time, as well as on differences in the not directly measurable impedances that produce annoyances and irritations to motorists. In order to avoid these impedances, the motorist is thus willing to pay so many cents either per identifiable impedance difference or for all residual not directly measurable impedance differences.

If these impedances have been measured along routes that connect a large number of pairs of zones in the study area which have widely varying impedance characteristics and widely varying volume of trips, it is possible, by the method of least squares, to determine the most probable average unit impedance costs of the limited number of measurable impedance differences.

The end product of the above procedure yields quite a simple formula. It states that between any pair of zones and any other pair in the study area numerical differences in aggregate impedance cost differences are associated with percentage differences, in the opposite direction, in trips.

There is one more philosophical step required before practical application can be made of such formulas to estimate probable future changes in trips resulting from changes in travel impedances. It is this: a numerical change of one cent in impedance cost during a given interval of time, would be equivalent to the effect of a difference of one cent, at the time of the study. In defense of this philosophical step, the author has this experience to offer.

In 1940, the author produced this "rule of thumb": that a one cent difference in impedance cost would produce a one percent difference in the opposite direction in trips. Recently, Westchester County Toll Parkways increased tolls from 10 cents to 25 cents or a difference of 15 cents. According to the above rule, assuming a change and a difference to be equivalent, there should have been a reduction in traffic volume of 15 percent. The reduction in traffic volume turned out to be 16 percent. But, with tolls 250 percent and traffic 84 percent before the toll increase, revenues turned out to be 210 percent of those before the toll increase. This revenue increase clearly indicates what the motorist is willing to pay for avoiding the not directly measurable impedances on alternate routes, of which there are a number.

The author has worked consistently with a mathematical function that relates percentage differences in trip volumes with numerical differences in impedance costs. St. Clair, some twelve years ago, as mentioned above, derived several other distinct types of integral functions. Although they are more complex than the author's original difference functions, they are nvertheless highly useful. Data could be collected to implement them. These functions would yield measures for a number of highly interesting characteristics of trip linkages between sites of concentrated economic activities and surrounding tributary residence areas. They would reveal relationships between

increasing travel impedance costs and decreasing rentals in residential areas located at various travel impedance costs from concentrated economic areas, like CBD's. These functions also indicate that person and vehicle trip data should be collected at concentrated sites and areas of economic and recreational activities, rather than in the homes through the "home interview" method.

The derivation of the formula for redistribution of traffic between any pair of zones among alternate routes connecting them, follows similar lines of reasoning and results in a hypothesis similar to the traffic generation theory. This hypothesis states that the percentage ratio of any given route to that of a standard route (which ratio the author terms the route's "quality rating") is inversely proportional to the numerical difference in the impedance cost between the given route and the standard route. Thus, on the Hudson River where between some pairs of zones, there were as many as 18 alternate ferry, tunnel and bridge routes, carrying significant portions of trans-Hudson trips between given pairs of zones, it was essential to reflect in the formula the number of significant alternate routes competing for revenue traffic.

The share of total trips, between any given pair of zones that any given existing or proposed alternate route would handle, was equal to the ratio which its "quality rating" (relative to a standard route) bore to the sum of the quality ratings of all alternate routes. The quality rating of any existing route was obtained from the trip data by dividing the trips between a given pair of zones via any given route, by those via the standard route. Correlations of quality ratings between alternate routes and impedance costs via alternate routes indicated that a numerical difference of one cent in impedance costs was associated with about a one percent difference, in the opposite direction, in the quality rating between alternate routes.

Today there is a wealth of trip volume data between small areas in more than 100 cities for which millions of dollars have been spent to assemble, and more millions for analysis. Far greater understanding of the basic factors which determine generation of traffic volumes, distributions among alternate routes and traffic expansion over time, could be derived from the voluminous original household interview data that have been assembled. Some of these original data should therefore be "exhumed" and re-punched on new cards. Some supplemental data should be punched into those cards. They should be tabulated and examined, at first by hand, in the light of the equations discussed in this paper. Electronic machines or computers could then be used to determine the most probable impedance costs. At the same time, the best types of mathematical functions could be firmly established. A great wealth of understanding would flow from such re-analyses.

Also serious consideration should be given to assemble future O-D data at sites and areas of concentrated economic, social and recreational activities in urban areas. In the opinion of the author a much richer body of data would thus become available for research on the underlying economic determinants of urban transportation.

FORMULAS FOR TRAFFIC DISTRIBUTION AND RE-DISTRIBUTION AMONG ALTERNATE ROUTES

$$J_{HP} = J_1 + J_2 + \ldots + J_s + J_m + = S_1^m J \qquad (1)$$

in which

$J_{HP} = S_1^m J$ = all journeys between a residence zone H and a purpose zone P, via existing alternate routes 1 to m inclusive.

J_1, J_2, J_S, J_m, = journeys between the residence zone H and purpose zone P, via individual alternate routes 1, 2, any other existing route m, and the most traveled route between zones H and P, adopted as standard route s.

$$s_m = \frac{J_m}{J_{HP}} \quad \frac{J_m}{J_1 + J_2 + \ldots J_m J_s} \qquad (2)$$

in which

s_m = share which any existing alternate route m handles of all journeys between residence zone R and purpose zone P, via all existing alternate routes, and other terms as above.

$$Q_m = \frac{J_m}{J_s} \; ; \; Q_s = \frac{J_s}{J_s} = 1 \tag{3}$$

in which

Q_m = "quality rating" of route m, relative to standard route s and other terms as above.

$$sm = \frac{J_m}{S_1^m J} = \frac{Q_m}{S_1^m Q} \tag{4}$$

in which

$S_1^m Q$ = sum of the quality ratings of all alternate routes, 1 to m between residence zone H and purpose zone P, and all other terms as above.

$$Q_m = (1-d)^{\Delta c_m}; \tag{5}$$

in which

d = discount from unity in "quality rating" of any alternate route, for every impedance cost difference of one cent via route m, compared with standard route s. Numerical value of discount (d) measures the "keenness of competition" among alternate routes, between zones H and P.

Δc_m or Δc_p = algebraic sum of the impedance cost differentials between either existing alternate route m or proposed alternate route p and the standard existing alternate route s and other terms as above.

$$\Delta c_m = \Delta mc_{\Delta m} + \Delta rc_{\Delta r} + \Delta wc_{\Delta w} + c_{\Delta t} + \Delta ic_{\Delta i} \tag{6}$$

in which

For journeys between zones H and P, the impedance differences between alternate route m and standard route s are:

Δm = distance difference (in miles)
Δr = running time difference (in minutes)
Δw = waiting time differences while stopping for traffic signals and other delays (in minutes)
Δi = impedance differences like left turns, pedestrian crossing, unparking of cars, etc. (in numbers)
$c_{\Delta m}$ = unit cost of mileage differences (in cent/min)
$c_{\Delta r}$ = unit cost of running time differences (in cent/min)
$c_{\Delta w}$ = unit cost of waiting time differences (in cent/min)
$c_{\Delta t}$ = cost of toll differences (in cents)
$c_{\Delta i}$ = unit cost of all other identifiable or residual impedance (in cent per impedance)

$$Q_m = (1-d)^{\Delta c_m} \tag{5}$$

$$\log Q_m = \Delta c_m \log (1-d) \tag{7}$$

let $\log Q_m = q_m$ and $\log (1-d) = d'$

then $q_m = d' \Delta cm$ (8)

but $\Delta c_m = \Delta mc_{\Delta m} + \Delta r\, c_{\Delta r} + \Delta wc_{\Delta w} + c_{\Delta t} + \Delta ic_{\Delta i}$ (6)

therefore $q_m = d'\, \Delta mc_{\Delta m} + d'\, \Delta rc_{\Delta r} + d'\, \Delta wc_{\Delta w} + d'\, c_{\Delta t} + d' \Delta ic_{\Delta i}$ (9)

Eq. 9 may be used to determine, by the method of least squares, motorist's evaluations of unit costs of mileage differentials, of running and waiting time differentials, and of other travel impedance differentials where differences in mileages, running and waiting times, and tolls have been determined from standard routes, for a large number of pairs of residence and purpose zones.

$$s_p = \frac{Q_p}{S_1^m Q + Q_p} \tag{10a}$$

$$s_{1-n} = \frac{S_1^n Q}{S_1^n Q + Q_p} \tag{10b}$$

in which

s_p = share which any proposed alternate route p.
s_{1-n} = share which all other existing routes would handle of all journeys between residence zone H and purpose zone P, via all existing alternate routes plus the proposed alternate route.
Q_p = "quality rating" of the proposed route p, obtained from Eq. 5,

$$Q_p = (1-d)^{\Delta c_p}.$$

Eqs. 10a and 10b are used to compute shares of total journeys between a residence and purpose zone which a proposed route would divert from existing alternate routes. And the share remianing on all individual existing routes with the proposed route in operation.

FORMULAS FOR TRAFFIC GENERATION

$$J_{HP} = K A_H I_p F(c_{HP}) \tag{11}$$

in which

J_{HP} = all journeys between a residence zone H and a purpose zone P.
A_H = autos domiciled in residence zone H.
I_p = Index of purpose satisfaction, in purpose zone P.
$F(c_{HP})$ = Some inverse mathematical function of aggregate costs of all travel impedances between residence zone H and purpose zone P.
K = "dimensionality constant" which converts product of the numbers representing the terms of A, I, and c into J_{HP}, representing the journeys between residence zone H and purpose zone P.

$$K = \frac{S_J}{S_A} = j_a \tag{12}$$

in which

S_J = sum of all primary journeys from all residences in the study area.
S_A = sum of autos domiciled in all residences in the study area.
j_a = average number of journeys made to all purpose zones by each auto domiciled in the study area.

$$I_w = \frac{E_w}{E_s} = e_w;\ I_b = \frac{F_b}{F_s} = f_b \tag{13}$$

in which

I_w = Index of work purpose.
E_w = Employment in the work zone.
E_s = Total employment in the study area.
e_w = Percent of total employment of study area in work zone.
I_b = Index of Business.
F_b = Floor space in business area.

F_s = Total floor space devoted to business in the study area.
f_b = Percent of total floor space of study area, in business zone.

$$F(c_{HP}) = F(mc_m + rc_r + wc_w + T + P + Ic_i) \tag{14}$$

Impedances between residence zone H and purpose zone P are:

m = distance (in miles)
r = running time (in minutes)
w = waiting time (in minutes)
I = residual impedances (like left turns, unparking of cars, pedestrian crossings, etc.)
c_m = unit cost per mile.
c_r = unit cost per minute of running time.
c_w = unit cost per minute of waiting time.
T = tolls at bridges, tunnels or toll highways.
P = parking fees in the purpose zone.
c_i = unit cost per identifiable or residual impedance.

$$J_H = j_a A_H F(c_H) \tag{15}$$

in which

J_H = journeys from the residence zone to all purpose zones in the study area.
j_a = average number of journeys per auto (domiciled in study area) between residence and purpose zones in the study area.
A_H = autos domiciled in residence zone H.
$F(c_H)$ = some inverse mathematical function of aggregate impedance costs between residence and purpose zones.

$$\frac{J_H}{A_H} = j_H \tag{16}$$

in which

j_H = average number of journeys to all purpose zones in study area per auto domiciled in residence zone H.

$$\frac{j_H}{j_a} = g_H \tag{17}$$

in which

g_H = ratio of frequency of journeys per domiciled auto from residence zone H, to that of average frequency of journeys from all residence zones in the study area. (This becomes an indicator of "generation" of journeys, with reduction in impedance costs.)

$$g_H = (1 + p)^{-\Delta c_H} \tag{18}$$

in which

p is the percent difference in journeys, for every difference of one cent in impedance cost differentials between journeys from residence zone H to the centroid of purpose zones, compared with journeys from the centroid of residences to the centroid of purpose zones.
Δc is the aggregate difference in impedance cost differentials between the residence zone H and the centroid of purpose zones compared with those between the centroid of all residence zones and the centroid of all purpose zones in the study area.

$$\Delta c_H = \Delta mc_{\Delta m} + \Delta rc_{\Delta r} + \Delta Wc_{\Delta W} + c_{\Delta T} + c_{\Delta P} + \Delta Ic_{\Delta I} \quad (19)$$

Impedances between the centroid of residence zones and centroid of purpose zones are compared with those between the residence zone H and the centroid of purpose zones, and the resulting impedance differences are as follows:

Δm is distance difference in miles.
Δr is running time difference in minutes.
ΔW is waiting time difference in minutes.
ΔI is residual impedance difference, in numbers.
$c_{\Delta m}$ is unit cost of mileage difference.
$c_{\Delta R}$ is unit cost of running time difference.
$c_{\Delta w}$ is unit cost of waiting time difference.
$c_{\Delta T}$ is toll cost difference.
$c_{\Delta P}$ is parking cost difference.
$c_{\Delta I}$ is differential cost of residual impedances.

$$g_H = (1 + p)^{-\Delta c_H} \quad (18)$$

$$\log g_H = -\Delta c_H \log (1 + p) \quad (20)$$

let $\log g_H = g'_H$ and $\log (1 + p) = p'$

$$g'_H = p' \Delta c_H \quad (21)$$

$$g'_H = -p'\Delta mc_{\Delta m} - p'\Delta rc_{\Delta r} - p'\Delta wc_{\Delta w} - p'c_{\Delta T} - p'c_{\Delta P} - p'\Delta Ic_{\Delta I} \quad (22)$$

Eq. 22 may be used to determine, by the method of least squares, the generation factor "p" and the unit costs of impedance differences, in the study area.

REFERENCE

1. Cherniack, Nathan, "Measuring the Potential Traffic of a Proposed Vehicular Crossing." ASCE Trans., Vol. 106, p. 520 (1941).

Discussion

Burch. —I know that everyone who has worked in O-D surveys and their analysis recognizes the great variety and great complexity of traffic movement. It often seems impossible to unravel the motivations and the decisions that are made by drivers as they choose their routes of travel.

Pendleton. —One of the frequent recommendations that economists make, particularly when urban facilities become very congested, is that a price of some sort, or a higher price at least than has been charged, be placed upon that facility as the most efficient way (at least in the short run) of meeting the problem.

I was wondering, in connection with the Westchester County freeways, what the motivation was for jumping the toll from ten cents to a quarter, and how you could justify to the public the collection of all this additional revenue which was presumably not matched immediately by increased costs.

Cherniack. —I can't speak, of course, for the Westchester Park County Commission, but I would guess that they were faced with a problem of building expanded highways and parkways; and under the present toll rates, they were unable to do that, while with the added toll they might be able to do it.

I can give you an example of one effect of inflation. The Port Authority built the first two tubes for about $80 million. When they came to build the third tube, one tube cost $100 million. In effect, you are really trying to retrieve the present 1959 costs with this added toll, and also to have the funds to expand when necessary.

Now, I can give you perhaps another illustration but in reverse. The floating bridge in Seattle was originally a toll bridge. It had paid itself off, amortized its debt sooner than expected, and so the bridge was made free of toll charges—at present it is operating at capacity, and the public wants to expand it. Now the problem is how to build a toll bridge under the costs of 1959, and to operate it in competition with a free bridge.

Motor Vehicle Operating and Accident Costs And Benefits Arising from Their Reduction Through Road Improvement

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●HIGHWAY benefit studies are concerned with those vehicle operating costs which are susceptible to change through highway improvement. The costs of fuel, oil, tires, maintenance, and depreciation are of this nature while other items of operating costs, insurance charges, registration levies, and garage fees, are generally unaffected by highway conditions. Driver costs, a vehicle operating cost of particular importance in commercial operations, is affected by those highway improvements which change travel time, but the benefit to vehicle operators associated with the time factor is of such importance that it is generally treated in benefit studies as a separate element of benefit. The benefits of time-saving will not be discussed in this paper.

The aggregate cost of highway accidents is determined by three factors: the number of accidents, the average accident severity, and the unit monetary value of the losses whether by death, injury, or property damage. Only the first two factors can be reduced through highway improvement since the unit values of the losses due to accidents are independent of highway conditions. Benefit studies include consideration only of cost reductions through reduction in the number and severity of highway accidents.

This paper will deal primarily with the determination of the motor vehicle operating and accident cost values that are pertinent to an analysis of highway benefits and will deal largely with the reductions in these costs which can be achieved through highway improvement. Except in connection with benefits brought about through change in route length, no attention will be given to the problem of predicting what the absolute or total operating and accident costs will be for operation on a given highway. Accurate predictions of this type are almost impossible since the absolute cost is the result of the interplay of many factors: speed, traffic conditions, grades, etc.

The benefit to users of highway improvement equals the cost of operation on the road if it is not improved less the cost if it is improved and can be expressed by the formula $A = TL\ (C_o - C_n) + TC_oa$ where A is annual benefit for a given vehicle type, T is annual number of such vehicles expected to use road, C_o is unit cost per mile for these vehicles if the highway is not improved, C_n is unit cost per vehicle mile if it is improved, L is the original length of route, and a is the change in route length brought about by improvement (shortening, if positive). The first term of this formula is the product found by multiplying the vehicle miles of travel for the new length of road after improvement by the reduction in cost or the benefit per vehicle mile. The second term, the benefit due to shortening of route, is the product of vehicle miles of travel eliminated through route shortening multiplied by the average unit operating cost for the route before improvement.

Thus the determination of annual benefits requires that four values be known for each type and weight of vehicle: (a) an accurate prediction of the vehicle miles of travel for the route after improvement (TL); (b) the reduction in cost in cents per vehicle mile which will be brought about through each kind of road improvement (C_o-C_n); (c) an estimate of the absolute operating costs for the route as it exists before improvement (C_o); and (d) the vehicle miles of travel saved through route shortening. The remainder of this report will describe methods of determining the second of these items (C_o-C_n) for motor vehicle operating and accident costs.

The motor vehicle operating cost affected the most by highway improvements is the cost of fuel which is determined by the magnitude of fuel use and unit cost of fuel. Since the unit cost of fuel cannot be changed by highway improvement, it will not be considered further. A decrease in the number and frequency of accelerations, number and steepness of grades, degree of road roughness and amount of curvature decreases fuel consumption at any given running speed. Reducing the amount of time vehicles are stopped with engine idling also saves fuel. On the other hand, highway improvements which result in higher operating speeds such as lane widening, an increase in the number of lanes, resurfacing, and sight distance improvement, usually bring about increased fuel consumption.

A reduction in the number of stops that must be made for traffic lights, stop signs, and access points saves both the amount of fuel consumed while idling at stop and the extra fuel needed during accelerations after stops. Similarly, a reduction of the number of access points, curves and caution situations which require vehicles to slow down will save on fuel use by decreasing the number of accelerations necessary.

The unit fuel use benefit or disbenefit (C_o-C_n) which can be realized through the above improvements can be found if, in addition to knowing the unit cost of fuel, the magnitude of fuel use for all vehicle types and weights is known as follows:

1. The fuel use per mile at constant speed at various running speeds on level, paved, straight road.
2. The additional fuel consumption per event to come to a stop and accelerate back to speed for various running speeds.
3. The additional fuel consumption per event to reduce speed by given amounts and accelerate back to speed for various running speeds.
4. The additional fuel consumption per mile to operate on a straight, level, gravel road rather than on a paved surface.
5. The fuel consumption per minute while stopped with engine idling.
6. The additional fuel consumption per mile to operate upgrade rather than on a level road at various running speeds.
7. The additional fuel consumption per curve to operate on curves of various degrees of sharpness at various running speeds.
8. The fuel consumption per mile to operate on paved level road of 2, 4, and 6 lanes at various ranges of traffic volume while floating with traffic.

Current studies being conducted by the University of Washington and the Bureau of Public Roads seek to determine values for each of these items. When the data for these studies have been analyzed, it should be practicable to predict accurately the net fuel saving to be achieved through highway improvements.

In addition to the above studies of fuel consumption as affected by separate items of highway change, the over-all difference in fuel consumption of passenger cars operating on high type highways (toll roads) and on alternate routes of older and hence inferior location and design (parallel free routes) was investigated at 14 different locations in 9 states. The difference in fuel consumption measured on the comparison routes reflects the net result of change in length, grade and curve reduction, elimination of both access points and intersections at grade, increase in number of lanes and lane width and surface improvement. The results of this study will be useful as a means of guarding against large errors in fuel consumption benefit determinations as found through item by item computations.

Other motor vehicle operating costs which may be reduced through highway improvement are those for oil, tires, maintenance, and depreciation. Highway improvement can reduce the rate of oil consumption through shortening of distance and improvement of road surface conditions. However, the large number of variables affecting oil consumption make it very difficult to assign oil use benefits to any highway improvement with the possible exception of distance reduction. Most vehicle users change oil after their vehicle has traveled some particular distance usually according to recommendations of the manufacturer. For example, the Federal Government has issued instructions that the engine oil of its passenger cars be changed each 4,000 miles. Many users must add oil between changes, usually because of some non-highway condition that increases

oil use. The most satisfactory way of including oil consumption in benefit studies is to compute the cost of oil per mile, based on the average number of miles of travel between oil changes and on the average cost of an oil change, and assign it as a benefit due to shortening of distance.

Tire wear is determined largely by tire use or travel distance, surface conditions, and operating speeds. Highway improvements that result in route shortening and/or improved surface conditions will save on tire cost while improvements that provide for higher operating speeds will increase tire cost. The amount of wear per mile is affected by several highway factors that can be changed through highway improvements in addition to surface condition and speed potential. These are number and steepness of grades, amount of curvature, and number of stop and go and slowdown operations required. The saving in tire wear per vehicle mile which can be achieved through any one of these highway improvements is so small that no practical method is available for measuring it accurately.

The literature contains considerable information on tire wear as affected by distance, surface condition, and speed. This information is useful in benefit studies although much of it is based on data collected a number of years ago and probably not accurate for the tire, road, and vehicle conditions as they exist today.

Maintenance costs include costs of parts such as air and oil filters, mufflers, lamps, fan belts, spark plugs, shock absorbers, springs, distributor and carburetor parts, parts for the electrical and cooling systems, pistons, valves, and the labor cost for lubrication, brake adjustment, tuneup, engine overhaul, transmission overhaul, replacement of worn parts and washing.

All of these costs will be reduced through highway improvements which reduce route length. In addition, the cost of some items such as for parts and labor for replacement of filters, brake parts, shock absorbers and springs and the labor cost for adjusting brakes, lubrication and washing will be reduced through improvement of road surface and improvements which reduce number of stop and go and slowdown operations.

Limited information is available in the literature on the cost of maintenance as a function of travel distance and on the difference in maintenance costs for operation on dusty, rough roads as compared to operation on paved surfaces. The magnitude of these costs warrants further study.

Depreciation cost, as a motor vehicle operating expense, is the reduction in value of a properly maintained vehicle that occurs during the period of ownership by a highway user; it is equal to the difference between the purchase price and the price received at the time it is later sold. The magnitude of depreciation is determined by the change in ownership that takes place at the time of purchase, length of time between purchase and re-sale, appearance and running condition of vehicle at time of re-sale, and the number of miles use accumulated between time of purchase and time of re-sale. For the private passenger vehicle the change in value is almost entirely caused by ownership change, duration of ownership, and appearance and running condition at time of re-sale. In the case of trucks the value reduction is primarily due to duration of ownership, appearance and running condition, and mileage accumulation.

The depreciation cost of a properly maintained passenger car can be reduced through road surface improvements, but the amount of such benefit is small and practically impossible to evaluate. The benefits passenger car users achieve through reduction of depreciation cost through highway improvement can be neglected.

In the case of trucks and buses, however, mileage accumulation is much more important in the mind of the purchaser and highway improvements which reduce route length as well as those which result in an improved road surface will be reflected in lower depreciation cost for a given amount of use. A convenient and logical means of computing the benefits due reduction of depreciation costs for trucks is to compute the depreciation cost per mile as equal to the average difference between the purchase and re-sale prices of properly maintained trucks divided by the number of miles use accumulated between purchase and re-sale and assign this as a benefit achieved through route shortening.

Motor vehicle accident costs depend on the number of accidents or the incidence of accidents, the average severity of accidents, and the unit costs incurred through

accidents such as those for vehicle repairs, hospitalization, and insurance premiums. Only the first two of these can be changed through highway improvement. The relation between the incidence of accidents and separate highway items, such as intersections at grade, curves, and number of lanes, has been investigated by a number of researchers. It is possible with the information available in the literature to estimate the total number of accidents which will be avoided through highway improvements for several types of improvement.

Accident severity or the number of accidents of various kinds (head-on collisions, rear-end collisions, etc.) as related to highway factors is at present under investigation by the Bureau of Public Roads. The Bureau study seeks to determine accident costs in general as well as accident severity. It is expected that this study will provide the information needed to evaluate the benefits resulting from highway improvements that reduce accident severity. Further investigation along these lines is needed.

The evaluation of motor vehicle operating and accident cost benefits arising from highway improvements is dependent on the availability of accurate information on motor vehicle costs and relation of these costs to highway improvement. The Bureau of Public Roads is collecting such data through the several studies mentioned in this paper. In addition, the Bureau is making a search of the literature of motor vehicle costs in order to have easily available all published information on the oil consumption, tire wear, and maintenance requirements of motor vehicles. More information than is being sought at present, however, is needed particularly in connection with vehicular maintenance requirements and accident severity.

Discussion

Burch. —It is apparent that Professor Claffey's work is bringing together and refining several types of data which we have been seeking for many years. We have all been working in this field, getting ever closer to exact values, but it seems that he has gone further into these refinements and revaluations than anyone who has come to my attention.

It would appear that the procedure described by Professor Lang on the use of digital computers in bringing together some of these interdependent variables would complement the study that Claffey is making to the mutual benefit of both studies.

One point that struck me, and I am not attempting to discuss the paper, is a factor which we all stumble over, and that is the forecasting of accident occurrence. It has very little regularity. In fact, as one person has put it, "accidents are very accidental." At least, on a given stretch of road, it is almost impossible to predict whether you will have one or a dozen accidents within a given year. The accident history on a segment of highway is never uniform or regular.

Hoch. —I have some empirical data from accident studies published by the Chicago Area Transportation Study[1] which may be of some interest to the group.

One interesting feature is that although accidents and accident rates may not be predictable for a given stretch, they seem to be fairly regular for a system as a whole.

We collected accident information on a total of 10 arterials in the city and compared rates in terms of accidents per million vehicle miles to rates on the Congress Street Expressway. We found that the average rate per million vehicle-miles was 14.3 for the sample of arterial streets, whereas on the Expressway, the rate was 2.8; a difference of approximately five or six times as much on the arterial streets.

We weighed the various accidents involved by estimated accident costs, that is the direct costs as based on the study in Massachusetts. We used $5,800 for a fatality, $960 for an injury accident and $225 for a property damage accident. On this basis we found the cost rate per million vehicle miles in 1958 for the arterial streets to be

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[1]Hoch, Irving, "Accident Experience: Expressways vs Arterials," Chicago Area Transportation Study.

$6,202, and for the Congress Expressway only $1,282.

Capitalizing this at an assumed life of 25 years and an interest rate of 5 percent yielded a saving per mile (assuming 100,000 vehicles used a mile of Expressway a year), the computed capitalized value was in the order of $2 million. So this is a rough estimate of the benefits derived from accident reduction on Expressways.

Burch. —Of course we all do recognize, the great safety advantages of the Expressway and I did not mean to deprecate it. We do have very good data showing that the control of access and the removal of crossings and traffic turbulence very definitely reduce accident rates and severity.

Van Riper. —I think possibly some figures from this report by the City of Los Angeles, "A Study of Freeway System Benefits," (prepared by Lloyd Aldrich, former City Engineer, Sept. 1954) might be of interest at this time. The data show the minimum benefits to motorists using freeways in lieu of the usual surface streets, with gasoline savings to be about a third of a cent per vehicle mile. Another item due to stop and go travel, and stop signals and stop streets, represents a saving of about a quarter of a cent per vehicle-mile, the exact figure being 0.24 cents. The accident savings per vehicle mile in the use of freeways as compared to travel on surface streets, according to this report, was 56/100ths of a cent.

So, if we add those three items, we get 1.13 cents per vehicle-mile savings in travel on the freeway as opposed to travel on the surface street, based on the figures developed in this report by the City of Los Angeles.

There is also the question of whether travel time savings should be included in benefits. There seems to be a difference of opinion. There seems to be complete agreement that allowance should be made for time savings in the operation of commercial vehicles; but whether or not there should be a time savings allowance on the operation of passenger cars seems to be questionable. Where time saving is included for the operation of passenger cars on freeways over operation on conventional type city streets, the value is given at 3.73 cents per vehicle mile. That time savings could have quite an influence on the size of the benefits that are computed for any given freeway.

Burch. —I am sure that we have all noted the fact that traffic does not always choose to operate in the most efficient manner, dollar-wise.

We remember Trueblood's diversion curve in which it was found that time saving was the major determining factor in choice of routes, and yet as we know and as Claffey has mentioned here, fuel saving related to distance in terms of dollars is the overriding economic factor. So that the composite driver or the average driver does not seem to be as much concerned with this fuel saving efficiency as he is in the saving of time, even though he may have to go a longer distance at higher operating cost.

Cherniack. —In New York we have made a rough study on the basis of these evaluations, and they indicate that, at the present time, the motorist apparently values time at somewhere between three and five cents. So apparently the motorist does use calculus by intuition. Apparently his logic checks the figures that Van Riper just brought out.

Saal. —I want to make only one comment, that is that Claffey here talked a lot about Public Roads. The inference was that we in the Bureau were doing everything. I want to say that in all this work we are doing, the states are cooperating in a large part of it through the accident studies. We are cooperating in it with the universities and with the state highway departments.

Burch. —Thank you. Of course, that is a chronic situation. People with the states know that when such work is done, the states do much of it.

Newcomb: —I had one question about the assignment formula. Take a simple case such as a new bridge across the Potomac in Washington, D.C. When I first came here there were two inadequate bridges and consequently the suburban residential or bedroom area was Chevy Chase. Then the bridge was built across the Potomac, which resulted in rapid residential expansion. The new traffic to Arlington went less than one-third as far as

the old traffic. This was a tremendous saving as a result of this new bridge at Georgetown. But I don't see any element in this formula where this saving would be revealed.

Claffey. —That formula only compares one route with another. We have all of the information available.

Newcomb. —In other words, if the new facility does save a great deal, in distance—by opening up a new area, the formula wouldn't reveal it?

Claffey. —That formula would not.

Pendleton. —Dr. Claffey, in your comparison of toll roads with alternate routes, what data, in addition to the fuel and other operating expenses did you collect, such as time or inconvenience of driving, that might be later used in making this comparison?

Claffey. —We recorded the fuel consumption, the distance and the total time. We had an electronic device that automatically gave us the speed at every second, and this is stamped out on a tape. The tapes have not been analyzed yet.

But we do have, in addition to fuel data on time and distance, the speed at each second. Also, we made a manual note as to the way everything affected our vehicle as we moved along, stopped at a stop light, trailed a vehicle on a two-lane road unable to pass, access points, etc.

St. Clair. —That would include passing maneuvers on two-lane roads?

Claffey. —That is right.

Grant. —I would like to call attention to the fact that Claffey takes a different viewpoint from the AASHO report with regard to treatment of depreciation on passenger vehicles, and to record the fact that I am in agreement with Professor Claffey on this.

Burch. —Mr. Hoch made a comment with respect to a certain report, and he tells me he has some information about the availability of that report.

Hoch. —There will be a report on the information referred to previously with a much fuller description. This should be out about November 1959, and it is Report No. 36520, "Accident Experience, Arterials Versus Expressways." It can be obtained by writing the Library, Chicago Area Transportation Study, 4812 W. Madison St., Chicago

St. Clair. —I have some observations referring particularly to Professor Grant's treatment (Session 3) of the items of cost, particularly of the interest rate and the depreciation term.

It would seem in a sense that if we have for example, the geometric dimensions of certain kinds of highways as determined by design engineers based on highway capacity research as being the designs most useful to accommodate traffic of a given magnitude; and we have found by the testimony of toll roads that the motorist and the truck operator are willing to pay the price of having such roads, then we have, in a sense, an economic analysis on the basis of supply and demand.

I think probably the reply to that would be that if you subjected such a road to an economic analysis by the rate-of-return or benefit-cost method you would get a very favorable answer, and that the ones that would not meet those specifications would get an unfavorable answer. I am willing to accept that, with qualification about as follows:

We have detached the depreciation rate, or rate of amortization, from any connection with the expected life of the investment and materially shortened it to a perhaps rather indefinite number of years.

Now, if one analyzer were the owner of an oil well, another the owner of a steel mill and a third a railroad president, it seems likely that the oil man would have a shorter depletion allowance than the owner of the steel mill, and the latter would probably have a shorter one than the railroad president. In other words, I think we have something that is rather unstable.

On the interest rates, although Professor Grant seemed to settle on 7 percent as being something to work with, nevertheless we heard figures of around 10 to 18

percent after taxes, or something around double these rates before taxes. That, it seems to me, introduces another unstable element.

I feel that this widening of the brackets on both of these items introduces a considerable element of instability or uncertainity, into the economic analysis. Perhaps it is a good idea for us to be uncertain for a while and to hope that we can settle down.

Evaluation of Unit Cost of Time and Strain-and-Discomfort Cost of Non-Uniform Driving

G. P. St. CLAIR, and NATHAN LIEDER, Bureau of Public Roads

●THE EXCHANGE of ideas between Nathan Cherniack and myself left us both with the hope that a development more practicable and at the same time more rational in theory than either of us had contrived would point to a valid solution for the problem of time and impedance costs.

It should be made plain that here we are dealing with costs which are experienced primarily by the passenger-car driver; and which, although objective and tangible enough in their impact upon him, are subjective in the values that he puts on them. These subjectively-valued costs are experienced by the driver of a commercial vehicle—indeed by anyone who operates or occupies any kind of vehicle—but the costs of commercial-vehicle time, involving wages, labor relations, business opportunities afforded or denied, and like factors, are so differently oriented that it seems best to treat them as an entirely different problem.

There was an inclination in earlier years to regard uncompensated passenger-car-driver time as free time, and to take no account of it in the reckoning of user benefits. The experience of the toll facilities tends to contradict this line of reasoning and has demonstrated the fact that the desire of the motorist for time savings is the dominant element in the demand for high-speed limited-access service. But it became clear that time-savings alone do not fully account for this extraordinary demand—the motorist is buying a package of advantages in paying, by tolls or taxes, for high-speed expressways. Studies of expressway origins and destinations have shown that a substantial percentage of motorists will sacrifice time-savings to gain the free-flowing traffic that the high-grade facility affords (1, 2).

Cherniack's earlier scheme was to set up a cost item for each identifiable cost (or cost-savings) in the package of expressway benefits (running costs, running time, waiting time, the cost of right turns, left turns, passing maneuvers, etc.) and to rely on the accumulation of instances occurring in the presence of toll charges to provide a statistical solution for the unit values of this collection of unknowns. The general method still offers great promise; but it became evident fairly early that a greatly needed economy would be gained by reducing the number of variables, or unknowns to be solved for. One method of doing this is to solve for some of the cost elements independently, so that they will enter as known terms, rather than unknown, in the statistical equations. This can be done with running costs (gasoline, tire wear, etc.) and, somewhat less easily and directly, with accident costs.

There remain the cost of time, or value of time-savings (subjectively appriased by the motorist) and a collection of other subjective cost evaluations, all of them linked with the package of advantages provided by the free-riding expressway, or more generally, with the difference in riding advantages afforded by any two trips subject to comparison. It is obvious that if a single attribute could be found that would act as surrogate for all the blessings of the free-flowing expressway that are associated with the reduction of strain, annoyance, or discomfort, the unknowns in the equation would be reduced to two: the cost of time and the cost of this special attribute.

At the time the authors were fumbling with these ideas, others were experimenting with the significance and practicability of measuring speed changes. Greenshields (3) in developing an index of the quality of traffic flow used the summation of speed changes

as the principal factor. Saal and others have used the measurement of speed changes as a tool in the study of vehicle performance under varying conditions of traffic and road.

Nearly all the factors that contribute to annoyance, discomfort, and nervous tension on a trip have their most direct and immediate effects in causing changes in speed (including reduction to zero speed). Sharp curves, steep grades, narrow roads, poor conditions of repair, left turns, right turns, stop signs and signals, passing maneuvers and many other items cause the motorist repeatedly to check his speed, to accelerate, to stop, to start, or, in other words, to depart from the condition of uniform speed which is the characteristic of a pleasant trip. The necessity for changing speed requires certain physical movements on the part of the driver and an increase of the attention he must pay to driving. On all occupants of the car acceleration or deceleration exerts forces that are proportional to the magnitudes of the speed changes. On this point Greenshields wrote as follows:

> ... It is not only slow speed but the range and the frequency of speed changes that annoy the driver and often cause him to seek a longer route that may take more time to travel .... It is reasonable to assume that the annoyance factor increases as the frequency and magnitude of speed changes increase. (3, p. 510)

Consideration of these facts led to the notion that the summation of speed changes on a trip might be used as a common denominator for the entire catalogue of impedances to uniform driving. This procedure would reduce the number of unknowns, or subjective factors, in the equation to two—the unit cost of time, to be measured in cents per minute, and the unit cost of the strain-discomfort factor, to be measured in cents per unit of speed change. The experimental work of Paul Claffey in measuring time and speed changes on toll roads and alternative routes, has been directed in part toward (a) testing the validity of the speed-change unit, and (b) determining reasonable average values of these two unknowns.

Claffey has stated informally that this summer's experience at 14 toll situations has caused him to question the adequacy of the speed-change unit as an index of the strain-discomfort factor, largely because it fails to take account of the annoyance caused by forced driving at reduced speeds on 2-lane highways, occasioned by slow-moving vehicles. There is also the case of prolonged stops, such as those at a red light, which involve a speed change at the beginning and at the end, but none during the duration. It is to be hoped the combination of time and speed change as subjective costs will be adequate to care for these two elements, but this cannot be counted on with assurance at this time.

THE EQUATION

Given a situation in which the number of motorists using a toll road, and the number using an alternative route for the same trip, are known or can be measured, the two requirements for a solution are: (a) that a valid equation of trip costs, including the two unknowns to be solved for, can be written; and (b) that a condition or situation can be found in which the trip costs on the toll road and its alternative route can be equated. If this can be done for a satisfactory number of cases, the group of equations can be subjected to a solution for the two unknowns by the method of least squares.

The equation of trip costs is as follows:

$$C = O + A + P + Tx + Dz \qquad (1)$$

in which

C = Total trip cost in cents;
O = Trip operating costs (mileage or running costs);
A = Accident costs (an expectancy term, based on the accident experience of the two classes of road);
P = Toll charge, if any (P for "Pay");
T = Time of trip in minutes;

x = Unit cost of time in cents per minute;
D = Number of speed-change units developed on the trip (the strain-discomfort term); and
z = Unit cost of speed changes in cents per unit of speed change.

Speed-change units have, of course, the dimensions of acceleration. In the 1958 summer tests in Maine and Pennsylvania speed changes were measured in miles per hour per 6-second interval.

Objections have been made to the procedure of setting up the unit value of time as applicable to the total time of trip, because of the logical conflict involved in equating the sum of a great many minute time-savings (such as a few seconds each) with the arithmetically equal sum of a much smaller number of much greater time-savings. It has been suggested that the conflict can be avoided by defining the quantity sought as the unit value of time-savings. This does not seem to avoid the conflict, which perhaps can only be evaded by a gentlemen's agreement not to accumulate huge sums of minute time-savings. In the actual working out of Eq. 1, however, the solution for the unit cost of time, x, will be dependent on observed values of time-savings on one alternative route as compared with another; and in actual applications to economic analysis this unit cost would be applied to time-savings rather than to total values of time of trip.

THE CONCEPT OF VARIABLE SUBJECTIVE APPRAISALS

Nearly all would agree that there is variation in the subjective appraisals that motorists put on the value or cost of time and of the strains and discomforts of non-uniform driving. For example, if the traffic between two points breaks 80/20 between a turnpike and an alternative route it is clear that those who pay the toll place a higher value on time-savings and on uninterrupted driving than do those who drive the less free-flowing alternative route. The toll charge tends to sort drivers into two classes; but it is reasonable to suppose that these appraisals range from very low to very high and group themselves about a mean value according to some statistical distribution. It is natural to assume that they are distributed normally, although there is something to be said for the assumption of a skewed distribution.

A normal distribution is characterized by two parameters, the mean $\bar{x}$, and the standard deviation σ . Since, in the trip-cost equation there are two subjective cost factors to evaluate, x and z, the number of unknowns to solve for increases to four, if one is to follow through with the assumption of a normal distribution of subjective appraisals.

Thus,

Time involves $\bar{x}$ and σ_x; strain-discomfort involves $\bar{z}$ and σ_z.

EQUATING TRIP COSTS AT THE MARGIN

The assumption of variable subjective costs makes it possible to equate trip costs for the two alternative routes. For, if the split is 80/20 in favor of the turnpike, and the toll is $1.00, that means that to 80 percent of those making the choice the advantages of the toll road are worth $1.00 or more; and to 20 percent these advantages are worth $1.00 or less. At a considerably higher toll, presumably, the traffic would break 50/50, and this toll would correspond with mean values of the subjective cost appraisals. Still higher tolls would provide 40/60, 30/70, and 20/80 distributions of the traffic. But note that, in the actual case, the trip-costs on the two routes are equal in the estimation of that group of motorists to whom the turnpike advantages are worth just one dollar. This group will break 50/50, the most trifling preference turning them to one or the other route.

Let us forget strain-discomfort for the moment and take the case where the only subjective cost item is the value of time. Let us denote as x_0 the value of time at the breakover point, and characterize by the subscripts 1 and 2, the costs on the toll-road and the alternative route. Equating costs,

$$O_1 + A_1 + P + T_1 x_o = O_2 + A_2 + T_2 x_o$$

$$x_o = \frac{(O_1 - O_2) + (A_1 - A_2) + P}{T_2 - T_1} \qquad (2)$$

$$= \frac{P - (O_2 - O_1) - (A_2 - A_1)}{T_2 - T_1}$$

Since the values of O and A are objective and therefore given, and the toll is known, the value of x_o is given by the data of the example. One more definition is necessary:

p_1 = The proportion of travelers using the preferred route.

For this single-variate case the equation relating to the mean value, $\bar{x}$, and the standard deviation, σ_x, can be readily derived by reference to the normal probability curve (Fig. 1). The proportion of motorists, p_1, using the preferred route is represented by the area under the curve to the right of the plotted value of x_o.

For any value, x_o, the area to the right of it can be expressed, as a proportion, by the integral—

$$p_1 = \int_{t=t_1}^{t=\infty} e^{-\frac{t^2}{2}}\, dt$$

in which

$$t = \frac{x}{\sigma_x}; \quad t_1 = \frac{x_o}{\sigma_x}$$

This formula for t is written for the case where $\bar{x}$ is put equal to zero. For the case where $\bar{x}$ has a positive finite value, the x-coordinate is shifted by replacing x with the expression, $x - \bar{x}$. For the value of t corresponding to the marginal or breakover values, p_1 and x_o, —

$$t_1 = \frac{x_o - \bar{x}}{\sigma_x}$$

The equation is then developed as follows:

$$x_o - \bar{x} = \sigma_x t_1$$

$$x_o = \bar{x} + \sigma_x t_1 \qquad (3)$$

The value of t_1 in any given case can be obtained by finding in the Table of Areas under the normal probability curve (see any standard text (5) in statistics) the value of t corresponding to the area value given by $p_1 - \frac{1}{2}$.

For any given toll situation the value of x_o would be obtained by solving Eq. 2. The value of t_1 would be obtained from the given value of p_1 by reference to the Table of Areas under the normal probability curve. From a series of toll situations a sufficient number of pairs of values of x_o and t_1 would be obtained to make possible a solution, by the method of least squares, for the value of $\bar{x}$, the average unit cost of time, and that of σ_x, the standard deviation of subjective appraisals about the mean value. The difficulty is that time is not the only thing that is paid for at the toll booths; and therefore such a solution is necessarily defective.

Figure 1 illustrates the solution for $\bar{x}$, the average subjective unit cost of time,

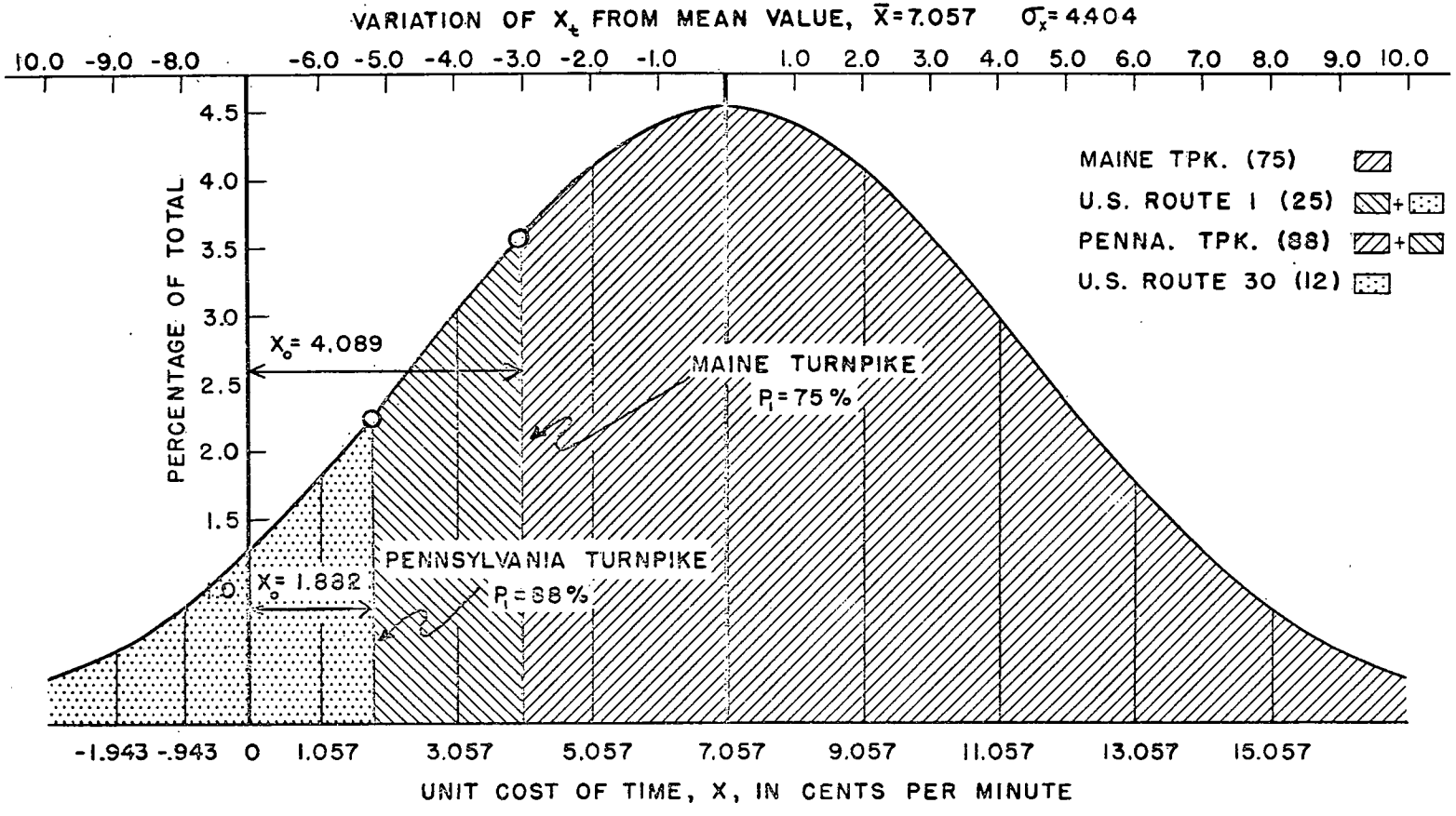

Figure 1. Solution for unit cost of time, assuming normal distribution of travelers' subjective evaluations and using results of Maine and Pennsylvania tests, 1958.

derived from the data obtained by Paul Claffey in the summer of 1958 from test runs on the Pennsylvania Turnpike and U S 30, and on the Maine Turnpike and U S 1. In this calculation the assumption was made that trip costs on the turnpike and the alternative route were equal except for the toll charge, P, and Tx, the cost of time. The percentages of motorists using the alternative routes were taken from the results of previous studies (4) which gave the ratios 75/25 for the Maine Turnpike and U S 1 (between Kittery and Portland) and 88/12 for the Pennsylvania Turnpike and U S 30 (between Philadelphia and Breezewood).

The terms of the solution gave values of x_0 (the appraised cost of time at the breakover point) of 4.089 cents per minute for the Maine Turnpike and 1.882 cents per minute for the Pennsylvania Turnpike. These points are plotted (Fig. 1) on the normal probability curve. The ordinates represent the proportions of motorists whose subjective appraisal of the value of time is equal to x as it takes different values along the abscissa of the chart, the class interval in the illustration being ½ cent. The cross-hatched area extending to the right of the point $x_0 = 4.089$ (Maine Turnpike) is 75 percent of the total area under the curve. The area in reverse cross-hatch extending from this point to the point $x_0 = 1.882$ (Pennsylvania Turnpike) is 13 percent of the area under the curve; so that the two areas combined equal 88 percent—the percentage of motorists using the Pennsylvania Turnpike. The remaining 12 percent of area, representing motorists preferring U S 30 is shown in dotted hatching. The two left-hand areas combined represent the 25 percent of motorists preferring U S 1 to the Maine Turnpike.

If 88 percent of motorists in the one case value time at 1.9 cents per minute or more, and 75 percent in the other case value time at 4.1 cents per minute or more, a solution satisfying both cases and postulating a 50/50 distribution of preferences will give a unit value of time considerably greater. When the normal probability curve is used the value is x = 7.057, with a standard deviation σ_x, equal to 4.404.

This very high value of the unit cost of time has to be deflated. If we assume that the effect of other cost items, such as the strain-discomfort factor, the motorists' appraisal of reduction in accident-cost hazard, and some slight difference in running costs, would have equal weight with time-savings, we may reduce the value by one-half to 3½ cents per minute, which is within shooting distance of the probabilities. The real point is that we have achieved a solution, such as it is, for the single-variate case of an assumed normal distribution of motorists' subjective appraisals of the unit cost of time.

BIVARIATE SOLUTION

No equation has yet been developed for the bivariate solution, where, in addition to the time-values, $\bar{x}$ and σ_x, we must solve for $\bar{z}$ and σ_z, the mean and standard-deviation values for the unit cost of speed change, the strain-discomfort factor. We have, however, experimented with a solution by trial-and-error or successive approximations, using the Maine-Pennsylvania data.

The principal instrument of this trial-and-error solution was the setting up of a table giving the ordinates of a bivariate distribution, assuming the two attributes concerned, x and z, to be independent of one another. For the purpose of generalization the class limits for both attributes were expressed as multiples of the standard deviation. An interval of 0.5σ was used in the calculation. Table 1 gives the bivariate distribution in abbreviated form, with a class interval of 1.0σ. The values tabulated are, in effect, the ordinates of a 3-dimensional surface of which values in the other two dimensions are the x-values (subjective unit cost of time) and the z-values (subjective cost of speed-change).

The Assumption of Independence

Since the two favorable attributes of expressways—time-savings and reduction of strain-discomfort—tend to go together it may be held that they are not independent, that is, that one is correlated with the other. If this were the case, or assumed to be the case, the equation for the solution would be complicated by the necessity to include

TABLE 1

BIVARIATE NORMAL DISTRIBUTION OF 1,000 INDIVIDUALS ACCORDING TO TWO INDEPENDENT ATTRIBUTES

Class Limits in Multiples of Standard Deviation, σ	$-\alpha$ to -3.0	-3.0 to -2.0	-2.0 to -1.0	-1.0 to 0.0	0.0 to 1.0	1.0 to 2.0	2.0 to 3.0	3.0 to α	Rim Totals
$-\alpha$ to -3.0	-	-	-	1	1	-	-	-	2
-3.0 to -2.0	-	1	3	7	7	3	1	-	22
-2.0 to -1.0	-	3	19	46	46	19	3	-	136
-1.0 to 0.0	1	7	46	116	116	46	7	1	340
0.0 to 1.0	1	7	46	116	116	46	7	1	340
1.0 to 2.0	-	3	19	46	46	19	3	-	136
2.0 to 3.0	-	1	3	7	7	3	1	-	22
3.0 to α	-	-	-	1	1	-	-	-	2
Rim Totals	2	22	136	340	340	136	22	2	1,000

in it an expression of the correlative relationship between the two attributes, which might, for example, be inverse. The assumption of independence of the two attributes has the advantage of relative simplicity.

There is, moreover, support for this assumption in both evidence and logic. Partial verification is found in the fact that a significant proportion of expressway users travel them at a sacrifice in loss of time. Conceptually, the independence of these two subjective attributes is attested to by the fact that they are psychologically very different. The value of time, stripped of irrelevant considerations, inheres only in the desirability of getting from point A to point B in a minimum of time. A motorist's subjective appraisal of the value of time is probably affected by (a) his economic and occupational status, (b) his personal characteristics, and (c) the nature of the particular trip, for example, vacation, home-to-work, or driving his wife to the maternity hospital. The reduction of strain, discomfort, and impatience, achieved by making it possible to drive at a uniform and uninterrupted speed, is an entirely different thing, both in motivation and in the nature of the satisfaction received, even though the same road characteristics produce both results. Thus there is no obvious reason why motorists' subjective evaluations of the strain-discomfort factor should vary either as a direct or as an inverse function of their subjective evaluations of time.

Solution Procedure Illustrated

The guessing procedure in this operation consisted of selecting a given set of values of the four unknowns, $\bar{x}$, σ_x, $\bar{z}$, and σ_z; and then computing the trip costs on the two turnpikes and their alternative routes for the values of x and z given by each cell in the bivariate distribution, or by a sufficient number of cells so that the percentage choosing each route was definitely determined. The computation for a single cell is illustrated in Table 2. The motorists comprising this cell, who value time at 2.375 cents per minute and relief from strain-discomfort at 0.015 cents per speed-change unit, would choose U S 1 in preference to the Maine Turnpike, but they would choose the Pennsylvania Turnpike in preference to U S 30.

After a considerable number of trials it was found that the values $\bar{x} = 3.0$ and $\bar{z} = 0.06$ gave a range of values in percentage turnpike choice close to the 75 percent for the Maine Turnpike and 88 percent for the Pennsylvania Turnpike that was the object of the quest. By varying the values σ_x and σ_z an area was delineated in which the percentages varied from 74/87 to 77/89. At this point it was decided that a qualified success had been achieved.

Figure 2 shows, in the form of a 3-dimensional surface in isometric projection, the results of the calculation for the following values of the four variables, or unknowns: $\bar{x} = 3.0$; $\sigma_x = 0.5$ (cents per minute); and $\bar{z} = 0.06$; $\sigma_z = 0.06$ (cents per speed-change unit).

TABLE 2

EXAMPLE OF CALCULATION OF ROUTE CHOICES

1. Values of mean and standard deviation
   $\bar{x} = 3.0\,\sigma_x = 0.5$ (cents per minute)
   $\bar{z} = 0.06\,\sigma_z = 0.06$ (cents per speed-change unit)
2. Coordinates of cell chosen for calculation
   Class interval of σ_x: -1.5 to -1.0
   x-values:
   Class interval: 2.25 to 2.50
   Midpoint: 2.375
   Class interval of σ_z: -1.0 to -0.5
   z-values:
   Class interval: 0.000 to 0.030
   Midpoint: 0.015
3. Calculation

Item	Maine		Pennsylvania	
	US 1	Turnpike	US 30	Turnpike
a. Time of trip, minutes	69.3	46.4	260.4	169.8
b. Total speed-change units	1,519	140	6,968	448
c. Time cost in cents (a x 2.375)	165	110	618	403
d. Speed-change costs, cents (b x 0.015)	22	2	105	7
e. Toll charge on turnpike, cents	-	90	-	170
f. Total cost of trip, cents	187	202	723	580
g. Choice of motorists in this cell	X	-	-	X

This particular solution gave turnpike ratios of 77/89 rather than the desired value, 75/88. It was chosen because the values of σ were such that multiples thereof could be plotted conveniently on coordinate lines of the isometric chart from which this drawing was traced. The vertical ordinates represent the number of motorists (out of 10,000) within a given cell of x, z values. The class intervals are 0.25 on the x-scale (time in cents per minute) and 0.03 on the z-scale (strain-discomfort factor in cents per speed-change unit). The surface is outlined by a sort of basket of profile curves, which are normal probability curves plotted in isometric projection.

The volume outlined in heavy full lines (Fig. 2) includes 77 percent of the volume, or number of motorists; and represents the number who would choose the Maine Turnpike in preference to US 1. The segment in broken line represents the additional 12 percent of motorists who would perfer the Pennsylvania Turnpike to US 30. Because of the discrete character of calculations using class intervals it was found difficult to make a satisfactory portrayal of this middle segment. The segment in light full line represents the 11 percent of motorists who would prefer US 30 to the Pennsylvania Turnpike. The light-line and broken-line segments combined represent the 23 percent who would choose US 1 in preference to the Maine Turnpike.

The values of x, the subjective appraisal of unit cost of time, are all positive and contained neatly between the values 1.00 and 5.00 cents per minute. The values of z, on the other hand, spill over rather badly into the negative quadrant. This fact signalizes our partial failure in this experiment; and at the same time is perhaps indicative of the relative accuracy with which the value of time and the value of that other factor can be measured at this stage. A skewed distribution, defined so as to exclude negative values, might prove successful. We are in hopes, however, that with a larger number of observations, an acceptable solution using the bivariate normal distribution will emerge.

In summary, we have a notion here that does not quite prove out. The essential germ of the idea is that any solution for the unit value of time and/or the strain-discomfort factor should take account, mathematically, of the variation in individual subjective appraisals of those values. It is not an easy thing to do, and this experiment is a first faltering step in that direction.

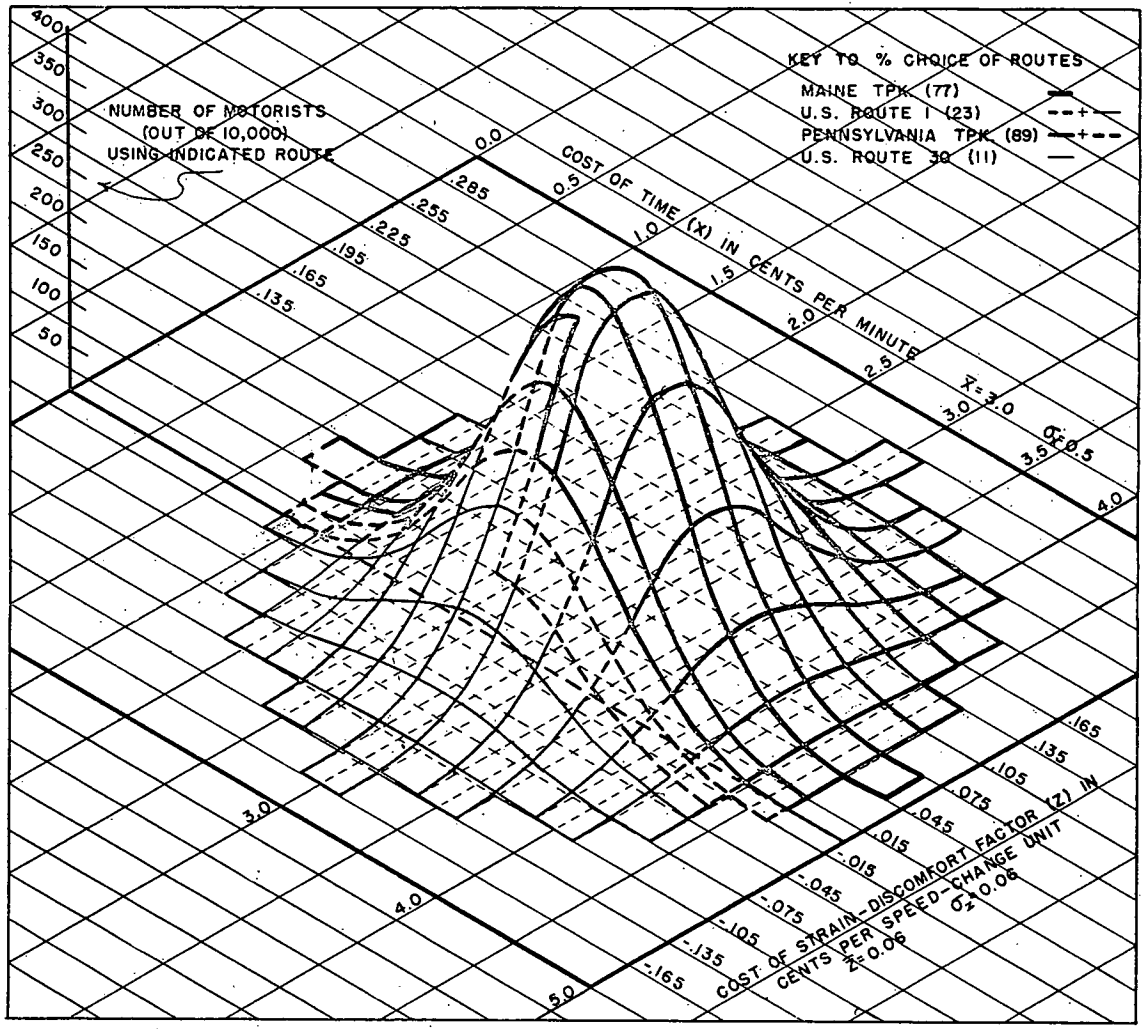

Figure 2. Illustrating bivariate normal distribution of subjective cost appraisals.

SINGLE-VARIATE SOLUTION

For comparative purposes the single-variate solution for mean value, $\bar{x}$, and standard deviation, σ_x, of motorists' subjective appraisals of unit cost of time, based on observations made in 1958, is as follows:

The experimental data on which this trial solution is based were, as previously mentioned, collected by Paul J. Claffey in the summer of 1958. Test runs were made on the Maine Turnpike and US 1 between common terminal points in Kittery and in Portland. Similar runs were made on the Pennsylvania Turnpike and US 30, between common terminal points in Philadelphia and in Breezewood. In each of the states, four pairs of trips were made (two in each direction), during which, in addition to the trip-time record, speedometer readings were made at 6-sec intervals. The speed changes thus recorded were tied in with their causes, such as red lights, restricted speed zones, turns, and passing maneuvers, by means of a log record. The speed-change data are not pertinent to this illustrative solution and are therefore not shown.

No O-D studies were made in connection with these test runs to determine the percentages of total travel between the termini that used the turnpike and the alternative routes. Instead, the reported results of origin-destination surveys made a few years previous were used (4). These studies indicated a 75/25 distribution of choice between the Maine Turnpike and US 1 on the trip between Kittery and Portland; and an 88/12 distribution between the Pennsylvania Turnpike and US 30 on the trip between Philadelphia and Breezewood.

The data used in the statistical solution for $\bar{x}$ and σ_x are given in Table 3. The eight observations are not entirely independent, since the proportion using the turnpike, p_1, varies only as between the Pennsylvania and the Maine situations. If it were practicable to have test runs on a turnpike and its alternative made at different times of day, days of the week, and seasons of the year, and to make O-D surveys that would supply values of p_1 applicable to each particular pair of trips, then the individual observations for a single trunpike situation would have greater independence, which would enhance the validity of the statistical solution. The test runs made under Claffey's direction in the summer of 1959 were accompanied by approximately simultaneous O-D studies conducted by the state highway departments. Values of p_1 (proportion using turnpike) will thus be closely tied in with the time of conduct of the test runs.

The time differences do show considerable variation, from 83 to 96 minutes on the Pennsylvania Turnpike compared with US 30, and 16 to 29 minutes on the Maine Turnpike compared with US 1. No objective or measured costs other than the toll charge enter into the solution; and the z term, the strain-discomfort factor, was neglected in order to reduce the problem to that of a single-variate solution.

The normal equations and the results of the solution by the method of least squares are given in the lower part of Table 3. For $\bar{x}$, the mean value of motorists' subjective appraisals of the unit cost of time, the solution gives the value, 7.057 cents per minute. The standard deviation, σ_x, of subjective appraisals about their mean value turns out to be 4.404 cents per minute. Since two standard deviations embrace only 95 percent of the observations, it is evident that the extreme low values of x in this solution spill over into the negative quadrant, as was the case with the bivariate solution. The possibility of substituting a skewed distribution (such as the logarithmic normal) was investigated briefly in connection with the bivariate solution. This procedure gave reasonable values of $\bar{x}$ and $\bar{z}$, but produced inordinately large values of the standard deviations, when expressed in real rather than logarithmic figures.

A similar single-variate solution was calculated for $\bar{z}$ and σ_z, the mean value and standard deviation of the strain-discomfort factor, on the assumption that this factor, rather than the value of time, was the quantity to be solved for. This solution gave the value of $\bar{z}$ as 0.3097 cents per speed-change unit, and the value of σ_z as 0.2304.

These solutions, based on somewhat disparate data from only two turnpike situations, are not of great significance in themselves. They indicate however, as does the bivariate trial-and-error solution, that, with a respectable body of data taken at turnpike situations, reasonable solutions for the unit value of time and of the strain-discomfort factor, based on the assumption of a normal (or perhaps skewed normal) distribution of subjective appraisals of these values, may be forthcoming.

TABLE 3

SINGLE-VARIATE SOLUTION ALTERNATIVE ROUTES IN 1958

State and Observation No.	Difference in Objective costs[1] P (cents)	Time Difference, $T_2 - T_1$ (min)	$\frac{P}{T_2 - T_1} = x_o$ (cents min)	Proportion Using Turnpike, p_1	$p_1 - \frac{1}{2}$	$t = \frac{x_o - \bar{x}}{\sigma_x}$
Pa. 1	170	95.7	1.776	0.88	0.38	1.175
2	170	93.9	1.810	0.88	0.38	1.175
3	170	83.0	2.048	0.88	0.38	1.175
4	170	89.5	1.899	0.88	0.38	1.175
Me. 5	90	29.0	3.103	0.75	0.25	0.674
6	90	16.4	5.488	0.75	0.25	0.674
7	90	23.5	3.830	0.75	0.25	0.674
8	90	22.9	3.930	0.75	0.25	0.674
Total	-	-	23.884	-	-	7.396

Equation:

$$x_o = \bar{x} + \sigma_x t$$

Normal equations:

$$\Sigma x_o = N\bar{x} + \sigma_x \Sigma t$$

$$\Sigma x_o t = \bar{x}\Sigma t + \sigma_x \Sigma t^2$$

Summations:

$$N = 8$$

$$\Sigma x_o = 23.884 \quad \Sigma t = 7.396$$

$$\Sigma x_o t = 19.871$$

$$\Sigma t^2 = 7.340$$

$$23.884 = 8.000\bar{x} + 7.396\,\sigma_x$$

$$19.871 = 7.396\bar{x} + 7.340\,\sigma_x$$

Solution: $\bar{x} = 7.057$ $\sigma_x = 4.404$ (cents per minute)

[1]Toll charge only.

ACKNOWLEDGMENT

The statistical work on this study was handled by the co-author, Nathan Lieder, Statistician. The calculations were performed by Bonnie Morrison, Statistical Assistant.

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Discussion

Burch. —Mr. St. Clair, it is apparent that you and your associates have done a lot of work to assign values to something which has heretofore been an intangible, and that you have made considerable progess in doing so.

Hoch. —I would like to say that I think this is a giant step, rather than a faltering step. As a further step, I think that you might well try a logarithmic normal distribution.

St. Clair. —We tried one and it looked like a promising thing because with the same parameters, you get a skewed distribution but it did not, in the brief trial we made, produce a satisfactory solution.

Hoch. —The reasons for it are that you would get negative values, and it might approximate the income distribution.

St. Clair. — You mean the income distribution of the respondents, of the people.

Hoch. —Yes, or just in the United States economy.

Grant. —I have a technical statistical comment and one question. There seems to be here need for another sigma, another standard deviation, and this is the standard deviation of vehicle running cost. I mean, some people have large old cars that make only 10 mi per gal, and some have small foreign cars that get 35.

I am not quite clear what this would do if it were included. One thing, of course, it would do, would be to give you a four-dimensional picture that you could not flash on a screen. This seems to me to be an element that belongs in the equation. There is that variability along with these other variabilities. The fellow that has the low mileage car has a great advantage in saving distance, let's say, on the Turnpike, if it does save distance, that is miles per gallon.

My question is, you are rather out on the extremes of preference here in the Maine and Pennsylvania cases. Do you have any unpopular turnpikes like West Virginia, or something like that, that you can operate on?

Claffey. —We studied all of them, except the West Virginia and the Virginia Turnpike, Massachusetts Turnpike and those in Connecticut. We studied all the others and I do not know which of them might be considered poor or rich. We have not analyzed the data.

Lindman. —With regard to turnpikes, you might say that the West Virginia Turnpike would not be comparable to the others. With regard to the tax implications of this (and I assume that this work is being done with the objective of getting at the problem of financing highways) I am wondering if it leads to the conclusion that a tax for highways related to income, rather than a tax related to benefits of fuel consumed or some other such measure, is indicated.

St. Clair. —The primary objective in this study was to find a means of obtaining average values of motorists' subjective appraisals of cost of time and of non-uniform driving. This trail led us to the concept of statistical variations of such appraisals about their mean values. This conceptis a necessary tool in the tentative solution we have developed. To us it is solely a matter of evaluating these benefits with reasonable accuracy. The idea that motorists' subjective appraisals might be correlated with income status may have long-run implications, but there is no present plan to use this idea in our tax-allocation analysis.

Jorgensen. —With reference to the Maine and Pennsylvania Turnpike data, I would like to know if account is taken of the fact that we probably have a new generation of drivers that don't even know there is a US 1 or US 30. I don't understand this phase of the analysis. I assume that it is based on the assumption that people do know there is some other way to go from Portland to Boston than by the Turnpike, for example, I think there are a lot of people who start out for Portland, Maine, and assume that there is just one way to go, that is via the Turnpike.

St. Clair. —Mr. Claffey, I believe you more or less take the attitude that your testing should be done with the local people?

Claffey. —This last summer we made a more extensive study than we made last year. Not only did we use the vehicle data from the electronic device, but we also had O-D studies made. These O-D studies were made to pick up the people from an origin city at the beginning of each of the study locations, so that the people we are concerned with are people that live at one end of a toll road and presumably would be able to make a rational decision as to which route they would prefer. For example, one location in Kansas was between Topeka and Wichita. The people of Topeka would be the ones that were interviewed. Everyone who passed was interviewed, but they were asked to give their addresses. I plan to use only those people with residences in that initial point.

Jorgensen. —It strikes me that in most places you do have a situation where people, even residents in Boston, are accustomed to the idea of only one way to get to Maine, and that is on the turnpike.

Saal. —Mr. Chairman, just to clarify the discussion, the first two studies we made in 1958 were the turnpikes in Pennsylvania and Maine. We found we had to revise our procedures. We were using O-D data of 8 or 10 years ago. The sections selected were too long, and could not tie down the trip data, from Breezewood to Philadelphia, for example, and there was too much variation. In Maine it was somewhat better.

So we realized that we did not have very good cases. That is the reason we studied the 14 cases this year, very carefully selecting the sections so we could get the data we wanted, and so we could get fresh O-D information.

I think the data we got in 1959 should begin to answer the question.

Pendleton. —I have a comment concerning Mr. Claffey's misgivings about the speed-change unit with respect to sustained slow speeds and long stops at traffic signals. Both of these would be picked up in your time variable, so it does not make much difference, if you get the whole picture.

On Mr. Lindman's question, it seems to me that this sort of analysis and evaluation is fully as valuable, if not more so, for highway planning than it is for the financing function, and I think it should stand or fall on that, even more than on the question of whether it contributes to how much we should charge.

Gardner. —Did this O-D study get data on the type of travel? Isn't the type of travel significant in the picture? I am thinking of the business trip versus a vacation trip.

Claffey. —Yes, we asked everyone the question of the purpose of their trip. I do not know just how we will treat the data, but we have it classed in six different purposes.

Moskowitz. —Have you tried to see what this would do to the problem of variable time values that must be placed on people where they fall in the 30 percent portion of the assignment (diversion) curve?

St. Clair. —We have these two variables, and we assume that there is not one value but a distribution of values.

Moskowitz. —Then the thing to do would be to use the distribution of values, if you used a percent assignment curve wouldn't it?

St. Clair. —I believe that would be the rigorous method, although it would be more simple to use the mean value as determined. We have not tried any applications because we regard it as dubious right now.

Moskowitz. —I agree with Mr. Hoch that this is a terrific step forward in determining objectively what value auto drivers place on time.

California has been forced to accept but one value instead of a distribution of values. The value we have been using is not arbitrary. It is the amount actually paid by motorists who drove at the average "free choice" speeds prevailing at the time the value was established. It is well known that the cost per mile of operating a car rises as the speed increases. By equating the excess cost of driving at 53 mph against the

time saved by driving at that speed instead of 53 less a differential, a value of 2.6 cents per minute was calculated (a curve showing cost per mile as ordinate and minutes per mile as abscissa was drawn. The slope of this curve at any point is the cost of time saved by driving at that speed. At 53 mph, the slope is 2.6 cents per minute, using unit costs in the 1952 AASHO Informational Report). At present speeds and present mileage costs, the slope might come out so much higher that we would be afraid to use it.

While it may be true that the motorist did not know how much he was paying for each minute, and that this kind of time may be different from the time lost sitting in a traffic jam, this approach at least is based on some fact instead of all opinion, and was resorted to in face of the necessity to assign a dollar value to the determinable benefits of time savings.

SESSION FIVE

Friday, September 18, at 1:00 P.M.

DETERMINATION AND MEASUREMENT OF EFFECTS OF HIGHWAY IMPROVEMENTS ON OTHERS THAN DIRECT USERS OF THE HIGHWAYS

WILLIAM ADKINS, Texas Transportation Institute, Texas A & M College System, Presiding

Highways as an Instrument of Economic and Social Change

ROBERT G. HENNES, Professor of Civil Engineering, University of Washington

● PROGRESS SEEMS to be inextricably infused with the process of evolution from the primitive to the complex. Transportation is a conspicuous factor in this process: from the subsistence farm to the supermarket is a development brought about largely by the exchange of commodities through transportation. The comprehension of modern commerce, and the transportation upon which it depends, presents a far greater challenge to the intellect than does the food-gathering activity of some primitive tribe. These challenges can be coped with only by simplifying a situation by ignoring all but the dominant factors. Then we are able to formulate relationships between the chief causes of the observed effects, to establish models, and to predict the nature and often the magnitude of the consequences of a series of actions. The ability to quantify is deeply imbedded in technology; it is responsible for much material accomplishment; it is a wholly admirable achievement of our times. But the trick in this technique is the simplification of the initial problem; if in the course of time some factors, originally trivial, grow in importance until they exercise a controlling influence on consequences, the conclusions will be erroneous, and the methods inadequate.

In retrospect the engineer of fifty or seventy-five years ago seems to have enjoyed far greater latitude in decision-making than his modern counterpart permits himself to have. Ira Baker's "Treatise on Roads and Pavements," first published in 1903, was still extant in its later editions during the road building boom of the 1920's, but it is more in tune with the circumstances of the present era. Baker wrote before the automobile came to dominate the scene. Baker's engineer actually did view highways "as an instrument of economic and social change." Good roads permitted the farmer to participate more fully in social and political activities. Good roads brought his children closer to school and his crops closer to market. The value of fuel and time consumed in vehicle operation (the usual "user benefits") were not in themselves significant factors. For the hay-burning prime-mover, fuel was a fixed cost — not a variable cost. So also with the wagon or buggy, which stood idle in the barnyard when it was not on the road. On the whole, even the alternate value of the farmer's time was negligible, because crops were hauled after the work of production was complete, and personal travel was either after hours or combined with other trip purposes. The city dweller paved his streets to keep his feet out of the mud, not to reduce the cost of

vehicle operation. Pavements made urban living more attractive, and so contributed to the urbanization of society.

But these social objectives had little to do with the pressure for better roads which automobile owners exerted after World War I. The existing rural highways were paved primarily to improve vehicle operating conditions, and the car owners were willing to pay the full marginal costs of these improvements. Presumably, their willingness to pay the costs was predicated on the assumption that the benefits they received outweighed the charges that they incurred. In such a situation the ratio of benefits to costs was the ratio of user benefits to user charges, and this ratio constituted a logical determinant of project acceptability. Road improvement still did provide social benefits, but these did not motivate the road-building boom and they were ignored in the shadow of traffic-minded good roads associations and automobile clubs.

As the good roads movement reached substantial proportions engineers tended to abandon the intuitive judgments that had formed the basis for policy decisions during a more primitive road-building era. This transition in professional methods took place for two reasons. First, the engineer or administrator must find refuge in some sort of objective measurements whenever political pressures inflict personal penalities for unpopular, undocumented decisions. Second, the magnitude of road-building activity multiplied ten times during the first quarter-century. Expansion on such a scale induces a shortage of professional talent. Decisions must be delegated to subordinates, who must be guided by definite standards and who must follow work patterns susceptible of review. The ratio of measurable user benefits to measurable costs provides an ideal professional tool in the circumstances just described. The most readily measured user benefit is the reduction of vehicle operating cost, and this procedure becomes even more plausible if value is placed upon time savings. Of course one may conjecture that even in the 1920's motorists desired pavements more for their own comfort and convenience than to save gasoline or time; but there still should be a good correlation between the two sets of factors, and if some scale differences remained error was inconsequential while there was a perpetual shortage of funds for building all the roads that had favorable benefit-cost ratios.

Actually, operating in that climate the engineer has had two principal questions to answer: where does the motorist want to go, and can such a road be built at a justifiable expense? Benefit-cost ratio was developed to provide a methodical solution to the second question, and in the case of the first question another mechanistic device was contrived to circumvent the need for exercising intuitive (and hence fallible) professional judgment. This was the origin-destination survey.

Taken together, these two tools are admirably adapted to the task of undertaking a large-scale system of road improvements wholly for the benefit of the users of the facility. The experience which led to the formulation and adoption of these techniques was experience acquired, for the most part, between the wars when American engineers were completing the job of taking over a pre-existing system of roads and streets, and making it over for the use of the motor vehicle. These same tools would not have been equally valuable in the horse-and-buggy days of Ira Baker, when vehicle operating costs were a less significant factor in determining the need for road improvement.

The question might well be raised at this point whether the combination of O-D surveys and B-C ratios is still sufficient for the present purposes; that is, whether the present program of expressway construction represents a continuation of the interbella period of road construction, or whether it may involve a return, in part, to the road-building climate of fifty years ago. It is noteworthy that the pressure for local road improvements once more comes principally from community organizations and chambers of commerce; the surviving good roads organizations and the automobile clubs are less vehement advocates for bigger programs and are more concerned about paying for them. Without too much exaggeration one might speculate that the job of renovating yesterday's roads for the automobile has been finished, and that tomorrow's expressways have consequences for the community and property owner as well as for the motorist. This returning recognition of the social importance of highway improvement is not just another cyclical swing, but rather a return to fundamental values after a temporary lapse caused by the concentration of attention on the vehicle. The anticipated growth of population

is in itself sufficient assurance of this. Meier (1) predicts that eventually 70 to 90 percent of the population will need to be urbanized. He anticipates the development of super-cities, with almost continuous urbanism extending for hundreds of miles. Doubtless the megapolis will require new and special forms of transportation, but the urban expressways seem to be at least a transitional prerequisite to the development of these complex assemblages of central and satellite cities. Under such circumstances the expressway acts as a catalyst – bringing about reactions much more important than itself, social changes which might make the expressway obsolete eventually.

Garrison has studied in some detail the impact of highway improvement on various elements of the economic structure of the community; these highway-induced changes are dynamic aspects of the urbanization process. In his most recent work (2) he reports sample studies of fundamental aspects of the geographical organization of economic life, emphasizing the influence of highway change. An interesting example, selected for the quality of data, dealt with the utilization of physicians' services, as affected by transportation. Improvement in access induces changes in the location of physicians, it confers monetary benefits on physicians, and it gives patients more medical service at lower unit cost. He also examines the spatial arrangement of business establishments and the sensitivity of existing arrangements to highway improvements. Some types of business tend to cluster; others tend to string out along an arterial strip; still others are less selective in this regard. The channelization of larger percentages of total traffic into expressways changes the spacing and size of these nuclei, it strongly affects arterial-strip development. The development of expressway systems triggers a whole set of interactions which determine, in part, the character and the growth-potential of urban areas.

Some of the internal stresses, or tendencies, which await release or which are stimulated into activity as transportation improves, have been discussed by Horwood (3). He notes that while the scale of activity in central business districts has held steady through recent years, on a per capita basis there has been some decrease. This has been more evident in retail sales than in office space. He finds that the core of the central business district is changing from a retail-oriented complex to an office-oriented complex. By and large, he states, the absolute gain in the office labor force, as determined by space change, has more than offset the loss in retail sales employees. His most significant deduction is that intercity transportation improvement will have a greater impact on the CBD than improvement in intracity transportation. Regional capitals will experience more CBD growth than will the lesser cities in their hinterland, due to the continual formation and concentration of new activities in the CBD which require central linkages.

The collection of evidence of the highway influence on business activity and land values has been going on in all parts of the country during recent years. The motivation of this research is evidence of a growing realization of the importance of these highway-induced changes in off-highway activity. It is of more than passing interest that many, perhaps most, of these studies were initiated to allay the fears of communities or economic groups that specific highway changes would adversely affect land values or the level of business activity. It is only natural that these people should differentiate between the "negative benefits" which they fear might be imposed upon them as owners of land or businesses, and the "positive benefits" which they might expect to receive as highway users. Reduced taxation through lowered valuations is not recognized as adequate compensation in such instances. However, if distinguishable injury can be caused by highway changes, distinguishable benefits should also be possible.

If social and other non-user benefits can result from highway improvement, should such benefits be considered in the justification of highway improvement? From a practical standpoint a compelling reason for the consideration of non-vehicular benefits lies in their influence on highway policy. As a matter of historical record, current interest in economic impact originated in the political pressures exerted by communities fearing the economic effects of being by-passed. The selection of major bridge as freeway locations is approved, rejected or postponed through the influence, in part, of local pressure groups. If, in reality, location and investment decisions are to be importantly influenced by consideration of non-user benefits it is most unrealistic to omit such

benefits from consideration in computing a benefit-cost ratio or the rate of return on the investment.

The larger considerations of the national, and local, interest in the long run, lead to the same conclusion. The prospect of the great urbanized areas which are to come, and in which the standard of living will depend upon efficient transportation under most difficult conditions, should compel recognition of social objectives in setting highway policy.

Policy decisions which include consideration of social benefits and social costs will not necessarily agree with policy decision that considered only vehicular benefits and highway costs. It is important that highway users should not pay the entire cost of improvements which are built differently than traffic considerations alone would require. This is true for reasons of equity; it is also expedient. Since local pressures are significant factors in the implementation of policy, it is desirable that these local pressures be subject to the realistic weighing of cost against benefit. This is not possible where benefits come free. In order to achieve some sort of proper balance of power between conflicting pressure groups it is desirable that each group should have to weigh its share of the cost of the facility against its anticipated benefit.

Whether such a concept is practical or not becomes a relevent question. If non-vehicular benefits can be measured, there are various devices by which corresponding charges against the beneficiaries can be collected. Benefits to the general public are, of course, diffused to the point where they are best charged against the general funds of the appropriate community, state or nation. A bridge might, for example, create a large new residential area at one portal, while its effect at the other end would be to raise the general economic level of the community through increased retail trade. It would be appropriate to recognize the increase in land value by an assessment, while the charge against the community at the other end could be met by an increase in the mileage.

If the Interstate System is found to confer large non-vehicular benefits on property owners and communities along its route a similar disposition of tax responsibility would seem to call for the imposition of property taxes by the Federal government. However, it would be possible to accomplish comparable results by other means. If the monetary cost were appropriate to the findings of responsibility, for example, the cost of interchanges could become the responsibility of local government. Intersections of interstate routes would be exceptions to this rule. Intersections of interstate routes with state primary routes also could constitute some sort of variant to the general rule. Interchanges in incorporated communities could be charges against the general fund; interchanges in suburban areas could be charges against local improvement districts composed of the land which gained access.

One objection that might be raised against collecting part of highway costs from others than highway users is that this would violate neutrality in the competition between rail and highway common carriers. Two comments might be made on this criticism. First, 75 percent of the motor freight movement is restricted to a very few intercity routes. It is not an appreciable factor on 90 percent of the road and street mileage, at least in Washington State (4). Hence, while neutrality should be observed, it does not of itself furnish a broad enough base for establishing over-all highway fiscal policy. Second, competition between rail and truck is largely limited to hauls over 300 miles (5). A recent writer states, "The scanty information that is available suggests that discrepancies between user costs and user taxes have been vastly over-exaggerated in some circles. The only flagrant violations, presently discernible, would appear to be those of diesel trucks and certain inland waterway operations. Furthermore, correction of even these abuses would probably not have much impact on the allocation of transportation resources because of the costs involved are small compared to total costs and rates." (6)

Regardless of the particular characteristics of whatever devices might be developed to collect appropriate costs from non-vehicular beneficiaries, it seems reasonable to assume that such devices could be found, and that they would serve a useful purpose. Before any such tax reform can be put into effect in any one instance, the benefits must be measured.

But the determination of social benefits is the area on which much more must be done in the directions suggested on preceding pages. Until all non-vehicular benefits can be expressed in quantitative terms we cannot modernize benefit-cost ratios to include all benefits which presently motivate highway investment. Lacking such precise instruments, the engineer or administrator should once again accept the responsibility for exercising some measure of intuitive judgment in the discharge of his responsibilities. To ignore realities because we cannot find numbers to put into formulas would be most unfortunate. It would mean that we were the willing victims of our own technologic success, confined by rules we had ourselves invented to fit other circumstances. Perhaps in the transitional period until all benefits and costs can be counted, only those projects should be authorized which have satisfactory user benefit-cost ratios, but that priority among the approved projects should be influenced by social benefits and costs.

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Identifying and Measuring Non-User Benefits

DAVID R. LEVIN, Chief, Division of Highway and Land Administration, Bureau of Public Roads

● PRESENT EFFORTS to modernize the highway plant already have had, and are likely to continue to have, a profound effect on all phases of public and private, rural and urban activity.

Highway officials are not seeking to go forward in a vacuum with their legislative mandates to build better roads. They are earnestly seeking to put the highways in the right places and design them in a manner as to produce a maximum of benefits to the Nation. They have undertaken a substantial program of research on the economic and sociological effects of highway improvements on rural and urban communities. It is in this connection that the identification and measurement of non-user benefits comes into play.

NON-USER BENEFITS

Non-user benefits may mean different things to different individuals. To some, non-user benefits may flow from the expenditures made directly for the highway improvements — in terms of numbers and kinds of employment the road program will provide, the number of barrels of cement and tons of asphalt that will be used, the countless kinds of equipment that will be engaged in the operation, the tons of steel that will be needed especially for bridges and structures, and related matters. To others, highways can be made to serve as functional boundaries between inconsistent land uses or neighborhoods of different types. Such transportation arteries can provide scenic views, needed open space, refreshing landscaping, and recreational areas.

Still others may be more concerned with the economic consequences of providing improved highways in terms of the nonvehicular net benefits, both direct and indirect. Included would be the creation of new industrial areas, changes in land values and land uses, and alterations in the patterns of retail distribution. Highways can eliminate blighted areas. Where authorized, highways can make available hundreds of thousands of miles of improved rights-of-way for public utilities of all sorts, frequently at no cost to the utilities. Highway lighting can illuminate surrounding areas, especially in urbanized communities. Sidewalks, viaducts, and grade separation structures can help to contain fire, flood damage, or soil erosion; drainage in the vicinity of highways may be changed. Perhaps all of these, and some others, need to be considered if the total picture of non-user or nonvehicular benefits is to be delineated.

RELATION BETWEEN USER AND NON-USER BENEFITS

In general, user benefits are those that are realized directly by the motor-vehicle user. These include savings in operating costs, time costs, and accident costs, and reductions in the strain and annoyance of driving under unfavorable circumstances. Non-user or nonvehicular benefits are those more indirect benefits that accrue to adjacent property, business enterprise, the community at large, and others.

There has been some difference of opinion among a few technicians in the field of economic impact research as to whether the kind of nonvehicular benefits being investigated is truly vehicular benefits or non-user benefits. One school of thought asserts that, in a particular case, land values at a point of interchange with a suburban expressway have increased dramatically largely because a shopping center has been built on what formerly was vacant land; and that the shopping center is successful only because excellent vehicular accessibility has been provided by the expressway to an enormous market that is governed by travel time rather than distance. This same

TABLE 1

CHANGES IN VALUE OF LAND NEAR SELECTED HIGHWAY FACILITIES

State	Place and Facility	Period	Unit of Measure	Original Value		Ratio of Percentages, Study Area to Control Area
				Study Area (%)	Control Area (%)	
California [1]	Oakland and San Leandro – Eastshore parkway	1941-53	Assessed value	8,700	5,200	1.67
	Ventura Boulevard (US Highway 101)	1951-55	Price per front ft	210	[2]	-
	Fresno (US Highway 99)	1946-49	Value per acre	[3]	[3]	-
	Orange Avenue Freeway (US Highway 99)	1946-49	"	438	[2]	-
	Los Angeles – Santa Ana Freeway	1949-54	Assessed value			
	A	-	-	168	154	1.09
	B	-	-	705	460	1.53
	C	-	-	412	390	1.06
Georgia [4]	Atlanta Expressway:	1941-46 & 1952-56	Weighted average price per sq ft	-	234	-
	East side:					
	Proximity Band A	-	-	234	[2]	-
	Proximity Band B	-	-	207	[2]	-
	Proximity Band C	-	-	101	[2]	-
	West side:					
	Proximity Band A	-	-	260	[2]	-
	Proximity Band B	-	-	68	[2]	-
	Proximity Band C	-	-	76	[2]	-
Illinois [5]	Edens Expressway	1940-57	Assessed value	[5]	[2]	-
	Calumet-Kingery Expressway	"	"	[5]	[2]	-
Massachusetts [6]	Needham residential	1945-57	Sales value	231	247	0.94
	Lexington residential	1945-57	Assessed value	264	242	1.09
	Influenced band	"	"	388	-	-
	Rest of town	"	"	-	239	-
New York [7]	Bronx River Parkway	1910-32	"	1,278	493	2.59
	"	1939-51	"	254	219	1.16
	Shore Parkway	1939-53	"	176	119	1.48
	Henry Hudson Parkway	1935-53	"			
	Bronx study area	-	-	202	77	2.62
	Manhattan study area	-	-	105	92	1.14
	Grand Central Parkway	1925-53	"	2,138	601	3.56
	Queens	"	"	-	332	-
Texas	Gulf Freeway, Houston: [8]	1939-41 & 1954-56	Value per Sq Ft [9]			
	Proximity Group 1	-	-	667	-	-
	Proximity Group 2	-	-	242	-	-
	Proximity Group 3	-	-	-	80	-
	Proximity Group 4	-	-	-	203	-
	Dallas Expressway: [10]	1941-45 & 1951-55	"			
	Proximity Band A [11]	-	-	723	240	3.01
	Proximity Band B	-	-	223	223	1.00
	Proximity Band C	-	-	285	227	1.26
	Interstate highway system [12]					
	Austin	1941-48 & 1954-57	Avg. price per acre / Non-subdivided land	460 / 622	389 / 322	1.18 / 1.93
	Temple	1941-48	Avg. price per acre	1,417	140	10.12
	Rockwall County:	1944-48 & 1952-57	Do.			
	First section Highway 67, Dallas County line to Rockwall	-	-	198	142	1.39
	Second section Highway 67, Rockwall interchange to Royse City interchange	-	-	99	142	0.70
	Both sections	-	-	151	142	1.06
	San Antonio Expressway [13]	1941-45 & 1952-56	Price per sq ft	[13]	[13]	-
Virginia	Lexington Bypass [14] [15]	1948-57	Value per sq ft			
	Buena Vista	-	-	-	175	-
	Greater Lexington (including suburbs)	-	-	183	-	-
	Lexington, less Main Street	-	-	-	180	-
	Main Street	-	-	243	-	-
	Central, less bypass	-	-	-	135	-
	Bypass	-	-	277		-

[1] "California Land Studies," Division of Highways, California Department of Public Works; "Camarillo Study (Ventura Boulevard)," by John F. Kelly, 1955; "Fresno," by Robert L. Bangs, 1954. See "Influence of Highway Improvements on Urban Land; A Graphic Summary," William L. Garrison and Marion E. Marts, University of Washington, Seattle, 1958, Section II, pp. 18, 21, 41, for data on Eastshore Freeway and Santa Ana Freeway.

[2] Not available.

[3] An analysis of 15 individual parcels vacant before construction of the Fresno Freeway indicated a value impact greater than twice on most parcels. Only one of these parcels had a larger gain before the freeway development than after that construction. In addition, 18 parcels of land adjacent to the Fresno Freeway and 23 parcels not abutting the freeway were analyzed. These were all the sales in the area. The Orange Avenue percentage gain is illustrative.

[4] "Expressway Influence on Land Use and Value, Atlanta, 1941-1956," James H. Lemly, Georgia State College of Business Administration, Atlanta, 1958, Table A-2, p. 106.

[5] "Highways and Their Meaning to Illinois Citizens," George W. Barton and Associates, Evanston, Illinois, 1958, p. 22. Land values within various distances of the Edens Expressway and Calumet-Kingery Expressway were charted from Olcott's Bluebook of Land Values. Increases in the over-all values were generally higher in the middle section through which the highways run. 1957 land value increases along the Edens Expressway ranged from 2.3 to 5.8 times 1940 values, and those along the Calumet-Kingery Expressway ranged from 2.5 to 3.5 times 1940 values.

[6] "Economic Impact Study of Massachusetts Route 128," A.J. Bone, et al. Massachusetts Institute of Technology, Cambridge, interim report, 1958.

[7] Garrison and Marts, op. cit., pp. 8-14.

[8] "A 15-Year Study of Land Value and Land Use Along the Gulf Freeway, Houston, Texas, 1956," Norris and Elder, Consulting Engineers, pp. 146-149.

[9] Value of improvements omitted after adjustment for construction cost changes. Table includes only land annexed to city before 1941; figures for land annexed since 1948 are even more striking. The proximity groups in the Houston study are defined as follows: Group 1 is the primary area immediately adjacent to the facility; Group 2 is a secondary band on each side of Group 1; Group 3 consists of properties in the same quadrant as the freeway, with good roads and access to the freeway, but farther away; Group 4 consists of ten acres widely distributed over all areas of the city except the southeast quadrant, through which the Gulf Freeway passes. The effort was made to select properties as closely similar as practicable to areas in Groups 1 and 2.

[10] "Effects of the Dallas Central Expressway on Land Values and Land Use," William G. Adkins, Texas Transportation Institute, College Station, 1957, p. 24.

[11] Bands were designated by distance from the expressway for study areas; control areas were selected with similar characteristics but out of the influence of the expressway.

[12] "Changes in Land Value and Land Use Along Three Sections of the Interstate Highway System of Texas," C. L. Haning, et al. Texas Transportation Institute, College Station, 1958, pp. 14, 17, 42, 58.

[13] "Economic Impact of San Antonio Expressway," William G. Adkins, Texas Transportation Institute, College Station, 1958, p. 11. Value of improvements omitted after adjustment for construction cost changes. Study shows only the differences between percentage changes of control and study areas, amounting to 133 percent.

[14] "The Influence of Limited Access Highway on Land Value and Land Use; The Lexington, Virginia, Bypass: Progress Report No. 1," Virginia Council of Highway Investigation and Research, 1958, Appendix III.

[15] Value of improvements omitted.

group would concede, however, that the improvement of neighborhood drainage, resulting from a highway improvement, is truly a nonvehicular benefit, and has little to do with the highway user as such.

Another group of researchers tends to discount the need to formulate a completely precise distinction between vehicular and nonvehicular benefits. What seems most significant to this group are not aritifcial labels, but rather that there are real and extensive beneficiary groups other than highway users as such that reap the advantages (and perhaps shoulder the shortcomings to a limited extent in some instances) of highway improvement; and that the total magnitude of these benefits is substantial.

It may be that, in the past, we have too narrowly circumscribed the definition of user benefit to include largely time, distance, and operating cost savings; perhaps we now should add a whole complex of other types of user benefits, but setting up, at the same time, the test of final incidence of the benefits, rather than tests we have been using up until now. It would seem that the really important consequences flow, not from the semantics as such, but from the basic concepts involved.

LAND VALUES AND LAND-USE CHANGES

Another dichotomy that seems to be involved in research efforts to identify and measure non-user benefits concerns land-value and land-use changes.

The economic effects of highway improvements impinge in many instances on land and its improvements, in whole or in part. The market value of such land and property responds accordingly. A series of studies has been made comparing land values adjacent to a highway improvement with land values of similar property removed from the influence of the improvement; or comparing land values before and after a given highway betterment has been completed (Table 1).

Investigation of the land uses involved in these land-value changes reveals that the amount of the value influence depends primarily on the type of land use of the property prior to highway construction, and the proximity of the property to the highway. Most spectacular increases seem to occur when the improved facility has been responsible for a conversion in the land use of the property under study, or an acceleration in such conversion. A conversion from agriculture or vacant land to residential, commercial, or industrial use produces a high percentage increase in land values. Vacant lands adjacent to improved highways develop faster than others, obviously.

It is quite obvious, accordingly, that land value and land use analyses must go hand-in-hand, if any true insight is sought into the nature and extent of nonvehicular analysis.

METHODS AND CONTROLS USED IN MEASUREMENT

Isolated evaluations of the economic effects of highway improvement in connection with designated projects are not new. The earliest of such studies, though admittedly modest in conception, probably can be identified with the earliest of arterial highway development. It was not until 1929, however, that any research of the kind we are concerned with here was reported (1). Other studies of this nature involving highways and rural land values included those by W.M. Curtiss (2), W.P. Walker (3), and C.L. Stewart (4).

A relatively large number of studies have already been completed—at least 70 studies in 21 states and six nationwide studies. The nature of these investigations is indicated in Table 2. Some of these are of limited scope, however. For example, some 47 of these studies involve land-use analysis in some form or another. But the analysis even of the best among these is not very sophisticated. Approximately 54 studies concern land values along isolated highway facilities; in some instances, assessed values were used as a base, even where an area-wide equalization mechanism may not have existed, and where a doubtful relationship existed between assessed values and current market price.

While the substantive content of the completed research in the aggregate is of good quality, generally speaking, much remains yet to be done. A good start in this direction, it is hoped, has been made by the research now under way. There are at present at least 50 studies under way in some 30 states (Table 3). The research talent for the

TABLE 2

ECONOMIC IMPACT OF HIGHWAY IMPROVEMENT[1]

State	Study	Research Agency	Date	Type of Highway Improvement	Nature of Study
Arizona	Arizona Location Studies: Re-routing U.S. 60-70	Maddock & Associates Engineers, Inc.	1959	Possible re-routing of Brenda-Phoenix Interstate Expressway	Economic consequences along old and new routes
	Economic Study in Flagstaff	Western Business Consultants, Inc.	1959	Relocation of U.S. 66	Economic effect of three alternate routes and interchanges
	Re-routing of Highway 86: Economic Impact of State 86 Relocation on Wilcox, Bowie and San Simon	Arizona Marketing, Inc.	1956	Contemplated 89 miles re-routing to bypass 3 small communities	Estimated income and business effects
	Safford Bypass Study: Business Survey of Safford Highway Relocation	Arizona Highway Dept., Division of Economics and Statistics	1953	Relocation of route away from business center, 1947	Interview survey of effect on retail and service trade
Arkansas	Travelers and Arkansas Business 1948 to 1956	Arkansas State Highway Commission et al.	1958	Analysis of travel business in Arkansas: effects of travel expenditures on economy and finances of the State	
California	Alameda County—(Eastshore Freeway) Industry and Freeways	California Division of Highways	1954	Freeway — new alignment, 3.3 miles 1950, 4.2 miles 1951	Industrial development and land use changes stimulated by freeway.
	Anderson	"	1953	4-lane expressway, ¾ mile and frontage road on one side, 1950	Evaluation frontage road business
	Auburn	"	1950	Freeway, expressway	Effects on retail trade and land values
	Buellton — Service Town, U.S.A.	"	1949	Expressway with frontage road, 0.7 mile, 1949	Local roadside trade and frontage property benefits
	Camarillo	"	1955	Freeway, partial control of access	Economic effects on business
	Crenshaw (Los Angeles) Outer Highways	"	1948	Service road flanking major highway	Traffic and business benefits in an uptown shopping area
	Delano	"	1959	Bypass	Effects on land values, development and business
	Effect of Freeway Development on Adjacent Land Value	"	1947	Freeways	Comprehensive study of land prices and land use along California freeways
	El Monte	"	1959	Elevated freeway-bypass	Before-and-after economic analysis
	Escondido	"	1951	Expressway bypass, 5¼ miles	Effects on business on bypass route
	Folsom — Bypass Effects (Part I)	"	1951	4-lane divided expressway	Effects on retail trade
	Fairfield (a)	"	1951	Freeway bypass — 6 miles	Economic effects
	(b)	"	1953	4.7 miles	" "
	Fresno-Fowler-Boost for Freeways	"	1949	Expressway with frontage road 9½ miles	Land use and value changes and retail trade
	Imperial-Bypass Effects (Part II)	"	1951	Expressway bypass	Effects on business, industries and land value
	Milk Farm — Outer Highway	"	1951	Expressway frontage road	Effects on roadside businesses
	Motels: Motels and Freeways	"	1954	Freeways, expressways, various conventional highways	Impact of improvements on motel business
	North Sacramento: Freeway Ups Business (a)	"	1950	Freeway — completely bypasses business section — 4 miles	Analysis of business and land value benefits
	Freeway Values (b)	"	1951		
	Oxnard: Here's Proof	"	1949	Freeway — outer highway near Los Angeles	Analysis of business benefits
	Residential Property: Residences and Freeways	"	1957	Various California freeways	Analysis of resale values
	Sacramento: The One-Way Street	"	1951	Change in traffic patterns	Effects on business and accidents compared with 2-way streets
	Santa Ana Freeway: Industry and Frontage Roads	"	1954	Freeway — sections of frontage roads on both sides, 5 miles	Analysis of industrialization and land values

TABLE 2 (continued)

ECONOMIC IMPACT OF HIGHWAY IMPROVEMENT[1]

State	Study	Research Agency	Date	Type of Highway Improvement	Nature of Study
California	Santa Barbara: Santa Claus	California Division of Highways	1956	Frontage road	Analysis of retail trade trends with relationship to safety and accessibility
	Shell Beach	"	1951	Expressway, 11 miles	Analysis of subdivision growth and land values
	Temecula	"	1951	Bypass	Effects on highway business
	Templeton	"	1955	Expressway bypass, 6 miles	Effects on business and road service establishments
	Tulare: An Economic Study of Tulare	"	1956	Freeway bypass	Comprehensive analysis of benefit and losses in the area
	Vallejo: Venture Success	"	1951	Freeway and paralleling secondary road	Effects on selected businesses
	West Sacramento: Roadside Merchandising	"	1957	Freeway bypass	Analysis of effects on roadside business establishments
	Westside Freeway Route 238: Regional Economic Effects of Five Proposed Routes and	"	1958	Controlled access highway	Economic effects
	Economic Effects of Six Proposed Routes in the Tracy Area		1958	" " "	" "
Colorado	Denver-Colorado Springs-Pueblo Freeways	Bureau of Business and Social Research University of Denver	1958	Section of Interstate System involving relocation	A before-and-after analysis of land use and land value changes on old and new routes
Connecticut	Connecticut Turnpike (Research prospectus issued)	University of Connecticut	1958	Toll expressway	Comprehensive before and after inquiry into social and economic impact
Florida	An Economic Study on the Proposed Florida Sunshine State Parkway	First Research Corp.	1956	Analysis of Florida's economic growth and implications of a major turnpike on the future economy of the state	
Georgia	Atlanta Expressways	Georgia State College of Business Administration	1958	Central and northwest section of Atlanta Expressway system	General analysis of land use and land values
Idaho	Value of Roads to and in Public Lands-Effect on Timber and General Values	University of Idaho	1958	Highways generally	Effects of highway improvements on value of timber lands
Illinois	Highways and Their Meaning to Illinois Citizens	George W. Barton Associates	1958	4-lane expressway	Stresses residential development, land use and land value change
Massachusetts	Economic Impact Study of Massachusetts Route 128	Massachusetts Institute of Technology	1958	Boston Circumferential Highway-Expressway	Analysis of industrial and residential development
Minnesota	The Economic Impact of Highway Development upon Land Use and Value (Methodological Introduction)	University of Minnesota - 1958	1958	Attempts to develop quantitative measures with respect to the relationship of highway services to land value and land use, including any changes in the latter attributable to highway improvement.	
Missouri	Economic Study Route 66 Bypass, Rolla, Missouri	Missouri State Highway Department	1957	Bypass-controlled access 4.9 miles	Evaluates effects on business and traffic
Montana	Montana Rural Study: Benefits from Highway Development, User and Non-user	Department of Agr., Economics and Rural Sociology, Montana State College	1956	Bozeman-Bridger area rural secondary roads (various)	Analysis of benefits to rural property and trading centers
New York	Changes in Westchester and How People Feel About Them	Westchester County Dept. of Planning	1955	Summarizes various county improvements and the opinions of citizens concerning those improvements.	
Oklahoma	Tulsa Metropolitan Expressway	Real Estate Research Corporation	1957	Metropolitan freeway	Economic impact of potential locations for metropolitan freeway; analysis of economic effects
	Economic Impact Research Public Information Program in Oklahoma	Oklahoma Highway Dept.	1957	A manual summarizing general procedures involved in conducting economic impact research	
Oregon	Oregon Public Utility Study	Bureau of Business Research, University of Oregon	1959		Economic benefits accruing to public utilities through use of highway rights-of-way
	Oregon Bypass: Economic Effects of Through Highways Bypassing Certain Oregon Communities	Bureau of Business Research, University of Oregon	1956	Eight medium small city bypasses completed between 1952-1955	Economic impact on business in bypassed areas

TABLE 2 (continued)

ECONOMIC IMPACT OF HIGHWAY IMPROVEMENT[1]

State	Study	Research Agency	Date	Type of Highway Improvement	Nature of Study
South Dakota	Economic Study Route 50 Bypass Tyndall	South Dakota Highway Department	1958	Bypass skirting Tyndall	General economic and traffic effects
Texas	Economic Impacts of Expressways in San Antonio	Texas Transportation Institute, Texas A&M	1958	Urban expressway	Changes in land use and land value along expressway system and comparable areas
	Economic Effects of the Camp Creek Road Improvement	Texas Transportation Institute, Texas A&M	1958	Rural (farm to market) road improvement	Effects of a rural road improved from dirt to all-weather on land values and land use
	Effects of the Dallas Central Expressway on Land Values and Land Use	Texas Transportation Institute, Texas A&M	1957	Urban expressway	Analysis of land use and land value along expressway system and comparable areas
	Gulf Freeway Study: (a) 1940-1950 (b) 1940-1955 A 15-yr Study of Land Values and Land-Use Along the Gulf Freeway	Norris Engineering Co. Norris & Elder	1951 1956	Expressway, Houston, Texas 6½ miles	Changes in land values and land use, before-and-after, and in comparable area
	Changes in Land Value and Land Use Along Three Sections of the Interstate Highway System in Texas	Texas Transportation Institute, Texas A&M	1958	A preliminary report of a study of the economic impact of the Interstate Highway System on local areas	
Virginia	Lexington Bypass	Virginia Council of Highway Investigation and Research	1958	Bypass re-routing US 11 around business district	Analysis of land values, land use changes, and retail sales
	The Impact of Industry on a Southern Rural County	University of Virginia	1956	Analyzes changes in road use, travel habits, and socio-economic characteristics 5 years after establishment of a new manufacturing facility in a rural area	
Washington	(a) Rural Washington: The Benefit of Rural Roads to Rural Washington	Washington Joint Highway Council	1956	Various roads in Snohomish, Chelan, and Douglas Counties	Effect of highway improvements in selected rural counties
	(b) Suburban Seattle: The Effect of Freeway Access upon Suburban Land Values	Washington Joint Highway Council	1956	Lake Washington Floating Bridge and access roads	Shows significant suburban development and rise in land prices
	Influence of Highway Improvements on Urban Land. A Graphic Summary	University of Washington	1958	General summary of selected economic impact studies of effects of highway improvements on land value, business, and traffic	
	Geographic Impact of Highway Improvement	University of Washington	1958	Highway realignment and improvement - US 99, Marysville	Uses large number of indicators to measure effects of highway improvement
West Virginia	Great Lakes to Florida Highway	Bertram H. Lindman	1956	Examines the implications inherent in the proposal to add a north-south highway to the national system of interstate and defense highways	
Nationwide	Impact of Improved Highways on the Economy of the United States	Stanford Research Institute	1959	General highway improvement	Implications of highway improvement programs on the U.S. economy, social, financial and other economic characteristics
	Highway Networks as a Factor in the Selection of Commercial and Industrial Locations	Real Estate Research Corporation	1959	Major highways	Commercial and industrial location study; evaluates role of highway in choice of location
	The Influence of Highway Improvements on Urban Land-Use Patterns	Real Estate Research Corporation	1959	Major highways	Analysis of land use changes in metropolitan areas resulting from highway construction and evaluation of resulting net benefits to various classes
	Studies of Highway Development and Geographic Change	University of Washington 1959	1958	Presents findings of studies of the spatial pattern of shopping centers in their relation to highway improvements, relationships between highway travel and commercial site location, and the utilization of highway transportation in relation to the arrangement of customer tributary areas and supplying centers at local, regional, and national levels	
	Studies of the Central Business District and Urban Freeway Development	University of Washton	1958	Effects of highway improvements on arrangement and use of urban land and on the central business district; evaluates changes resulting from construction of urban highway networks; studies collaterally the feasibility of charging some of highway costs to non-vehicular beneficiaries	
	The Economic Impact of Highway Improvement	Agricultural Research Service, U.S. Dept. of Agriculture	1958	General highway improvement	Sets forth principles and concepts with respect to economic impact of highway improvements and the relationship of such improvements to land value and land use

[1] Studies completed as of June 1959.

TABLE 3

ECONOMIC IMPACT OF HIGHWAY IMPROVEMENT[1]

State	Study	Research Agency	Type of Highway Improvement	Nature of Study
Arizona	Alternate Locations for Interstate Route 8 in Kingman-Ash Fork Area	Hurst, Rosche, Meurer, Serafini & Associates, and J.K. Kipp	Alternate locations for Interstate Route 8	Economic effect of alternate locations
Arkansas	Economic Effects Study	Arkansas State Highway Department	Representative Interstate Primary and Secondary	Land value, land use, and general economic analysis
California	Land Economic Studies	California Division of Highways	Economic impact studies conducted by the California Division of Highways are carried on as a regular part of the state highway operation Also continuing case studies of land values and and severance damages to remainder properties after partial takings for right-of-way	
Connecticut	Connecticut Turnpike	University of Connecticut	Eastern third of Toll Expressway	Comprehensive before and after inquiry into social and economic impact
Delaware	Delaware Freeway Impact Study	University of Delaware	Interstate System, limited access	Economic effects, land use, land value, commuting patterns, and public services
Georgia	Georgia Bypass	Georgia State College of Business Administration	Tifton, Jonesboro, and Forsyth bypasses	General economic effects
Idaho	Impact of Road Development on Public Lands in Idaho	University of Idaho	General highway improvement	Interrelation of highway and public land development with emphasis on forestry, mining, and recreation
Illinois	Severance Damage Studies	University of Illinois	Case studies of land values and severance damages to remainder properties after partial takings for right-of-way	
Indiana	Indiana Bypass	Purdue University	Bypasses in Lebanon and Kokomo without control of access	Will bring 1953 study up to date in terms of economic and traffic changes
Iowa	Bypass Studies	Iowa State Highway Department	Boone, Red Oak, and Sheraton	Economic effects of route locations on bypasses, especially business volumes
Kansas	Economic Impact of Highway Improvement	Kansas Agricultural Experiment Station	All types of highway improvement	Benefits and costs of highway improvement with emphasis on effects on land use, real estate, and farm organization and operation
	Economic Effects of Bypass Highways on Urban Communities	University of Kansas	Bypass highways	Measure the effects of bypass highways on urban land values, land patterns, and value of retail trade
Kentucky	Kentucky Bypass	Bureau of Business Research, University of Kentucky	Watterson expressway bypassing Louisville; northern route expressway bypassing Lexington. Current expansion of both to 4-lane routes also to be studied.	Land use changes and other economic effects; contrasts limited-access bypass with bypass without access control
Michigan	Michigan Studies: The Economic and Social Effects of Highway Improvement	Michigan State University, Highway Safety Center (8 University departments cooperating)	General highway improvement	A comprehensive 3-yr inquiry which will attempt to document the impact of highway improvement, on a broad and conceptual basis
	Small Communities and Limited Access Highways	Michigan Highway Safety Center, Michigan State University	Limited-access highways	Research on highway impact, to assist small communities
Minnesota	General Economic Impact	University of Minnesota	Suburban portion of Interstate expressway and Interstate expressway across southern Minnesota, including interchanges	Economic impact on suburban development and analysis of impact upon agricultural territory and business development
Mississippi	Land Use, Value, and Fragmentation	University of Mississippi	Panola, Hinds, and Forrest Counties	Analysis of effects on land use, value and fragmentation
Missouri	Missouri Bypass Studies	Missouri State Highway Commission	Lebanon, Waynesville, and Sullivan bypasses	Economic effects, especially on retail sales
Montana	The Impact of Tourism on Highway Use and on the Economy of Montana	Montana State University	Analysis of in-state tourists in Montana as well as out-of-state tourists, to determine the effect of good highways on the promotion of tourism	

TABLE 3 (continued)

ECONOMIC IMPACT OF HIGHWAY IMPROVEMENT[1]

State	Study	Research Agnecy	Type of Highway Improvement	Nature of Study
Nevada	Winnemucca-Lovelock area	Bureau of Business and Economic Research, University of Nevada	Highway improvement in Winnemucca-Lovelock area	Economic impact of highway improvement
New Mexico	New Mexico Bypass	New Mexico College of A & M Arts	Raton, Grants, Santa Rosa, Anthony, Santa Fe, and Pecos	Economic impact of controlled access and relocation of highways
Ohio	Ohio Bypass Studies	Ohio State Division of Highways	Piqua, Circleville, and St. Clairsville bypasses	General economic effects
	Ashland and Richland Counties	Ohio State Division of Highways	Interstate Route 71	General economic effects
	Severance Damage Studies	Ohio State Divison of Highways	Case studies of land values and severance damages to remainder properties after partial takings for right-of-way	
Oklahoma	Re-routing of Interstate Highway US 77 (N-S)	Oklahoma Highway Department	Oklahoma City to Kansas border route — bypasses Guthrie, Perry, Tonkawa, Blackwell, and minor areas	Land values, retail sales, and other economic effects
	Healdton Bypass	Oklahoma Highway Department	Relief of city from oil traffic	Land values, retail sales, and other economic effects
Oregon	Economic Impact of Controlled Access Highway Location	Oregon State Highway Department	Bypasses	Economic effects of bypasses on small and medium sized communities
	Severance Damage Studies	Oregon State Highway Department	Case studies of land values and severance damages to remainder properties after partial takings for right-of-way	
Pennsylvania	Project WAMBY	Pennsylvania State University	Highways generally; Washington, Monroeville, Blairsville, and York	Economic impact of interchanges, and abutting land development along Interstate highways
Rhode Island	Rhode Island Bypass	University of Rhode Island	Bypass of Hope Valley by 4-lane 9-mile expressway	General economic effects of rerouting main New York-Providence truck route and bypassing of 3 communities
	Downtown Pawtucket and the Freeway	Blair Associates	New Expressway system	Economic effects, traffic and parking, and land use
South Dakota	South Dakota Bypass	South Dakota Highway Department	Bypasses Tripp and Bowdle communities	General economic and traffic effects
Texas[2]	Texas Economic Impact Study	Texas Transportation Institute, Texas A & M	Rural and urban highway improvements	Impact on land use and land values
Utah	Use by Utilities of Highway Right-of-Way	University of Utah	Highways generally	Evaluation of benefits to utilities in Utah through free use of highway right-of-way
	Interstate Route Bypass	Utah State University	Bypass American Fork	Land use, land values, and economic effects
Virginia	Economic Studies — Bypasses, Limited Access	Virginia Council of Highway Investigation and Research	Studies designed to ascertain the economic effect upon communities and their environs of by-passes and limited access highways. Such projects as the Washington, D.C. Circumferential are included.	
Washington	Washington State Studies: Spokane Economic Impact Study	Washington State Council of Highway Research, University of Washington	Suburban Spokane highway system	Traffic patterns, land values, and land-use interrelationships
Wisconsin	Severance Damages	University of Wisconsin	Case studies of land values and severance damages to remainder properties after partial takings for right-of-way	
Nationwide[2]	The Economic Impact of Highway Improvement	Agricultural Research Service, U.S. Department of Agriculture	Analysis of land-use control techniques and application to selected areas; relation of farm values to road quality and urban land values to highway access	
	Impact of Highway on Local Public Services	Wilbur Smith	Analysis of the relationship between highway improvements and selected public and semipublic services such as schools, hospitals, etc.	
	Land-use Planning and Control at Freeway Approaches and Inter-Change Areas	University of Washington	Interchanges and approaches	General economic effects
	Benefits to Utilities from Use of Highway Rights-of-Way	Georgia State College of Business Administration	Benefits to public utilities in selected urban and rural areas	

[1] Studies in progress as of June 1959.
[2] Nationwide studies and some of Texas studies are financed from Bureau Administrative Funds.

TABLE 4

COMPLETED ECONOMIC IMPACT STUDIES OF HIGHWAY IMPROVEMENTS BY STATE AND SUBJECT MATTER, JUNE 1959

Study	Land Use	Land Value	General Economic Effects	Effects on Agriculture	Effects on Tax Revenues	Traffic Patterns and/or Safety	Effects on Industry	Residential	Retail Business	Community Growth	Public Utilities	Public Services	Bypass	Frontage Road	Metropolitan Area	Roadside Business & Motels	Other
Arizona																	
Arizona Location Studies			x	x	x	x			x	x							[1]
Economic Study in Flagstaff	x	x	x			x											[2]
Wilcox, Bowie, San Simon			x			x			x				x				[3]
Safford Bypass			x		x	x			x				x				
Arkansas																	
Travelers and Ark. Business				x	x				x							x	[9]
California																	
Alameda County		x	x				x										
Anderson		x		x		x	x		x	x			x	x			
Auburn		x				x		x	x				x				
Buellton-Servicetown USA		x							x				x	x			
Camarillo	x	x			x	x		x	x	x			x				
Crenshaw-Outer Highways	x	x	x			x		x	x	x				x			
Delano	x	x		x				x	x	x			x				
Eff. Fwy. Dev. Adj. Land Use	x	x							x					x			
El Monte	x					x			x	x			x				
Escondido	x	x				x			x				x				
Folsom-Bypass Effects						x			x				x				
Fairfield	x	x	x			x			x				x				
Fresno	x	x					x		x					x			
Imperial-Bypass Effects				x		x	x		x				x	x			[4]
Milk Farm			x						x				x	x		x	
Motels and Freeways			x			x			x					x		x	
North Sacramento Freeway Values	x	x				x			x				x			x	
Oxnard: Here's Proof	x	x							x								
Residences and Freeways	x	x				x		x									[5]
Sacramento-One-Way Street		x				x			x				x				
Santa Ana Freeway Industry and Frontage	x	x	x				x							x			
Santa Barbara-Santa Claus	x		x						x					x		x	
Shell Beach	x	x	x					x	x	x							
Temecula		x	x			x			x				x			x	[6]
Templeton				x		x			x	x			x				
Tulare	x	x	x	x	x	x			x				x				[7]
Vallejo-Venture Success			x			x			x							x	
W. Sacramento-Roadside Merchandising	x	x							x				x			x	
Westside Freeway R.238 5 Proposed Routes	x	x	x	x	x												
Westside Freeway R.238 6 Proposed Routes Tracy Area	x	x	x	x	x												
Colorado																	
Denver-Col. Springs	x	x	x	x	x			x	x				x				
Connecticut																	
Connecticut Turnpike (Prospectus)	x	x	x				x	x	x			x					[3]
Florida																	
Proposed Sunshine St. Pky.	x	x	x				x		x								[3, 4]
Georgia																	
Atlanta Expressway	x	x			x	x	x	x					x		x		
Idaho																	
Value of Roads to and in Public Lands-Timber and General Values		x										x					[8]
Illinois																	
Hwys.-Meaning to Illinois Citizens	x	x			x	x	x	x	x	x				x	x		

[1] Includes substantial origin and destination material
[2] Alternate routes, interchanges
[3] Tourism
[4] Population
[5] Home financing
[6] Advertising
[7] Employment
[8] Effects on timber industry
[9] Basically a study of methodology
[10] National Defense
[11] Includes study of physician service

TABLE 4 (continued)

COMPLETED ECONOMIC IMPACT STUDIES OF HIGHWAY IMPROVEMENTS BY STATE AND SUBJECT MATTER, JUNE 1959

Study	Land Use	Land Value	General Economic Effects	Effects on Agriculture	Effects on Tax Revenues	Traffic Patterns and/or Safety	Effects on Industry	Residential	Retail Business	Community Growth	Public Utilities	Public Services	Bypass	Frontage Road	Metropolitan Area	Roadside Business & Motels	Other
Massachusetts																	
Study of Mass. Route 128	x	x	x		x	x	x	x		x		x	x		x		
Minnesota																	
Hwy. Development on Land Value and Land Use	x	x		x		x									x		-9
Missouri																	
Study Route 66 Bypass Rolla, Missouri			x			x			x				x			x	
Montana																	
Rural Study; Benefits from Hwy. Dev., User and Non-User	x	x		x					x								
New York																	
Changes in Westchester and How People Feel About Them	x	x			x			x	x							x	
Oklahoma																	
Tulsa Metropolitan Expressway	x	x	x			x			x					x	x	x	
Economic Impact Research Public Information Program in Oklahoma	x	x	x			x			x								
Oregon																	
Oregon Public Utility Study		x									x						
Oregon Bypass: Effects of Through Hwys. Bypassing Communities	x	x				x			x	x			x			x	
South Dakota																	
Route 50 Bypass, Tyndall, South Dakota		x	x			x			x				x				
Texas																	
Expressways in San Antonio	x	x				x	x	x	x					x	x		
Economic Effects of Camp Creek Road Improvement	x	x		x		x											
Effects of Dallas Central Expressway on Land Values and Land Use	x	x			x			x	x								
Changes in Land Value and Land Use Along Three Sections of the Interstate Highway System in Texas	x	x				x	x	x	x								
Gulf Freeway Study	x	x				x	x	x	x					x			
Virginia																	
Lexington Bypass	x	x							x				x				
Impact of Industry on a Southern Rural County			x	x		x	x		x								
Washington																	
Benefit of Rural Roads to Rural Washington	x	x	x	x	x	x											
Effect of Freeway Access upon Suburban Land Values	x	x	x			x											
Influence of Hwy. Improvements on Urban Land, A Graphic Summary	x	x				x			x				x				
Geographic Impact of Hwy. Improvement	x	x	x			x		x	x				x		x		
West Virginia																	
Great Lakes to Florida Hwy.			x			x	x										-10
Nationwide																	
Stanford Socio-Economic Project	x	x	x	x	x	x	x	x	x	x		x			x	x	
Hwy. Networks as Factor in Selection of Commercial and Industrial Locations	x	x	x				x		x					x		x	-7
Influence of Hwy. Improvements on Urban Land Use Patterns	x	x	x			x	x	x		x		x			x		-7
Studies of Hwy. Development and Geographic Change	x	x				x		x	x			x					-11
Studies of the Central Business Dist. and Urban Freeway Development	x	x	x		x	x	x		x		x				x	x	
Economic Impact of Highway Improvement	x	x	x	x													

largest portion of such projects is recruited from the universities of the several states. The studies involve expressways, by-passes, circumferentials, industrial and commercial development, interchanges, urban and rural communities generally, and others. Table 4 gives the studies by subject matter.

The approach generally used in the studies varies considerably. Some use the so-called before-and-after approach, seeking to contrast economic developments before and after a highway improvement has been made. Others use the comparative approach, contrasting so-called affected areas near the highway improvement with control areas removed from the influence of the improvement. Some make use of mathematical techniques that seek to isolate the effects on a number of variables that operate simultaneously in a specific situation. In one or two instances, an entirely new approach is being taken.

If one is so inclined, one may be critical of some of the existing methods that are used in economic impact research. For example, the comparative method of analysis, under which a study area is compared with a control area, presumes that these two are sufficiently comparable to warrant their use together. In many instances, the method used is valid. In some instances, it is almost impossible to find such comparable areas. For example, in connection with the Route 128 Study in the Boston metropolitan area, it was almost impossible to find control areas that were comparable in their physical, functional and economic elements to justify their use.

Another difficulty confronting researchers in this field involves attempts to separate land from improvements in land-value analyses. The objective is to derive ultimately a land-value change on a unit basis; obviously, if improvements of differing kinds are involved, it is almost impossible to reduce the values to a common basis. Some technicians have refused to make the separation and, accordingly, have had to be content with comparisons of other sorts. Some have made the separation, sometimes using relative values assigned under the property assessment process, sometimes using the BLS index of building material costs; some researchers have even derived a fine-spun method of using cost and accrued depreciation. In this area alone, there is much room for improvement.

With respect to research methods and techniques in general, we have learned by doing, in the economic impact research effort. The first studies probably appear pedestrian to day; the newest studies have the greatest depth.

Concerning the matter of incidence of land-value changes, most of the studies completed do not assign values in terms of the final incidence of benefits on the groups involved. To illustrate the importance of this matter of incidence — if a tract of agricultural land on the fringes of an urban complex becomes ripe for development because of highway improvements, the farmer-owner may sell the land to a developer; in the process, the farmer may thus appropriate a portion of a larger, total increment in land value. The developer processes the land, sells it off in lots to homebuilders, and the developer reaps a profit in the process too. The builder constructs homes on the land and presumably sells these to individuals, at a profit. So, by the time a homeowner gets into the picture, most, if not all, of the increment in land value may have been capitalized. Each of three or four or more different beneficiary groups thus shared in dividing up an aggregate whole.

Accordingly, it is essential to consider not only the several beneficiary groups that are involved in the benefits resulting from highway improvement, but also the final incidence of those benefits as well, in terms of each group.

NEED FOR QUANTIFICATION ON SYSTEM AND REGIONAL BASES

Much of the highway economic impact research of the past has been concerned almost exclusively with an evaluation of the impact of a single highway facility or several facilities — the new improvement and the one it displaces functionally. Though this type of study is useful from a number of points of view, the time has come when we should investigate not only particular facilities, but also an entire area, region, or metropolis as a physical and functional whole.

This could include investigation of the economic impact of a particular highway

system in the area, as the primary system, the secondary system, the arterial system, etc. Or it could include several systems or portions of such systems. Or, conceivably, it could comprehend all highways in the area.

It is desirable to seek the larger coverage because that is probably the only scientific way in which net impact of highway improvement can be ascertained and evaluated. Study of a particular facility may indicate a substantial increment in land value within the scope of its influence; but this eruption of value may be counterbalanced, in part at least, by a diminution in land value in another portion of an area. On the other hand, study of a particular facility may reveal a decrease in land values or sales volume in areas within the scope of its influence; but this might be more than offset by substantial increases in these items elsewhere.

Efforts to expand the scope of economic impact research to systems and area bases may be frought with difficulties all of their own. It is quite obvious that many factors operate simultaneously and among each other, in a given area or region. To attempt to assign precise mathematical values to one of the elements -- the highway component -- may be well nigh impossible, unless a series of assumptions are made. The final result may be no better than the validity of the assumptions made.

CONCLUSION

A formidable array of benefits to many important segments of the American economy is being documented in current research efforts. Based upon studies that have been completed to date, a scientific basis has been sought upon which an effort to quantify these benefits might be mounted. In terms of what data are now available, a solid basis for projecting the various kinds of nonvehicular benefits on a unit basis seems to be lacking.

Notwithstanding, it is apparent that there are identifiable groups that are the beneficiaries of highway improvement and that the magnitude of their benefits is substantial, though these vary from class to class.

It is entirely possible that, as the research techniques are perfected, the means for a more precise quantification will emerge.

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The Incidence of Highway Benefits

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IMPACT OF HIGHWAYS ON NATIONAL PRODUCT AND EXPENDITURE ACCOUNTS

● THE ECONOMIC impact of highway improvements on the national product and expenditure accounts, that is, the nation's economic balance sheet, will be analyzed in terms of full employment. (The treatment for a condition of unemployment would necessarily be modified to the extent that highway expenditures put otherwise idle resources to work. In the circumstances deficit financing would tend to close a deflationary gap; on the other hand, pay-as-you-go financing might well reduce consumption in other areas resulting in unemployment that would affect employment generated by highway expenditure. Benefit-cost analysis in an unemployment situation may require substantial modification either by discounting costs or enhancing benefits, the full implications of which we cannot explore here. It is pertinent to note, however, that the choice between alternative projects may still appropriately be influenced by conventional benefit-cost comparisons when employment stimulating effects are equal.) The first effect of an expenditure for highway improvement is a transfer of resources from other activities to highways. To avoid inflation, there must be a reduction in expenditure for other consumption or investment purposes. Taxation is usually the most effective means of bringing about a non-inflationary shift of expenditures.

The economic justification of the taxation necessary to finance the highway improvement lies in the benefits which it provides. (A pay-as-you-go financing program at a time of great activity in highway building is likely to draw more from the economy than the highway improvements provide in the way of benefits during a given time period. In other words, highway expenditures will exceed highway benefits during the period, even though the latter exceeds highway costs spread appropriately in time.) Presumably, the highway improvement is intended to reduce the total costs of highway transport (or improve the quality which also can be stated, for simplcity but rather clumsily, as a reduction in cost). This saving in user cost may be regarded as the "private" benefit of the highway improvement. But unless it exceeds the public costs incurred in providing the highway there is no net gain for the economy. Moreover, there would be no net gain for users if the highway costs were assessed against them through user taxes; the benefit is offset by the taxes. If, however, some portion of the cost is assessed against general taxpayers, then users as such may experience a net gain. But this gain represents nothing more than a subsidy of highway users by the general taxpayers, which, of course, involves a redistribution of income, the incidence of which is dependent on the nature of the general taxes used. The fact remains that unless total highway transport costs (including the subsidy, if any) are reduced by the improvement there is no net gain to the economy.

Actually, of course, we expect highway improvements to provide benefits to users considerably in excess of their costs — that is to say, we anticipate a surplus. It is the disposition of this surplus that causes so much difficulty in understanding of highway economics. Suppose that it were public policy to recover the surplus, as well as the highway cost, from highway users. Motorists would enjoy no net gain but neither would they experience loss. The immediate economic effect of the highway improvement would simply be the reallocation of resources resulting from the shift from other economic activity to highway construction. But government would be left in possession of the surplus, and its disposition would effect a redistribution of income. For example, general taxes of one kind or another might be cut or additional public services might be provided.

The conventional approach to highway finance, in the United States at least, has been

to recover no more than the costs of highway improvement through taxation. (Certain selective taxes are collected from highway users which are not used for highway purposes and in a few states there is diversion to non-highway purposes of portions of taxes that are clearly of the use-tax variety. It seems that these practices were established as a matter of expediency and their justification, however flimsy, is to be found in general fiscal policy; certainly they were not reasoned out in terms of highway finance policy and established to recover surplus highway benefits.) We do not seek to capture for public use the full amount of benefits provided by highway use. Thus, the surplus of benefit over cost remains with the private sector of the economy.

The benefits of highway improvement, including that portion which offsets costs, as well as the surplus over costs are experienced in the first instance through use of the facility. We are led, therefore, to look to the impact of the improvement on the highway users.

A sizable portion of total highway transportation is used in the production of goods and services. Thus, it enters directly into the product accounts of the nation. A reduction in the costs of highway transportation means a reduction in the costs of production. In the interests of brevity and simplicity, we shall assume that competitive forces bring about a reduction in prices of goods and services, the production of which involved highway transportation. As a result, less disposable income is required for the purchase of a given volume of goods and services. The savings will be available for consumption of other goods and services (including more highway transportation) or for personal saving and subsequent investment. The additional production to satisfy the demand for more goods and services will have been made possible by the release of resources previously used for highway transportation (that is to say, by the excess of highway benefits over highway costs).

That part of highway transportation used for personal (non-business) affairs will also be benefited by the highway improvement. Some part of the benefit will be reflected in lower money costs of personal highway transportation. Examples would be lower vehicle operating costs or lower accident costs. Reduction in these money items will result in the release of disposable income which will then be available for the purchase of other goods and services (which again might include more highway transportation).

However, a considerable part of the estimated benefit of highway improvement will not release income nor provide for added production. For example, time savings or added comfort and convenience for commuters or shoppers or vacationers which are sometimes quantified for highway benefit analysis, will not enter into the nation's product and expenditure accounts. This is not to say that these intangibles do not have economic value; the economic justification lies in the better quality of highway service for which we may be perfectly willing to spend more. However, the point to note is that spending for a given volume of highway transportation service may actually increase even though the benefit-cost ratio for highway improvement is favorable. We should realize that we are using more resources for highway transportation rather than less which is the usual assumption of the "good roads don't cost — they pay" line of argument. With accelerating efforts to meet the urban commuting problem with highway transportation, this fact is likely to assume ever-increasing importance in highway policy decisions; for personal time-savings as well as riding comfort and convenience are the major elements of highway benefit for peak hour commuting.

Whether we are concerned with reduced costs or improved quality (or some of each) it is my thesis that the benefits of highway improvement can be realized only as they are generated by highway use. This is not to say that there are no sequential effects. As a matter of fact, we are dealing with the reverse of the economic problem that involves impact, shifting, incidence, and effects of various taxes. When government collects a particular tax, for example a gasoline tax, it is collected but once. Yet how often is it claimed that both the oil company and its customers pay the tax? Not infrequently the argument is carried further: It may be suggested on the one hand, that the tax is shifted backward to owners of oil-producing lands, or on the other, that it is shifted forward from the oil companies to the truckers and finally to the consumers of goods hauled by truck. Most economists would agree that any one of these things or per-

haps a little of each, might happen in given circumstances. But I doubt that anyone would say that the tax burden is four times as much as the tax imposition simply because some part of the tax incidence may rest with the highway user, some with the oil company, some with the land owner, and some with the consumer of goods hauled by highway.

Yet, we are precisely in danger of doing this kind of multiple counting when we start to add up the benefits of highway improvement by looking alternately to the highway user, to the land owner, to the consumer, and so on until finally we come to the happy conclusion that everybody benefits from highway improvements. The danger is particularly acute because the highway benefit problem is so often attacked in parts. Thus, one group studies land values, another user costs, and a third freight rates. And, of course, each may find that highway improvements have resulted in benefits — in the one case to land owners, in the second to highway users, and in the third to consumers.

Therefore, I would emphasize again that the benefits of highway improvements can be realized only through highway use, which is simply another way of saying that highway users are the initial beneficiaries of reductions in costs or improvements in quality. In tax parlance, we would say that users bear the impact. But just as taxes may be shifted, so may benefits; and just as taxes have sequential effects, so do benefits.

In the case of highway improvements we may expect that one of the sequential effects will be an increase in highway usage. Certainly there will be some elasticity in the demand for personal highway service just as there is elasticity in demand for all economic goods and services. Moreover, with lower costs we may expect some transfer of commercial traffic to highways from other modes of transportation. All of this is simply to say that the new cost (and/or quality) conditions create a disequilibrium to which the economy will react until a new equilibrium is reached. The new equilibrium will involve a higher volume of highway usage, but not necessarily will the whole of the highway benefit be channeled into more highway usage. For example, in the case of personal transportation, the return to the consumer from each additional unit of highway service diminishes, and at some point the marginal return from an additional unit of highway service will be less than the return from equivalent expenditure on some other goods or services. The more inelastic the demand for highway service the less impact the benefit of highway improvement will have on use; and the greater will be the saving that may be channeled into other consumption or investment.

Now, if the costs of highway improvements are assessed directly against users only the surplus (that is, the excess of benefits over costs) will be available for dispersion through the economy in some manner. At the same time, the cost assessment against users will reduce the impact of the improvement on highway use, for the simple reason that the net benefit (cost reduction) is less. To state the matter the other way, if costs of highway improvements are defrayed by general taxation, or by deficit financing, neither of which impinges directly on highway use, the benefits to users will appear to be that much greater and there will be an additional stimulus to highway use. On the other hand, withdrawal of resources through general taxation (or deficit financing) will tend to reduce other consumption and investment. In essence, user financing of highway improvements tends to offset the stimulus for additional use while general taxation tends to enhance it. The question of public policy then, is whether there is sound reason for promotion of highway use through general subsidy which will probably involve income redistribution and, of course, can be provided only at the expense of production and consumption of other goods and services. Without going into detail, I believe there is a strong presumption in the negative.

It is a relatively simple matter to assess highway costs directly against users and permit the surplus (the excess of benefits over costs) to fall where it may. It is quite another matter to attempt to trace the benefits and lay taxes at their final resting places. The particular conditions surrounding each individual highway improvement will affect the shifting and incidence of benefits. The variables involved include such things as characteristics of the traffic using the facility, the nature of existing and potential land uses in the neighborhood, and availability, quality, and costs of alternative modes of transport.

Actually, if public policy decrees that only highway costs be recovered there is not

much point in looking beyond the highway user; by user taxation we initially reduce the amount of benefit that might be shifted or capitalized and thereby reach the ultimate beneficiary. For example, we might consider the alternative of taxing truckers or the consumers of goods hauled by truck. The result may well be the same. In the one case the trucker passes the cost on to the consumer; in the other, the truck rates are lower since no tax is included, but the consumer pays the tax. The practical difference is that the truckers can be identified, and they can undertake the problem of spreading the cost among users of their services; whereas it would be virtually impossible for government to identify in any meaningful way the consumers who enjoy highway benefits through consumption of goods hauled by truck, and to lay taxes on them in proportion to such benefits.

Consumers may enjoy net benefits even though they bear highway costs through direct or shifted taxes, simply by reason of the excess of benefits of highway improvement over highway costs. But this simply means that one of the main objectives of all economic activity has been achieved — increased productivity and consumption. In this context, a highway improvement may be treated as any other improvement in technology which reduces costs or improves quality of goods and services. Admittedly, there may be windfall gains as we move toward a new equilibrium, but the treatment of such windfalls is a matter of general policy involving social and economic considerations that extend far beyond questions of highway policy and practice. Decisions in this sphere appropriately should apply across the board, and, to the extent that they are effected through fiscal policy, general taxation for general puposes is appropriate. Capital gains taxation, for example, might recover some of the excess benefits of highway improvements that find their way into certain land values; but there are innumerable other causes of windfall gains all of which might be treated uniformly by capital gains taxation. Instead of attempting to trace the specific cause of each capital gain, we can look simply to the result for tax purposes.

IMPACT OF HIGHWAY IMPROVEMENTS ON LAND VALUES

The impact of highway improvements on land uses and values seems to cause most concern as well as confusion among many students of highway affairs.

One of the claims often advanced by highway protagonists is that highway improvements enhance land values. If this were true as a general propositon it might well be used as an argument against rather than for highway improvements. Actually, transportation improvements do not affect fertility or productivity values but only site or accessibility values which in themselves are functions of pre-existing transportation conditions. Thus, if highway improvements could be supplied ubiquitously the tendency would be toward reduction rather than increase in aggregate land values. For reduction in transport costs tends to reduce accessibility values of previously favored locations and to increase values of those previously less favored. Moreover, with reduction in transport costs the supply of usable land for particular purposes is increased. With "magic carpet" transportation, site or accessibility values would disappear entirely.

Although any hint of reduction in land values seems to spell economic tragedy in the minds of many, Belloc has pointed out as one of the "blunders of the science of economics" the idea that destruction of site values "is in some way an expenditure of real wealth." The fact is that such values are artificial, representing neither wealth nor production potential. However, those finding comfort in high and ever-increasing land values may be consoled by the fact that any tendency toward reduction in land values as a result of transport improvements may be offset (perhaps more than offset) by increases in the demand for land which may also result from the transport improvement. Thus, some part of the previously described addition to disposable income resulting from highway improvements may be used for purchase or rental of land in lieu of other goods and services. Beyond this, since magic carpet transportation is not possible, lower highway transportation costs along with added comfort and convenience may so affect consumer preference that additional income (more than is provided by the highway improvement) is devoted to acquisition or rental of land. For example, dwellers on small city lots may move to suburbia. Here of course, there is a shift in demand which would tend to reduce values of the city lots while increasing suburban values.

Not only is it impossible to have unchanneled, "magic carpet" transportation, but it is not even practical to improve transport channels ubiquitously. A highway improvement, for example, must be made at a specific place and at a specific time. Immediately it disturbs a previously existing theoretical equilibrium. The improvement raises the comparative accessibility values of sites within its zone of influence. It exerts a gravitational pull which channels demand for land in that direction by drawing it away from other areas. A kind of chain reaction is set in motion; the highway improvement attracts a factory; the factory attracts employees who seek homesites; the resulting population growth attracts retail stores, service industries, etc. Competition for sites begins to increase land values and availability begins to decline until a new equilibrium is reached. Simultaneous and uniform improvements in two directions would have a less dramatic impact on land values because the supply of sites of equivalent accessibility values would be doubled. Similarly, a second improvement (b) closely following a first (a) would probably show a less dramatic increase in land values than the first. And, finally, if equilibrium had been reached after a first improvement (a), a second improvement (b) might show that land values increased in the vicinity of the second improvement while they remained stable or even declined in the vicinity of the first. Are we to say then that highways benefit (b) lands but do not benefit (a) lands? Here, the danger of excessive reliance on before-and-after studies becomes all too clear.

Unfortunately, neither highway-user taxation nor any practical kind of general taxation can cope effectively and equitably with the shifting of land values resulting from highway improvements channeled in time and space. Tolls on each highway improvement would be theoretically ideal, but of course, impractical. Even in this case land values could rise along the toll facility because no more than highway costs are recovered by the toll authority.

Highway-user taxation in practice is uniform in the taxing jurisdiction and applies to usage of all roads and streets and not simply to those being improved in a given period. Thus, a certain insult is added to injury when the users of unimproved road AC are taxed to meet a portion of the costs of improvement of road AB. Beyond this, the attraction of lands along AB is greater than it would otherwise be, because AB users are not paying the full cost of the improvement. The justification of this method of finance must rest in the notion that we are financing highway systems and that ultimately the equities will balance out reasonably well. It is especially important to note that the dilemma is not solved by abandoning user charges in favor of some kind of general tax. A general property tax to defray the cost of the highway improvement, for example, would apply to AC lands as well as to AB lands with the result that the comparative benefit to AB would be enhanced as much by property taxation as by user taxation.

SOME IMPLICATIONS OF BENEFIT ANALYSIS

There is an obvious preoccupation with problems of highway finance in my treatment of the incidence of highway benefits. Even so, the analysis may contain some hints of economic impact that have pertinence for highway programming, location, and design. Thus, it has been asserted that highway improvements by reducing cost or improving quality, or both, will tend to increase volumes of highway use; but that the increase is likely to be less when highway use taxation defrays the highway cost than when it is met by general taxes (or deficit financing).

More importantly, it has been argued that the very fact that highway investment must be made at particular places and at particular times will have a profound effect on land use and land values. While we have questioned the relevance of this finding insofar as practical fiscal policy is concerned, we believe it has pertinence in highway planning and design.

The fact is generally highway improvements are provided in areas where development has already taken place or is about to take place. To an extent, then, the highway improvement is an effect of the economic development rather than a cause. But it is not to be overlooked that the highway improvement will accelerate the forces for development by exerting a gravitational pull and setting in motion something of a chain

reaction. Unless this impact which will be manifested in increased highway travel is anticipated there is danger that the highway improvement will be underdesigned. This suggests the need for continuing research in traffic generating forces.

The fact that the highway can and does influence land uses and values also has grave implications for comprehensive regional and city planning. Here is one of the basic causes of conflicts that sometimes arise between the planner and the engineer. The former would like to plan land uses and build transportation facilities accordingly; the latter often builds highways in the absence of comprehensive general plans and, in so doing, materially influences the shape of the community. Unfortunately, in many cases there is no well settled policy as to whether the transportation system should be built and other plans modified accordingly, or whether a comprehensive general plan should control decisions on transportation facilities.

It has been observed that highway engineers generally will respect comprehensive plans that are reasonably definitive and have official sanction. It must be noted, however, that in an economy in which private economic decisions are relatively unfettered, the limits of land use control, even by comprehensive planning, are comparatively narrow. Thus the impact of putting a highway improvement in place in conformity with an over-all plan may be more profound than the planner had anticipated, with the result that the plan itself must be modified in light of the accomplished fact and its sequential effects.

Some of the recent experiences in California demonstrate rather clearly that there will be occasions of real and direct conflict between users interested in better highway service, on the one hand, and a particular community's objectives and values, on the other. These values, including, among other things, esthetics and amenities of living, may in some circumstances be adversely affected by highway improvements of greatest benefit to highway users (or to others when shifted).

California law requires that the state highway commission give consideration to expressions of community value brought before it by local agencies of governments in making its final determination on specific freeway locations. We have become convinced that these community values can be determined in the present state of the art only by the community itself and that they may best be expressed through an officially adopted comprehensive local plan which has been exposed to the debate of the political forum. Any substantial modification of such an expression of community values by state or federal interests should be made only when necessary to resolve conflict between two or more local plans or where there is clear violation of overriding state and national interests. The latter determination as well as the finding of intangible community values, involves value judgments that no amount of highway benefit chasing will resolve completely.

Discussion

Rothrock. — Zettel talked about windfall benefits of property.

Assuming that the entire cost of the highway is recovered by taxation upon the user and that it is true that there is some surplus which may fall upon property as a windfall to the owner, some economist has said that these windfalls should not be taxed to get funds with which to build additional facilities, but should be taxed or recovered for what he called the collective good.

I would like to have an opinion on that statement.

Zettel. — I think that theoretically there is a surplus of benefits over costs, which will be distributed throughout the economy in some manner. Some of it may go to consumers or because of the particuler circumstances it may well be capitalized in the values of land. I assume that when we have paid for the highway with highway user taxes only the surplus is shifted.

If we are to attack this windfall profit, we can do it through some sort of capital gains taxation, if we wish. It occurs to me there are many cases of windfalls through both the public and private activity and we need a general policy on this kind of gain.

If we put the tax on capital gains into the highways, then the windfall would simply

be that much greater. I suggested, why not tax the highway user in the first instance, so the windfall gain would be less than it would otherwise be.

It is not policy in the United States to recover through highway taxation more than the cost of the highway (using the term "costs" loosely). If we want to prevent windfalls, perhaps we could just tax the whole benefit away from the highway user. There would still be these shifts in values because of the fact that transportation has to be channeled, but the charges have to be uniform. If we could tie our financing down to a specific highway and the specific lands affected by that highway, as by a toll system, excess benefits might be recaptured and no windfalls would result.

Rothrock. — Is it possible, or is the theory tenable, that all benefits or increases — surpluses — which are created by the construction of the new highway system are not already measured in the decrease in costs of transportation of goods and people?

Zettel. — I think that the benefits accrue from the use of the highways and only in that manner. They are then distributed into the economy, depending on different circumstances with respect to different market conditions, different conditions of land use along particular highways, etc. But, of course, society in one manner or another is going to enjoy these benefits.

Rockrock. — I would call that a gradual growth of income due to the continual and increasing expansion of the transportation system, as a whole.

Zettel. — Initially, we have assumed an equilibrium situation and I have tried to leave out the growth factor in this analysis entirely. Theoretically even if there were no growth in the economy the surplus of benefits would be transmitted through the economy, given a stable economy. Of course, it is very highly complicated when you bring in new conditions, including the growth.

This is what makes suggestions about highway-caused land values seem a little unrealistic to the practical person because he sees population increasing and land values going up for that reason, rather than the reasons I was trying to express.

Levin. — I could follow your rationalization of the truck and goods concept where you tax the trucker and he passes it on. There you do not have any inequities.

When the Interstate System is completed, we will have perhaps 15,000 interchanges. These will be favored areas for land value increments, shopping centers, etc.

Assuming the scale and magnitude of present user taxes are what they are now, would you say that you would increase present user taxes in order to account for these changes and increments that are going to take place at 15,000 interchanges? How are you going to rationalize getting from the user to the persons that are getting the actual benefits?

Zettel. — Unless we change our entire concept of highway finance and attempt to recover all of the benefits I woud not do it. The user has enjoyed the benefits. He has paid enough in taxes to meet the cost. Assume that there is a surplus. This is what we are all hopefully doing — improving our transportation system by this highway program. This surplus, if we call it that, may get transmitted to consumers. It may in certain circumstances rest with the users, and it may in some circumstances cause shiftings in land values. I would not tax users — we accept the shiftings. At least, we accept the possibility of such shiftings. Therefore, I would simply ignore it. Certain property owners may have benefited; there is a windfall gain here. Certain other property owners — this is more diffused so it is not so dramatic — have been disadvantaged. We have not become sophisticated enough to tax the benefits from those whose properties have benefited in order to compensate those properties that have been disadvantaged. This would be an entirely different policy which would have little to do with highway finance. It would be simply a matter of taking care of inequities or what might be called compensable disbenefits.

Levin. — Increasingly, the highway funds are being called upon to pay for larger and ever larger areas of disbenefit, so to speak. Capital gains or windfalls of land value are at present captured through the capital gains tax and increased retail trade through

the income-tax mechanism, both of which now find their way to the general funds of the state and Federal government. Would you condone a use of the portion of these funds for highways, on the theory that this is somewhat highway oriented, or highway actuated or stimulated?

Zettel. — Yes, but I would also condone the use of such taxes for general purposes. The gains are similar to many others that take place as the economy changes or technology improves. When the railroads locate in a certain place, they have a tendency to shift land values. These are dramatic changes, probably much more than highways will cause because of the greater ubiquity of highways.

I think Heer's study indicated that the railroads caused a much greater change than is likely to happen from highways.

But I think that is part of the way our economy operates. It so happens that the public agency is making the investment in highways which causes these changes; but when the gas or electric company puts a power line in a certain direction frequently there are increments in land value. If we want to attack them we can do so through the general tax structure.

I would like to cite the case of a huge shopping center near where I live. All of the properties around there are being improved. Some are being developed into gas stations, and other facilities. Property values have increased a great deal. Now, this was private investment which affected the values for at least a block around the shopping center.

Through capital gains taxation and income taxation, as well as direct property taxation, we recapture some of the gain for general tax purposes. But there are so many causes of capital gains that I think we need only to look at the effect and go after that rather than to try to trace back to the cause; in other words, tax the effect rather than the cause.

St. Clair. — What is the relevance to this situation of the age-old custom of benefit assessments, whereby the government actually does assess individual property or strips of property for the benefits caused by highway improvements or other types of improvement?

Zettel. — These assertions do not lead me to the conclusion that all highway costs have to be borne entirely by highway users in all circumstances. One of my qualifications is that there may be a genuine governmental overlay. For example, in order to get children to a school a highway might be improved which would not be provided in response to the demand of highway users; then perhaps the cost should be charged against the school budget as a matter of public policy.

The other qualification is that in the case of lightly traveled roads and streets the realities of the highway financing tax systems are such that on grounds of equity we can improve highway financing programs by assessing the charges against the property owners for land service roads. But I am not trying to track benefits. I am not saying that the benefits accrue to property owners rather than to users.

I still insist that it is as a user that I am enjoying the road. But as a practical matter of taxation, it is easier to get at me as a property owner than it is as a highway user.

If you could put a toll gate on this land-use road, I would be perfectly satisfied that that was the proper way to defray the cost because I am using the road. But without the toll gates you can get at me best by getting at me as a property owner.

Particularly is this true for new residential roads and streets. It seems appropriate to bring these roads and streets into the highway system with direct assessments. In other words you join the system bringing your road with you.

Cherniack. — I would like to add to the comment on one part of Mr. Zettel's paper. Let us assume an improvement in a highway produces a surplus and that the surplus is divided among the different beneficiaries, one of whom is a passenger car user. Now, the passenger car user chooses to utilize his benefit in this way:

He now lives 10 miles from his plant or CBD and he chooses to move out 20 miles because his rent will be cheaper. After moving, he is the same time away from his

plant, maybe three-quarters of an hour, as before, but now living 20 miles away. Where before he had 20 miles a day to drive to and from work, he now has 40 miles, so he is contributing twice as many vehicle miles. That is the way he cooses to collect his benefit.

Of course, he has a number of companions who react in a similar manner. That is one of the reasons why we have traffic generation because we collect these vehicular miles. In the first instance, there is a 10-mi radius and an area within that circle. Now there is a 20-mi radius and an area four times as great as that of the previous circle. That creates quite a problem. The new traffic begins to absorb the capacity of the new freeway.

In addition, the man that goes out to the suburbs now lives in a sparsely settled area and really needs a car, perhaps two cars. Even though he may not be able to afford them, he has two cars now.

Our studies show that the more sparsely settled the area the more cars there are per person or per family. The more cars there are, the more trips they will generate. So from both standpoints, the fact that there are longer trips and more cars, there are both more vehicle miles and more mass to demand vehicle miles.

There is now a chain reaction that perpetuates the need for highways. Where do we go from here?

Zettel. — I guess we continue to build more highways. This is precisely what is happening. I suggest again that I think the system of taxation has some connection with the extent of this kind of impact. That is to say, if you were to provide the highway without assessing any part of the cost against the user, this chain reaction could be even greater than it is. Perhaps the user would move 22 miles instead of 20 miles if he didn't have to pay additional taxes in order to pay for the cost of the highway improvement. Thus, the results would be a little different under alternative methods of financing. The method that would deal most directly with the problem would be to defray the highway cost with direct taxes on users so that their benefits would not be as great as they otherwise would be. The chain reaction would be less than if costs were met by deficit financing or through the income tax structure or something else which would not have a direct impact on highway usage.

Cherniack. — I omitted a third point which makes the reaction even greater. That is that a heavy truck, a tractor-trailer combination, puts a heavier impact on the structure of the highway than a delivery wagon, so we try to recover the cost by increments in some way. But when we are through we have a residual that falls upon the passenger car.

But passenger car journeys to and from work create sharp peaks on the highway and absorb the geometrical capacity of the highway — and the geometrical capacity is perhaps far more costly than the structure. In other words, you can add a few inches to the thickness of concrete at less cost than is required to add a lane to provide two lanes in each direction, to absorb these sharp peaks. What do we do about it and how do we stop this chain reaction again?

Zettel. — I don't know the answer, of course. I think I would have to agree that you have put your finger on perhaps one of the critical problems in the building of modern highway facilities, including the Interstate System, because as far as I can see "Interstate System" is something of a misnomer. What we are building in California and calling Interstate highways are routes for commuters. We could take all the interstate traffic into downtown Los Angeles on a two-lane highway but we are putting 8- and 10-lane roads paralleling other freeways to serve the commuter.

On this peak hour problem, the sophisticated approach would be to find some way of pricing that peak hour movement. The prices should obviously be higher. It is a perennial problem that we have in all mass transit. The fare should be higher when you are standing and holding on to a strap than when the lady passenger travels downtown for shopping in comfort at an off-peak hour. If we had a way of assessing the added cost we should do so.

But getting away from user taxation seems to be only to aggravate the situation. The

problem is to get more sophistication into our user charge systems. Toll systems would help.

Lindman. — Several years ago I heard that the Public Works Administrator had said at a Bureau of Roads Session for Foreign Engineers, "You have been listening to all these engineers and their theoretical points and that sort of thing. Actually, we politicians make the major highway decisions in this country."

I think this points up that we have a bit of a conflict going on between the engineers and the politicians. The engineers are not exactly hopeless in this fight because they have some very powerful allies, but we still have the fact that we have major decisions made by the politicians. In fact, I had one economic colleague say that the decision to build a highway is a political decision, not an economic decision. Well, that annoyed me a bit, but the more I think of it, the more I believe he is right. I think that as I look at the Interstate System today I find the system to be entirely different from what we would have had if we had had a toll road system. That would have been an economic system.

But the Interstate System has many routes on it that I suspect can not be justified in terms of benefit-cost ratios. If they are to be justified, it is necessary to do an awful lot of stretching. If extra costs were added, such as Professor Grant suggested, I think there would be even more difficulty justifying some projects.

So my point is this, that fundamentally our highways are politically determined and I think we can only charge the users for that portion of the cost which the users cause and which benefits them. We have to expect that there is going to be a sizable residue of costs left over that are political, military and all that sort of thing.

Adkins. — I would suggest that the politician finds himself with pressures that have arisen from economic sources and that he is certainly a decision maker, but I believe that it is not as purely a political decision as your point would make it.

Winfrey. — I was pleased that the desirability of looking farther than the immediate foreground around a highway improvement has been mentioned.

Levin brought out that in considering the effect upon business and on land values it is desirable to go farther and take in a whole area. That is along the line that I suggested when I said that we need to look for offsetting types of consequences.

I think the engineer, or the engineer and economist in each field, is entirely too prone to look for benefits of a positive character. He does not search very far to find adverse conditions. It is as essential to look for those as it is to look for the close at hand benefits.

As an illustration I would like to refer back to private enterprise. A person in competitive business is not concerned about the good health of competitors. He brings out a new product or he brings out a new pricing system or changes his organization in order to make a profit within his concern. He is not concerned about others, and even beyond that he may not be concerned about the health of the nation particularly. He may even do things which are adverse to the national government, and the people as a whole, because it makes him individually a profit.

Now, as we follow this trend in transportation and building highways, I wonder if we are not getting to the point where we are willing to make highway decisions without regard to the consequences in other areas of government or in other areas of transportation. It seems to me, if we are going to do our job properly that we must look afield to see what the ultimate consequences are in all aspects and not look just solely to the highway field.

Theoretically, I have made an analysis of a proposed highway location some 20 miles in length and because of the particular circumstances involved I came up with a zero net change in motor vehicle operating cost. I also came up with a zero net change in the time values, time consumptions. But I do find that comfort, strain and convenience and the like give me the equivalent of 3 cents a mile or 2 cents a mile in benefit. I have also interviewed the people in the area and they say, we will gladly pay for it.

Therefore, as the Highway Administrator I elect to build that road on the basis that my economic study, if we can call it economic, indicates comfort and conveneince,

relief from mental strain, etc., are so highly beneficial that its construction is justified on that ground alone.

Now, then, what happens to the national economy when we build highways on that basis?

Hennes. — I think this question goes back to the basic assumption that I think everyone accepted, that we build roads to reduce the cost of transportation. I think that this axiom can be defended or attacked depending upon the way in which you want to set up the problem.

If we use the terms that people use in ordinary conversation it is not true that we build roads to reduce the cost of transportation. We build them in large part because people want to have roads, to drive on and to consume.

If we want to solve economic problems we have to find numbers to measure this desire for the people to use their wealth in that particular fashion; and so we go to Mr. Cherniack's cost of impedance, or we express this desire to avoid undesirable characteristics of travel by putting a dollar value on the avoidance of discomfort. So I think it is perfectly all right for me to spend my money on chocolate bars, or bourbon or highways if I choose to do so, rather than to produce goods which produce other goods.

Winfrey. — I didn't make my question clear. What happens to the economic system of the country if we build the highway on that basis? We have no net monetary benefit from it so we have to adjust the internal economy some way to get the money to pay for the highway. What readjustments do we go through in order to pay for the highway that we build on that basis?

Zettel. — I think that what you are suggesting (given an equilibrium situation at full employment) is that consumer preference has changed. They decide simply to buy a better road for which they are willing to pay. They are getting better quality. As standards of living rise we may insist on better highway quality. The circumstances are similar to what I tried to suggest with respect to time savings. We are measuring a lot of time saved that the people may be willing to pay for, but in order to pay to save that time they take part of their product, part of their income and buy more time and buy less of something else, or save less, if that is the case. Perhaps it comes out of savings which could reduce investment or it might come out of other consumption. One can't tell. Any kind of improvement in product which raises the price creates the same kind of reaction — for example, when people decide to move up from Fords to Cadillacs.

Winfrey. — I have no objection to building highways on that basis. I like comfort myself and am willing to pay for it. But I want to bring out the point that there is a shift internally in the economic system. It is hard to trace it to its ultimate consequences, but we each settle it in our own individual way. Nevertheless, there is an adjustment, and there are the ultimate consequences that are involved even though we can not trace them positively.

Grant. — I have a comment that I would like to make that relates to the major theme of this conference, which is decision-making on highway programming, location, and design. The point is that you have to be very careful about not counting the same thing twice.

It is easy, if you are minded to get some good benefits for your project and make it look good, to count the motorists' savings also in the land values increases. There is a classic case of this that has been quoted many times. It has to do with flood control in the Connecticut River Valley.

There was a big flood in the Connecticut River in the mid-1930's, the first such flood for some 60 years. Nobody was around who remembered that the Connecticut River could flood. And the effect of this flood was to depress greatly the value of land in the flood basin of the Connecticut River.

The Army Engineers conceived a project for relief of floods in the river valley and in figuring the benefits on this they figured the reduction of flood damages. Then they looked at the current land values and the land values before anybody thought there would

be any floods. They said these will be restored and thus they were counting the same thing twice.

These were not imperfect measures of the favorable consequences of flood control. This was the same thing being counted twice. This is extremely easy to do when you look at non-user consequences.

Now, I don't disagree with anyone who has been talking about the importance of evaluating non-user consequences to the extent that this could be done. I want to say when you do this there are conceptual problems that have to be solved and it is easy to double count.

Levin. — The way we are now handling user benefits through the benefit-cost ratio, is that we ascertain as scientifically as we know exactly what the fuel savings are, the time savings, savings in accident costs, etc. In terms of this formulation, do you think that we are double counting when we seek to take account of land increments as they occur?

Grant. — I think the only answer is a sort of weasel word and it says you may be. It depends.

Levin. — How can we avoid theoretically this double counting business?

Grant. — I would like to pass this on to some of the professional economists like Pendleton and Zettel.

Adkins. — I would like to emphasize the seriousness of the approach. The non-user benefit studies have been conducted in isolated areas and perhaps the benefits may be entirely transferred and transitional. Perhaps user groups who have borne the major portion of the cost, if not all of it, in many of our systems will look to these measured benefits and say "you have been overcharging us." The non-user groups who seem to find a finger pointed at them will say, "yes, but these studies have been made in isolated places, on small segments of road, and benefits may be transitional." I think a very serious contention may arise, and probably has already arisen, on this very point.

Lang. — Perhaps this problem can become a little clearer if we are willing to accept Zettel's thesis from a standpoint strictly of land impact.

On the economy, the only measure of benefit is the savings in user cost. If you are not willing to accept that, then the rest of what I say will not make too much sense. But I accept it without any question. Suppose you accept that as covering the economic side, including land impact. Then realize that, in addition to being an instrument of economic policy, highway improvement is an instrument of social policy. It can be used to implement social changes which the body politic considers desirable. Expenditures above and beyond what will be justified on the basis of user cost savings, which is, strictly speaking, the only economic benefit, may be judged on the basis of whether or not the social change produced by the construction of highways is what we want and whether it gives us enough of what we want. Perhaps in this framework the whole problem will become a little clearer.

This is substantially what Winfrey was trying to get at in pointing out that in fact you have many highways which do not show any user benefits, yet they are considered desirable because they implement social change. They permit the development of a different land-use pattern which the community feels is desirable and is willing to pay for. The additional expenditure that is made strictly to implement the social change then should be judged as to whether or not this social change is one which you want and is adequate.

Burch. — That is substantially the line that I wanted to mention. It seems to me that the public wants highways not because they are economically justified or because they are self-paying. The people simply want them as a manifestation of their desire for a higher standard of living, even as they want a 4,000-lb automobile to drive a mile to get a spool of thread. There isn't anything economic about that. But they simply want to do it.

If in the process there is some waste, either in the use of the big car or in the

excessive expenditure for the highway of the type which you say is not paying, it has not concerned the people in general. For a great many years we have been riding an upward curve of standard of living, and no one has been concerned.

I think the people do not look at highways as an end product or as something which creates wealth, but as something which is desirable and often necessary as a tool for the creation of wealth, or for social values. Highways are a means to an end in the eyes of the body politic rather than an end within themselves.

Pendleton. — I am in complete agreement with Levin that we badly need an overhauling of our terminology on benefits. For instance, we practically always classify land value changes as non-user benefits. Now, I will go along with Zettel and say that they probably are a reflection of the surplus of user benefits above what the user has to pay for the use of the facility.

I would go further and say the main purpose in studying land values may well be to get a better measure of user benefits. In other words, as user gains, which are not charged for, become capitalized into land values I think we have here a key source of data for what nonmeasurable comfort and convenience are worth to the people who enjoy them. The thing is, you don't pay the highway department for them. You pay the land owner for them. If we could find out enough about these land values, I think we might go a long way toward solving this question of how much the more elusive benefits are worth.

The two sources of information which seem most plausible to me are the toll road experiences and land-value impact data, which, if they are collected and handled in the right way, should lead to very valuable insights into various other benefits.

I have one more comment for Mr. Adkins on this general question of handling land-value data. I was called upon about eight months ago to review his land-value study of the Dallas Expressway. It occurred to me at that time that when you choose a control area with which you are going to compare the land-value increments along a new highway you run a very great risk. The closer the control area is in characteristics to the highway area the more likely the control area is to experience a negative effect on land values. Thus, when you make the comparison of highway area values with control area values you are really exaggerating considerably the road influence. What in effect happens is that the highway drains off some of the value which would have accrued to the control area in the absence of the highway.

This is just a methodological question. I have no answer to it but I think it ought to be recognized because it is another consideration which may lead to less spectacular discoveries of land value increases along new highways.

Adkins. — I think there is no doubt that some of the laboratory conditions we assume in economic impact research are not so good. But upon occasion we are forced to plunge into the problem rather than back and hedge. I appreciate your comment, and certainly it contains elements of truth.

McKain. — I believe that in the awarding of defense contracts the government tries to single out labor surplus areas, which is not an economic thing to do, strictly speaking.

In considering the net effect of a highway modification I think it is important to go back to the original objective. For example, a certain region may benefit and its land values may go up even though the land value in another area may go down. But if the objective of that program was to improve the economy of the area, it is a very important thing to evaluate the influence. The justification for some of these so-called narrow studies can be based on this ground. When we talk about the consequences to whomsoever they accrue, we should not have too broad a base when we talk about the whomsoever. We should think of the consequences that the original legislation or plan was intended to effect.

Hoch. — Mr. Cherniack points out that demand in the long run will probably be a lot more elastic than in the short run, demand for highway services in particular.

This undoubtedly will imply that benefit-cost ratios, which are developed for the short run essentially will change. Now, I am not sure in which direction they will change. One hunch is that with increased demand you will probably need more capacity. That is why highway engineers often understate future needs.

Rothrock. — Changes in land values either are a derivative of the change in costs of transportation, or they are transferred from a similar place. I think that is a double count.

If that is true — I think that double counting, counting these values that you are willing to pay for, or this money you are willing to pay for convenience, is all right, if you can quantify. But when you quantify some of these increased values of land, commercial, residential, increased business, some of those things can be shown to be double counting if you take full account of the differences in the cost of transportation as well.

Gardner. — Mr. Levin says, "In one or two instances an entirely new approach is being taken."

Inasmuch as we in Pennsylvania have such a study going on and we haven't reached the point of no return, I wonder if you could enlarge on that for me, the particular point you have in mind?

Levin. — The general reference was to some of the studies going on in Prof. Hennes' bailiwick where he has some economic geographers who are focusing on spatial interrelationships between economic and commercial activities and highways. Dr. Garrison, for example, has developed, quite appropriately, the concept that in a given cross-section of time there is an observed relationship between transportation facilities and the arrangement or organization of commercial enterprise.

Commercial enterprise will gather around existing facilities in a certain way and you can document this pattern. Then you do something to your transportation plant, resurface the road or do anything, divide the highway, and over a longer period of time this has some effect geographically and functionally on the regrouping.

There is some kind of regrouping of commercial enterprise, or of land uses generally, resulting from improvements and accessibility and other transportation characteristics.

Garrison is seeking ultimately to document a theoretical approach with some empirical data to develop some generalized relationships between transportation changes and the regrouping of commercial enterprises and other land uses.

I think it is a hopeful and refreshing approach to this problem.

Hennes. — I would like to refer to the discussion on double counting benefits.

This danger actually does exist, of course, if land values go up in response to reductions in vehicle operating cost; but of course I think we may also assume that many times land values go up not because of reduction in vehicle operating cost but because the road improvement makes driving more pleasant and convenient. That is, suburbanites may move to some particular suburb and buy a Cadillac. We may assume they didn't move in order to achieve reductions in vehicular operating cost, but in order to achieve additional ease in getting to work.

In such a case we don't have double counting unless we actually did place some money value on these amenities and included them with vehicular benefits. If benefit-cost ratios don't include these amenity values, then increases in land value that are the result of these amenity values do not represent any double counting.

The possibility of double counting is present not only in the transfer of user to non-user benefits, but also in the independent appraisals of different proposed additions to a road system.

Seattle, for example, is a city which is bounded on one side by Puget Sound, and on the other side by Lake Washington. Three major public improvements in transportation had been advocated in recent years, each involving user and non-user benefits.

One proposal is for a bridge to cross Puget Sound. This was subjected to a study. The bridge would produce a new bedroom area for Seattle.

Another study dealt with the north-south freeway. This would introduce a bedroom area for Seattle to the north. It would produce a certain amount of traffic. The third proposal is an entrance to the city from the east, with another bridge across Lake Washington. This would introduce a new residential area.

Each porposal is considered separately. If all three were built simultaneously there would not be this much increase in the population of the city. Both the non-users'

benefits would have been exaggerated by this separate counting and also the actual traffic that is used to justify this project.

I want to read from an article from Garrison's (et al.) book, "Studies of Highway Development and Change" (Univ. of Washington Press, 1959).

"In discussions with both lay and technical groups, the author has often encountered the argument that attention to nonvehicular benefits is, at best, specious double counting of benefits. It is argued that nonvehicular benefits (observed, for example, as increases in property values) should not be brought into benefit calculations along with materials on travel time savings, lower cost of vehicular operation, and other items related to vehicles. It is observed that nonvehicular benefits are actually anticipated savings in time, vehicular operating cost, etc., and these savings are already counted when vehicular benefits are computed. This observation certainly contains elements of truth. It is the assertion from this that is faulty — that no attention should be given to nonvehicular benefits.

"The element of truth in the statement above is a result of faulty estimations. When properly estimated... counting of vehicular and nonvehicular benefits does not lead to double counting.

"It is true that improper counting of benefits of vehicular and nonvehicular types may lead to double counting, and thus an overstatement of highway benefits. It is false to say that counting benefits of non-vehicular and vehicular types necessarily leads to double counting.

"The difference between the two previous statements may well be that between an adequate and efficient highway system developed in terms of its total benefits to the economy, and an incorrect system developed in terms of a partial evaluation or an over-evaluation of benefits."

Rothrock. — I agree with him. He also agrees that there is some double counting.

Hennes. — Double counting is most apt to occur in analyzing individual improvements, rather than system improvement.

Rothrock. — Where a man has had the value of his land changed because it is converted from a swamp to good land because of construction of a highway, his benefit is the same as if the state had built a dam to accomplish the same purpose. That is a benefit presumably which is not double counted.

Now, as far as these other benefits are concerned, the things that you talked about — the comfort and convenience factor — a man pays a higher price for the land because its adjacence to the highway gives him comfort and convenience. He pays for that because of his use of the highway. And the traffic on the highway accounts for that if it is quantified.

Hennes. — Yes, if it is quantified, but it isn't, yet.

Rothrock. — I was inclined to think that the whole thing could be measured only in the benefits to transportation but I agree with the Garrison statement.

Campbell. — Mr. Newcomb began to explain a concept of his about the economic purpose of highways and their effect. I would like to hear him further on this concept.

Newcomb. — I come at this from an entirely different standpoint than most of the rest of you. I was in the Council of Economic Advisors where the problem was economic growth and what the highway does for the economic growth of the country.

Now, that is a little bit different from asking what it costs to build a road, and what the highway user gets out of it. I think, as a matter of fact, economic growth is just as important a concept.

A couple of years ago, I said in the Engineering News-Record that we needed to spend a lot more on highways than we were spending, from the standpoint of economic growth. I got back very strong letters from engineers asking if I didn't know that railroads were more efficient than highways for moving goods and that we should spend the money on them.

As an economist, I came to the conclusion that businessmen make decisions on the

basis of what is most profitable for them and they were using highways rather than rails because it was more efficient.

So I went to a steel company and asked why they had shifted their movement of steel from rails to highways. They said, "when we shipped by rail to Youngstown Stove, we had to stock up a full day's supply of steel on the cars that they gave us. Then the locomotive would come along some time in the evening and shuttle them off to a yard. Maybe they got on the right tracks that night and maybe they didn't. If they didn't, they stayed there all day and the next night another locomotive came along and hauled them over to Warren and then they got shuttled over to Youngstown Stove. That meant a lot of inventory, uncertainty and costs.

"Now, we just have one trailer back against the door and load three rolls of sheet. When we have loaded the three rolls, a tractor comes along and three hours later the delivery is made to Youngstown Stove. And if the tractor breaks down, we get another one in an hour or so."

This was an entirely different problem from the cost to move a ton over a mile of road. It was the total problem, the inventory accumulation, the handling, the accounting, the cost of the finished stove. The finished stove in Youngstown was cheaper because of the greater highway efficiency, so Youngstown could compete more effectively.

We looked at highways from the point of view of what they do to the economy. The economy grows because the productivity of man-hours goes up and it has been going up 3 percent a year. The increase in man productivity is cut a little bit in the production of man-hours per year, because of the reduction in hours of labor; but the net result of increases in productivity per man-hour, increases in labor supply, and decreases in number of man-hours per man is something like 4 percent a year.

This is what the highway is for. The highway should be a device for increasing the productivity of the belt lines.

But if men who meet in places like this can consider the highway not just as something that involves costs of 2 cents or 10 cents a ton-mile, but as something that affects the cost of the stove that comes out, I think our problems may be somewhat different from what they have appeared to be as we have discussed them.

For instance, the question was raised about the low density of traffic. It has been implied that the farm road is inefficient — that it doesn't earn its own way. Well, the bolls of cotton in the field are almost worthless; they do not have any value unless and until we get them to a gin that can put them into a bale and make them usable, and until we can move them from there to a mill that weaves them.

Counting the tons of cotton that go over this little road before they get to the main system may suggest that the road isn't earning its way at all. But it it were not for that little road, we wouldn't have any clothes on our backs. So somehow or other we should look at the road as a link in a chain which makes the total system work. Our pricing system isn't such that we price each link in such a fashion to make that link appear to pay for its own way. But if we look at this from the standpoint of economy, I think that even the farm road is essential to the growth and prosperity of the country as a whole. So our problem, it seems to me, is determining what a growing economy needs.

I would take exception very vigorously to Zettel's efforts to discuss the problem assuming a stable economy. Growth is the essence of our economy and has to be put into our formula before we talk of anything. We have to think in terms of growth.

If we think of how the highway enables the economy to grow, we can explain many things, that from the standpoint of stable equilibrium, and each cost matching each price, doesn't seem to make sense. So I would like to emphasize that this group is working in an essential part of a system which is growing vigorously. The highway should be studied as a part of a growing system, not as a piece of mechanism operating by itself.

Levin. — Let's forget taxes. Suppose you wanted to join with two alternatives, A and B, two cities. Let's say they cost the same thing from the standpoint of construction and maintenance and right-of-way maintenance and you computed user benefit-cost ratios and obtained equivalent ratios.

Let's say that one of these alternatives has a terrific industrial potential, it will open up a great industrial area. The other one is negative from this point of view. Do you think it legitimate to explore the industrial potential and that this should bear on which of these two routes you should settle on?

Zettel. – The answer is, yes, of course.

Levin. – In other words, you are not discounting entirely the use of non-vehicular benefits?

Zettel. – The last sections of my paper pointed out that we should consider the economic, and somebody pointed to the sociological. I used the terminology "community values," because we have some serious conflicts coming up in my state.

We actually, in certain circumstances, have conflict between what would be an economic analysis from the point of view of users, and what the community might like to be like, and the example you used would be a consideration when other things are equal. There may actually be a conflict. One of these may be better from the point of view of the users than the other. This is a judgment that has to be established by the community.

This is the one other thing I would insist on, that this sort of thing is a community judgment and not a Washington judgment, for example.

CLOSING SESSION

Friday, September 18, at 4:00 P.M.

G.P. ST. CLAIR, General Chairman, Presiding

The closing session of the Conference was devoted to a summarization of the discussions and a general agreement by the participants as to the future value of the Conference results.

St. Clair. — We have asked three men to give us briefly their reaction to the conference so that we may find out what kind of conference we have had.

Baker. — Forest Green and I were comparing notes and, after such a stimulating discussion at such a high level, we are convinced that this appraisal is going to be anticlimactic.

Quite frankly, I have quite a list of ideas and I could talk at great length on the numbers of research ideas that have occurred to me throughout this conference. I suspect that there is no one in this room who has not added at least one such idea; and so I can say with complete assurance that as far as I am concerned this has been a successful conference.

I am going to mention briefly one idea that has been in my mind, perhaps from the very beginning of the conference. It attacks really the very foundations of applying economic analyses to decision-making.

This does not mean that I would throw out economic analysis. However, it seemed to me that at the beginning far too little was said about objectives and guides to this problem of making decisions based on economic analyses. We accepted an assumption, it seemed, quite readily, that decision-making can be based on economic analyses.

It has been perhaps in the last two hours that we have come close to focusing on this phase of the problem.

The idea struck me right from the beginning, when Cherniack discussed the large part of the iceberg that might be below the surface. The end point is: "Would you as a highway administrator be impressed by someone attempting to convince you that you should make one decision or another if he has to admit that he can't see very much of the iceberg?"

I wonder whether our basis for economic decision-making is held up by one thin pile that goes down to bedrock, or just how many piles do we have, or do we have them not quite deep enough yet, or should we have a different type of pile?

Keep in mind I am not condemning economic analysis. I think it reflects what occurs when you go into a new area with a theory which has been developed for some other set of conditions and try to apply it to another problem.

Having been active in soil mechanics for many years I have been condemned for using elastic theory with a material which anybody can tell is not elastic. And, of course, what we do over the years is to transfer from the elastic theory to something else. We are still fundamentally based on the elastic theory because this is the best way to quantify a very difficult problem.

So I am suggesting that certainly from the enthusiasm here and the demonstrated knowledge of the problem, I think the economic theory is the proper theory. But I am concerned that we explore this iceberg just a little bit more.

With reference to exploring the iceberg I think the one area of science which is most missing from the highway field and particularly from this gathering, is the group that attempts to quantify human behavior. We get quite a disagreement on what people want. From Mr. Gardner we have the thought that you can't get a gas tax through the legislature. Mr. Burch thinks that perhaps the gas tax can be raised. In Ohio I would be inclined to agree with both of them. It was extremely difficult to get an increase through the legislature, but during the ensuing period — a month or two months — there was absolutely no decrease in the sale of gas. In fact, I think the normal trend of gas sales continued.

I don't know that we are sure what people want. I think that in a democratic society this is important because decision-making must account for these desires. I was impressed with the fact that Mr. Zettel very clearly approached this from the viewpoint of community planning.

I will finish on that note, but emphasizing the fact that I am not suggesting the abandonment of the economic theory.

Green. — During the past two days interesting and worthwhile presentations and discussions have been shared by individuals having a wide variety of backgrounds and interests. A single subject has been approached from many angles. It has occurred to me that this subject might have appeared less complicated, and the related problems somewhat easier to solve, if we could have paused for a moment to give more emphasis to the fact that there are actually at least three basic problems, or phases of a single problem, for which answers are needed. Applications of economic data in general should be divided into three separate categories:

1. Data needed for broad, general planning, including area studies and fund allocations.
2. Specific analyses for developing construction programs with project priorities.
3. Detailed engineering analyses to aid in highway location and design on individual projects.

I believe that Carl Fritts was right when he said that a primary need for highway economic studies is in its application to analysis of system needs and broad planning. But I also think that Karl Moskowitz was right when he emphasized so strongly that specific project analysis is also needed.

It is the last item of these three phases that I would like to discuss briefly. I think that I am speaking for design engineers in state highway departments and in the Bureau.

The need for engineering analyses for use in location and design is specific and urgent.

We need a practical method for routine analysis, by which each individual project can be appraised by engineers without special research by planners or highway economists.

We need to be able to decide upon a proper location, or best design.

We need a procedure that is factual, reliable and comprehensive, and easily understood by non-economists, yielding sufficiently accurate results to at least provide relative indications.

And we need to work together, taking advantage of all of the varied talents and different specialties, to produce such a tool for the engineer.

It has been almost unbelievable the way in which the very few design guides have been so universally accepted and used by design engineers. The Capacity Manual, for example, has been accepted all over the country, even though some of the data have had to be adjusted and expanded from time to time.

The same acceptance has been evidenced for the two Geometric Design Guides.

At the time the Informational Report on Road User Benefit Analyses for Highway Improvements (AASHO) was prepared, good information was lacking on many factors and this fact was carefully noted in the publication. Yet design engineers have made

extensive use of this report, knowing that it was one of the few prescribed and standardized methods available as a guide.

A new printing is needed at this time and we are still sadly lacking in usable data. Research is under way, and theories are being developed, but design engineers are still using cost information that is at least eight years old, and some of it much older. We need more accurate and more comprehensive data now. Such a guide could never be kept current, because some data would be out of date before it could be printed. New approaches are constantly being developed and refined. Why should we be kept waiting for the final word on this involved subject, when we know that this kind of a thing can never be finalized?

Now, just a word about the problem of relative accuracy of the various factors in an economic analysis.

In college classes there usually is at least one lecture in any engineering course concerning the importance of balanced data; that is, factors or measurements with comparable degrees of accuracy. We all recognize that this concept is important. Yet, in the discussions during this conference this subject has not been emphasized. It is recognized that some types of data may be readily obtained to a greater degree of accuracy than others. It is important that a proper balance be established in applying this information.

There seems to be at least one basic fault with our past performances. There has been too wide a gap between research and practical application to specific projects. The scope of data gathering has been increasing faster than procedures have been developed to help the engineer with location and design problems. We need to continue our broad approach to research, but we also need to stop and re-appraise the situation, and come to grips with the problem of providing a workable, everday tool to help design engineers do a better job. This conference may provide some additional incentive to help bring this about.

St. Clair. — Thank you, Mr. Green. I am glad we scheduled this series of reactions. We will now hear from Hope Wiley of the New Mexico State Highway Department.

Wiley. — This conference has been very stimulating to me. Some of the things I have heard here had never occurred to me before.

I thought the discussions concerning economic analysis touched on every conceivable angle. I, for one, had never considered the possibility that there might be benefits connected with a death, yet, it was suggested that from a cold-blooded economic viewpoint this might indeed be so. I believe we all recognize that economic analysis is the proper approach in determination of feasible and defensible expenditure of public funds. I was, however, very surprised to find such wide diversity of opinion as to what items should be included in these studies, and as to the monetary value of the various items.

The determination of road-user savings, although involving many controversial items, appears to be not too difficult. The evaluation of "consequences to whomsoever they accrue" in some instances seems almost imponderable. There are many indirect benefits and damages which are elusive, and which overlap or dovetail in such manner that to place a monetary value on them seems unlikely for some time yet. It is encouraging that so much research is in progress.

One of the problems that we have in the states is occasioned by the fact of indirect savings or consequences experienced by those who do not use the highways, and even a lot of the savings that are made by road users themselves are dollars that do not find their way into the road fund. Now, this perhaps is proper, but since the need invariably is larger than the money available, there always seems to be the need of additional money.

As to the matter of programming, which is one of the very important problems that we have in the states, I was a little disappointed in this conference, as I have been disappointed over the last two or three years, because, as Mr. St. Clair put it, many seem to be looking down their noses just a little bit these days at the idea of using sufficiency ratings in programming. I don't subscribe exactly to the method of evaluation which Karl Moskowitz first used some 13 or 14 years ago, but we do have methods that have evolved which give very valuable information for programming. These

ratings are measures of the ability of present roadways to perform the job that they are called on to do. They give a good indication of a highway's structural adequacy, how safe it is, and whether it has the capacity to handle the volume demand.

From these data we can determine what is wrong with a road section and get a fairly good, quick appraisal of what is needed to bring that road up to date or up to some adequate standard. We can separate the goats from the sheep by this method and get all of the critical sections into a list and arrange them in order of their adjusted rating. This gives a very valuable working tool for setting up priorities.

I hope that with all of the work on the more complicated economic analyses we will not overlook the fact that we do need something to use in programming; something that can be applied to systems, that can be explained, and used to convince the public that we are trying to accomplish the thing that will do the most good for them, and will bring the over-all system up to a reasonable degree of adequacy.

Now a word or two about systems. I think Mr. Moskowitz is right when he says that when a road needs improvement, it needs improvement whether it be on a system or not. But the essentiality of a road should be considered in the determination of what mileage goes on a system.

We must have systems, if only for purposes of administration, and because certain moneys are set up by law for expenditure on specific systems. These systems quite often are established jointly by the states and the Bureau of Public Roads, and the state system itself is generally created by law or by the state highway commission. We all must recognize that many, many miles of roads on these state systems are not, and never will be, self-supporting. Yet, they often are vital to the very existence of many residents.

As I said before, the needs are always higher than the revenue. We must evaluate these systems by some method, whether by economic analysis or sufficiency ratings; and on the basis of available revenue, we must either cut down the mileage, if that be possible, plead for additional revenue, or simply struggle along as we have always done, trying to do the best job we can on the mileage for which we are responsible.

We may think, or be reasonably sure, that we know what the public needs and what we should do to correct that need. But to convince the public of this is not always so easy.

St. Clair. — I know that there are two people who want to offer resolutions.

Baker. — I believe all of us are aware that we have several sponsoring agencies for this meeting. The Automotive Safety Foundation and the Bureau of Public Roads each made $1,500 available very graciously, and the Highway Research Board has of course lent their talent and staff, plus some financial outlay, to its conduct.

Therefore, I would like to propose the following resolution and move for its adoption.

> RESOLVED: The conferees attending this Workshop Conference on Economic Analysis in Highway Programming, Location and Design wish to acknowledge and express formally their sincere appreciation of the contribution of the Automotive Safety Foundation, the Bureau of Public Roads and the Highway Research Board in sponsoring this meeting.
>
> Further, we feel that the caliber of the discussion and the spirit that prevailed have resulted in a most stimulating and worthwhile period of study, and that future research and utilization of economic analyses in the transportation field should be markedly accelerated.

(Motion was seconded by Zettel and unanimously adopted.)

Fritts. — This has been a very excellent two days of discussion and certainly I for one appreciate all of the wholehearted participation by every person here.

Out of all these papers that have been presented I know that we are going to get some real value and some stimulation but I am inclined to believe that this sort of thing can be of even more value particularly as it relates to the work of the Highway Research Board. So I am going to propose a resolution:

> RESOLVED: That the Department Chairman take under consideration

the desirability of having prepared by an appropriate committee a series of problem statements on the important aspects of analysis as pointed up by this Workshop.

That either the Committee on Economic Analysis take under consideration the preparation of this series of research problem statements or that an ad hoc committee be appointed to do so. And that in the meantime anyone in the Conference is invited to send suggestions to the Board for such statements, these to be referred to the proper committee chairman.

I think that such statements would be extremely helpful to the work of the Board and they might also be helpful to the work of a lot of other agencies who are interested in this field.

(The motion was seconded by Levin and approved.)

Campbell. — On behalf of the Board I would like to express appreciation to Mr. St. Clair for his able guidance and to each one of you for your valuable contributions. I am sure that those who planned the meeting have had their expectations realized. It was not expected that you would come here and solve all of the problems but rather that the problems might be placed in better perspective and a research prospectus prepared. I believe that the resolution just passed will help to do that.

St. Clair. — I want to add my thanks to everybody who participated and also to the men who have really done the organizing of this Conference, particularly Earl Campbell, who is an indefatigable worker, and Rob Winfrey, Carl Saal, and Bob Hennes, who helped out on the organizing.

But it is the participation here, and particularly the discussion between papers that has made this conference a real success, in my opinion, and I thank you all.

Appendix A

If a highway is to operate at tolerable speeds as recommended by the AASHO, the average daily volume of traffic should not exceed the following:

Width (ft)	ADT[1]
18	2,600
20	2,950
22	3,300
24	3,800
24 - Divisor - 24	18,000

[1] Adapted from p. 93 AASHO Design Policy for Rural Highways.

It is obvious that the above values pertain to the final year of the life of the highway, since volumes are increasing every year and at a rate of 5 percent per annum. Therefore, assuming a life of 20 years for the original construction and 20 years for one resurfacing, it follows that the volume of traffic when originally constructed should not exceed one-fourth of the above values, and that the average ADT over the 40-yr period is one-half the sum of the original ADT and the 40th year ADT. These values are as follows:

Width (ft)	Const. Date ADT	Avg of 40 - Yr ADT
18	650	1,625
20	740	1,845
22	825	2,063
24	960	2,375
24 - Divisor - 24	4,500	11,250

It follows then that over the 40-yr life, for tolerable driving conditions, and per mile of highway, the following vehicle miles will be driven annually for the respective widths: 593,125, 673,425, 752,995, 866,875, and 4,106,250.

In Addendum 1 to this Appendix will be found the above types of roads, including the costs of original construction, resurfacing, right-of-way, maintenance, and administration but excluding any interest charges. If these roads are to be self supporting from road user taxes, it is evident that the annual cost, divided by the average vehicle miles will determine the annual revenue per vehicle mile required from tax sources. Therefore:

Width (ft)	Annual Cost ($)[1]	Avg. Vehicle Miles	Tax Requirement Per Veh Mi ($)
18	4,681	593,125	0.007892
20	5,067	673,425	0.007524
22	5,328	752,995	0.007076
24	5,984	866,875	0.006903
24 - Med. - 24	22,008	4,106,250	0.005360

[1] Flexible type paving.

Let us examine what the highway user is presently paying per vehicle mile for road use.

From Addendum 2 of this Appendix for the 1957-1959 biennium, the net income from the 4½ cents fuel tax (½ cent of the 5 cents tax goes directly to counties) amounted to $283,783,761, of which $74,173,660 was distributed by law to municipalities leaving a net for state highways of $209,610,101. Motor license fees totaled another $157,139,166 and Federal-aid allocations total $142,176,000 (the 1960-61 allocation figures are used for purposes of "future" costs in the following exposition). The latter item is paid by road users and rightfully should be credited to his payments.

In total, then, the road user paid for State Highway expenditures:

Gasoline tax	$209,610,101
Motor license fees	157,139,166
Federal aid	142,176,000
Total	$508,925,267

The vehicle miles driven during the above period as shown in Addendum 3 of this Appendix is 38,870,000,000 plus 40,170,000,000 or 79,040,000,000. Thus, the user has been contributing $508,925,267 divided by 79,040,000,000 or $0.006439 per vehicle mile. (Note that the Federal-aid shown above includes $99,186,000 for the Interstate System, which amount is scheduled for a 13-yr period, and might more properly be prorated over the 40-yr road life.)

By comparison of $0.006439 with the annual cost figures, it is evident that only the 24-ft divided highway is self-sustaining. Although this divided highway is in reality earning money for the system, there are only 319.5 miles of them out of 38,220.8 miles of rural roads on the state highway system. So their earnings are insignificant in the total picture.

It is therefore evident that, without an increase in revenues, the service rendered by our roads will be sub-standard, since we are compelled to put higher volumes of traffic (ADT) on 2-lane highways. Congestion must therefore be accepted, and lower travel speeds result.

What is the difference in gas taxes required to make the roads self sustaining? It has been calculated that on the average, commercial vehicles included, one gallon of gasoline is required per 13 mi of travel. One cent tax therefore results in $0.007692 per mile revenue. The following table shows the tax increase thus required:

Width (ft)	Difference Between Annual Cost and Present Tax per Veh Mi	Tax Increase, ¢ per gal
18	0.001453	1.89
20	0.001085	1.41
22	0.000637	0.83
24	0.000464	0.60

It can be shown that at the present tax levels, to make a 24-ft-highway self-sustaining would require an average ADT, over a 40-yr period, of 3,546 vehicles, compared to the previously indicated 2,375 vehicles. With this additional volume, about 2½ mph of speed will be lost, or, in other words, it will take 0.063 min more to drive one mile. If time is of value to the operator, it and the vehicle costs will approximate $2.00 per hr (and in the cost he pays for transportation of goods and services, a substantially higher figure). In 100 miles, the lost time will amount to (0.063 ÷ 60) x 100 x $2.00 or 21.0 cents.

However, if the road user pays an additional tax of 1¢, these 100 miles of travel cost him only $\frac{1¢}{13\ \text{mpg}} \times 100 = 7.7¢$ additional.

In other words, for every saving of $1.00 in gas tax, he will be paying $2.73 in time and operating expense.

Similar savings can be demonstrated for the other indicated widths of highways, but the 24-ft width has been selected as the desirable safe highway to build.

The question is then raised, as Administrator of the Highway System, is it the proper functioning of our office to permit this concealed waste of the highway users money?

Furthermore, it is evident from the tables that narrower widths and lesser volumes become increasingly inefficient and incapable of "paying thier own way." Therefore, the minimum possible investment should be made in them.

ADDENDUM 1

HIGHWAY COSTS PER MILE

Const., R/W, and Eng. Based Upon 1958 Costs
Resurfacing and Maint. Based Upon 1957 and 1958 Costs

	Type	High (Flex)
18 ft		
	Const. cost	98,932
(15%)	R/W	1,485
	Resurf.	22,453
(10.7%)	Eng. and admin.	13,100
	Total	135,970
(40 yr)	Annual charge	3,399
	Annual maint.	1,158
(10.7%)	Eng. and admin.	124
	Total annual cost/mi.	4,681
20 ft		
	Const. cost	125,824
	R/W	1,885
	Resurfacing	22,102
	Eng. and admin.	1,600
	Total	151,411
	Annual charge	3,785
	Annual maint.	1,158
	Eng. and admin.	124
	Total annual cost/mi.	5,067
22 ft		
	Const. cost	130,768
	R/W	1,968
	Resurfacing	24,777
	Eng. and admin.	1,685
	Total	159,198
	Annual charge	3,980
	Annual maint.	1,158
	Eng. and admin.	124
	Total annual cost/mi.	5,262

	Type	High (Flex)
24 ft		
	Const. cost	150,586
	R/W	2,260
	Resurfacing	28,000
	Eng. and admin.	1,990
	Total	188,098
	Annual charge	4,702
	Annual maint.	1,158
	Eng. and admin.	124
	Total annual cost/mi.	5,984

	Type	High (Rigid)
24 ft (Div. 4-lane)		
	Const. cost	726,701
	R/W	10,900
	Resurfacing	56,000
	Eng. and admin.	8,480
	Total	802,081
	Annual charge	20,052
	Annual maint.	1,767
	Eng. and admin.	189
	Total annual cost/mi.	22,008

ADDENDUM 2

PENNSYLVANIA DEPARTMENT OF HIGHWAYS
MOTOR LICENSE FUND
RECEIPTS AND EXPENDITURES
(1 June 1957 – 31 May 1959 Biennium)

Item	Est. for Period Ending 31 May 1959 [1]
Balance – start of biennium on 1 June 1957	$ 140,488,637
Gasoline and fuel use tax-regular 0.045¢	283,783,761
Gasoline and fuel use tax-flood disaster 0.01¢	4,746,687
Motor license fees	157,139,166
Federal-aid payments to Pennsylvania [2]	155,141,231
Construction and miscellaneous receipts	13,237,341
Transfer from general fund-state police	1,197,079
Total collections and receipts	615,245,265
Total funds available for period	755,733,902
Expenditures	
All other departments expenditures	60,611,212
Cities, boroughs, townships regular approp.	74,173,660
Fund 11 – highways and bridges – flood disaster	9,300,804
Fund 12 – paid to political sub div – flood disaster	–
All other appropriations for highways	44,761
Total other expenditures	144,130,437
Fund 28 - by Department of Highways	
Construction and reconstruction and resurfacing [2]	327,692,136
Right-of-way	57,661,070
State highway and bridge authority rentals	15,822,197
Maintenance	95,730,478
Special work and local roads	3,302,316
Administration	47,988,215
Engineering contracts	23,562,081
Stores and operation of equipment – credit	1,905,040
Purchase of equipment	9,989,503
Total general operations	579,842,956
Total expenditures – motor license	723,973,393
Actual balance available	$ 31,760,509
Plus unpaid vouchers and adjustments in process motor license fund balance	

[1] Revised estimate date 6 March 1959.
[2] Does not include state highway and bridge authority projects.

2-1-58

COMMONWEALTH OF PENNSYLVANIA

History and Forecast

of

Population, motor-vehicle registrations, travel, and fuel consumption of the highways

1930 - 1991

Group 1

		Potential Driver Forecasts			Motor-Vehicle Registrations		Trucks and Buses					Motor Vehicle Travel		Motor-Vehicle Fuel Consumption		
Yr	Total Population (1,000)	Pop. age 15 to 74 (1,000)	Total Drivers Licenses (1,000)	Ratio of Col. 4 to Col. 3	Total Veh. Regist. (1,000)	Pass. Cars (1,000)	Trucks and Buses (1,000)	% Trucks and Buses of Total Veh.	Total Veh. per 100 Persons	Total Persons per Veh. (all veh.)	Pass. Cars per 100 Drivers	Miles per Veh. Present Pred.	Total Pred. Travel (million veh. mi.)	Avg. Mi per Gal	Avg. Gal per Veh.	Total Gal (1,000,000)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(10a)	(11)	(12)	(13)	(14)	(15)	(16)
1930	9,649	6,561	2,112	0.322	1,775	1,545	230	13.0	18.4	5.44	73.2	6,583	11,684	13.0	506	898,739
1931	9,707	6,601	2,165	0.328	1,764	1,532	232	13.2	18.2	5.50	70.8	7,785	13,733	13.0	598	1,056,357
1932	9,764	6,640	2,101	0.316	1,683	1,453	230	13.7	17.2	5.80	69.2	7,627	12,837	13.0	586	987,461
1933	9,784	6,653	2,089	0.314	1,653	1,415	238	14.4	16.9	5.92	67.7	7,925	13,100	13.0	609	1,007,697
1934	9,795	6,661	2,185	0.328	1,700	1,466	234	13.8	17.4	5.76	67.1	8,379	14,244	13.0	644	1,095,688
1935	9,774	6,646	2,260	0.340	1,764	1,516	248	14.1	18.0	5.54	67.1	8,329	14,692	13.0	640	1,130,137
1936	9,767	6,642	2,421	0.364	1,888	1,626	262	13.9	19.3	5.17	67.2	8,479	16,009	13.0	652	1,231,433
1937	9,790	6,657	2,583	0.388	2,005	1,739	266	13.3	20.5	4.88	67.3	8,813	17,670	13.0	677	1,359,249
1938	9,852	6,787	2,714	0.401	1,997	1,732	265	13.3	20.1	4.98	63.8	8,766	17,505	13.0	674	1,346,545
1939	9,901	6,733	2,828	0.420	2,076	1,804	272	13.1	21.0	4.77	63.8	8,905	18,486	13.0	684	1,422,004
1940	9,896	6,729	2,950	0.438	2,168	1,884	284	13.1	21.9	4.56	63.9	9,101	19,731	13.0	700	1,517,775
1941	9,918	6,744	3,118	0.462	2,309	2,017	292	12.6	23.3	4.30	64.7	9,131	21,083	13.0	702	1,621,781
1942	9,714	6,606	3,071	0.465	2,178	1,894	284	13.0	22.4	4.46	61.7	7,518	16,375	13.0	578	1,259,615
1943	9,424	6,408	2,910	0.454	1,983	1,707	276	13.9	21.0	4.75	58.7	6,317	12,526	13.0	485	963,566
1944	9,247	6,288	2,639	0.420	1,928	1,645	283	14.7	20.9	4.80	62.3	6,876	13,257	13.0	528	1,019,750
1945	9,180	6,242	2,755	0.441	1,983	1,682	301	15.2	21.6	4.63	61.1	7,667	15,203	13.0	589	1,169,456
1946	9,880	6,718	3,090	0.460	2,209	1,854	355	16.1	22.4	4.47	60.0	9,220	20,368	13.0	709	1,566,737
1947	10,201	6,937	3,219	0.464	2,393	1,994	399	16.7	23.5	4.26	61.9	9,198	22,011	13.0	707	1,693,179
1948	10,287	6,995	3,323	0.475	2,571	2,140	430	16.7	25.0	4.00	64.4	9,284	23,868	13.0	714	1,835,983
1949	10,390	7,065	3,510	0.497	2,753	2,309	444	16.1	26.5	3.77	75.8	9,278	25,536	13.0	713	1,964,306
1950	10,523	7,156	4,037	0.564	3,010	2,539	471	15.6	28.6	3.50	62.9	9,128	27,474	13.0	702	2,113,360
1951	10,407	7,077	4,022	0.568	3,189	2,697	492	15.4	30.6	3.26	67.1	9,215	29,387	13.0	708	2,260,529
1952	10,571	7,188	4,171	0.580	3,267	2,764	503	15.4	30.9	3.24	66.3	9,474	30,951	13.0	728	2,380,877
1953	10,646	7,239	4,350	0.601	3,420	2,908	512	21.2	32.1	3.11	66.9	9,460	32,353	13.0	727	2,488,662
1954	10,586	7,198	4,754	0.660	3,554	3,022	532	15.0	33.6	2.98	63.6	9,356	33,250	13.0	719	2,557,720
1955	10,898	7,549	4,640	0.615	3,737	3,208	529	14.2	34.3	2.92	69.1	9,578	35,793	13.0	736	2,753,293
1956	10,993	7,578	4,792	0.632	3,890	3,345	545	14.0	35.4	2.83	69.8	9,665	37,595	13.0	743	2,891,909
1957	11,088	7,607	4,970	0.653	3,990	3,420	570	14.3	36.0	2.78	68.8	9,742	38,870	13.0	749	2,990,000
1958	11,183	7,636	5,180	0.678	4,130	3,540	590	14.3	36.9	2.71	68.3	9,726	40,170	13.0	748	3,090,000
1959	11,277	7,665	5,380	0.702	4,270	3,655	615	14.4	37.9	2.64	67.9	9,681	41,340	13.0	745	3,180,000
1960	11,371	7,695	5,560	0.722	4,420	3,783	637	14.4	38.9	2.57	68.0	9,706	42,900	13.0	747	3,300,000
1961	11,461	7,761	5,720	0.737	4,570	3,915	655	14.3	39.9	2.51	68.4	9,700	44,330	13.0	746	3,410,000
1962	11,551	7,828	5,890	0.752	4,720	4,050	670	14.2	40.9	2.45	68.8	9,640	45,500	13.0	742	3,500,000
1963	11,641	7,895	6,060	0.768	4,890	4,208	682	13.9	42.0	2.38	69.4	9,571	46,800	13.0	736	3,600,000
1964	11,731	7,962	6,220	0.781	5,040	4,340	700	13.9	43.0	2.33	69.8	9,518	47,970	13.0	732	3,690,000
1965	11,820	8,029	6,370	0.793	5,180	4,467	713	13.8	43.8	2.28	70.1	9,486	49,140	13.0	730	3,780,000
1966	11,927	8,102	6,530	0.806	5,310	4,585	725	13.7	44.5	2.25	70.2	9,475	50,310	13.0	729	3,870,000
1967	12,034	8,175	6,690	0.818	5,420	4,680	740	13.7	45.0	2.22	70.0	9,474	51,350	13.0	729	3,950,000
1968	12,141	8,249	6,830	0.828	5,570	4,820	750	13.5	45.9	2.18	70.6	9,406	52,390	13.0	724	4,030,000
1969	12,248	8,323	6,980	0.839	5,690	4,929	761	13.4	46.5	2.15	70.1	9,413	53,560	13.0	724	4,120,000
1970	12,355	8,397	7,110	0.847	5,800	5,026	774	13.3	46.9	2.13	70.7	9,414	54,600	13.0	724	4,200,000
1971	12,487	8,456	7,240	0.856	5,920	5,139	781	13.2	47.4	2.11	71.0	9,377	55,510	13.0	721	4,270,000
1972	12,619	8,515	7,370	0.866	6,020	5,228	792	13.2	47.7	2.10	70.9	9,372	56,420	13.0	721	4,340,000
1973	12,751	8,574	7,490	0.874	6,120	5,320	800	13.1	48.0	2.08	71.0	9,368	57,330	13.0	721	4,410,000
1974	12,883	8,634	7,610	0.881	6,230	5,421	809	13.0	48.4	2.07	71.2	9,348	58,240	13.0	719	4,480,000
1975	13,015	8,694	7,710	0.887	6,300	5,485	815	12.9	48.4	2.07	71.1	9,368	59,020	13.0	721	4,540,000
1976	13,198	8,739	7,820	0.895	6,390	5,570	820	12.8	48.4	2.07	71.2	9,379	59,930	13.0	721	4,610,000
1981	13,909	9,021	8,385	0.929	6,875	6,015	860	12.5	49.4	2.02	71.7	9,341	64,220	13.0	719	4,940,000
1986	14,620	9,303	8,850	0.951	7,360	6,460	900	12.2	50.3	1.99	73.0	9,308	68,510	13.0	716	5,270,000
1991	15,331	9,585	9,415	0.982	7,845	6,905	940	12.0	51.2	1.95	73.3	9,280	72,800	13.0	714	5,600,000

ADDENDUM 3

Appendix B

RATE OF RETURN FOR ANNUAL RECEIPTS

The table of "Rate of Return for Annual Receipts for Various Salvage Values" at the end of a 20-yr study period, was calculated as follows:

1. Assume an investment of $100.
2. Assume a percent of salvage at the end of the period.
3. Multiply the percent of salvage by the present worth factor for a single payment at 20 yr for an assumed rate of interest.
4. Deduct the present worth of the salvage value from the original investment, which leaves the amount to be amortized during the 20-yr period.
5. Divide the amount to be amortized by the present worth factor for a uniform series of annual payments, over the 20-yr period at the rate of interest assumed in Step 3.
6. The result is the annual return of income, uniform series necessary to recover the amortized portion of the investment of $100. This is the percentage sought.

Example:

Assumptions:

Investment	$100 (=100%)
Salvage at end of 20 yr	$ 30 (= 30%)
Rate of return	6%
PW factor for single payment at 6% at end of 20 yr	0.3118
PW factor for uniform series at 6% for period of 20 yr	11.470

(PW factors from interest tables)

Calculation:

PW of salvage value (Step 3)
$30 \times 0.3118 = 9.354$

Amount to be amortized (Step 4)
$100 - 9.354 = 90.646$

Annual return necessary to amortize $90.646 in 20 yr at 6%

$$\frac{90.646}{11.470} = 7.903$$

The figure 7.903 is the percentage of the invested amount necessary to give a return of 6 percent under the assumed conditions. For other study periods, another table would have to be calculated.

TABLE 1

RATE OF RETURN FOR ANNUAL RECEIPTS FOR VARIOUS SALVAGE VALUES[1]

Rate of Return	Salvage at End of 20 Yr (Percent of Investment)													
(%)	0	5	10	15	20	25	30	33.3	35	40	45	50	55	60
1	5.54	5.31	5.09	4.86	4.63	4.40	4.18	4.03	3.95	3.72	3.50	3.27	3.04	2.82
2	6.12	5.91	5.70	5.50	5.29	5.09	4.88	4.75	4.68	4.47	4.27	4.06	3.85	3.65
3	6.72	6.53	6.35	6.16	5.98	5.79	5.61	5.48	5.42	5.23	5.04	4.86	4.68	4.49
4	7.36	7.19	7.02	6.85	6.69	6.52	6.35	6.24	6.18	6.01	5.85	5.68	5.51	5.34
5	8.02	7.87	7.72	7.57	7.42	7.27	7.12	7.02	6.97	6.81	6.66	6.51	6.36	6.21
6	8.72	8.58	8.45	8.31	8.17	8.04	7.90	7.81	7.77	7.63	7.49	7.36	7.22	7.09
7	9.44	9.32	9.20	9.07	8.95	8.83	8.71	8.63	8.58	8.46	8.34	8.22	8.10	7.98
8	10.19	10.08	9.97	9.86	9.75	9.64	9.53	9.46	9.42	9.31	9.20	9.09	8.98	8.87
9	10.95	10.85	10.76	10.66	10.56	10.46	10.37	10.30	10.27	10.17	10.07	9.98	9.88	9.78
10	11.75	11.66	11.57	11.49	11.41	11.31	11.22	11.16	11.14	11.05	10.96	10.87	10.79	10.70
11	12.56	12.48	12.40	12.33	12.25	12.17	12.09	12.04	12.01	11.93	11.86	11.78	11.70	11.62
12	13.39	13.32	13.25	13.18	13.11	13.04	12.97	12.93	12.90	12.83	12.76	12.69	12.62	12.55
13	14.24	14.18	14.11	14.05	13.99	13.93	13.86	13.82	13.80	13.74	13.68	13.62	13.56	13.49
14	15.10	15.05	14.99	14.94	14.88	14.83	14.77	14.73	14.72	14.66	14.61	14.55	14.50	14.44
15	15.98	15.93	15.88	15.83	15.78	15.74	15.68	15.65	15.64	15.59	15.54	15.49	15.44	15.39
16	16.87	16.83	16.78	16.74	16.69	16.65	16.61	16.58	16.57	16.52	16.48	16.43	16.39	16.35
17	17.77	17.73	17.69	17.65	17.62	17.58	17.54	17.52	17.50	17.46	17.42	17.38	17.35	17.31
18	18.68	18.65	18.61	18.58	18.55	18.52	18.48	18.45	18.44	18.41	18.38	18.34	18.30	18.27
19	19.60	19.57	19.54	19.51	19.48	19.45	19.42	19.40	19.39	19.36	19.33	19.30	19.27	19.24
20	20.54	20.51	20.48	20.45	20.43	20.40	20.37	20.35	20.34	20.32	20.29	20.27	20.24	20.21
21	21.47	21.45	21.43	21.40	21.38	21.35	21.33	21.32	21.30	21.28	21.26	21.24	21.21	21.19
22	22.42	22.40	22.38	22.36	22.34	22.32	22.29	22.28	22.27	22.25	22.23	22.21	22.19	22.17
23	23.27	23.35	23.33	23.32	23.30	23.28	23.26	23.25	23.24	23.22	23.20	23.19	23.17	23.15
24	24.33	24.31	24.30	24.28	24.26	24.25	24.23	24.22	24.21	24.20	24.18	24.16	24.15	24.13
25	25.29	25.28	25.26	25.25	25.23	25.22	25.20	25.19	25.19	25.18	25.16	25.15	25.13	25.12
26	26.26	26.25	26.23	26.22	26.21	26.20	26.18	26.17	26.17	26.16	26.14	26.13	26.12	26.10
27	27.23	27.22	27.21	27.20	27.19	27.17	27.16	27.15	27.15	27.14	27.13	27.11	27.10	27.09
28	28.20	28.19	28.18	28.17	28.16	28.15	28.14	28.13	28.13	28.12	28.11	28.10	28.09	28.08
29	29.18	29.17	28.16	29.15	29.14	29.13	29.13	29.12	29.12	29.11	29.10	29.09	29.08	29.07
30	30.16	30.15	30.14	30.14	30.13	30.12	30.11	30.11	30.10	30.09	30.09	30.08	30.07	30.06

[1] Expressed as percent of investment.

Appendix C

EXPLANATION OF TABLE AND CHART — PRESENT WORTH OF PROJECTED REVENUE

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The accompanying table and chart are for illustrative purposes. The table is one of a series extending from a discount rate of 1 percent to that of 8 percent — each based on an original unit of revenue or traffic growing at 5 percent a year in a straightline increase. The tables are computed to show the year-by-year growth and present worth for a 30-yr period.

In practice, the year-by-year growth would ordinarily be computed by forecasting each component that enters into the composite forecast, because each state or local project might have different rates of traffic growth and revenue earnings.

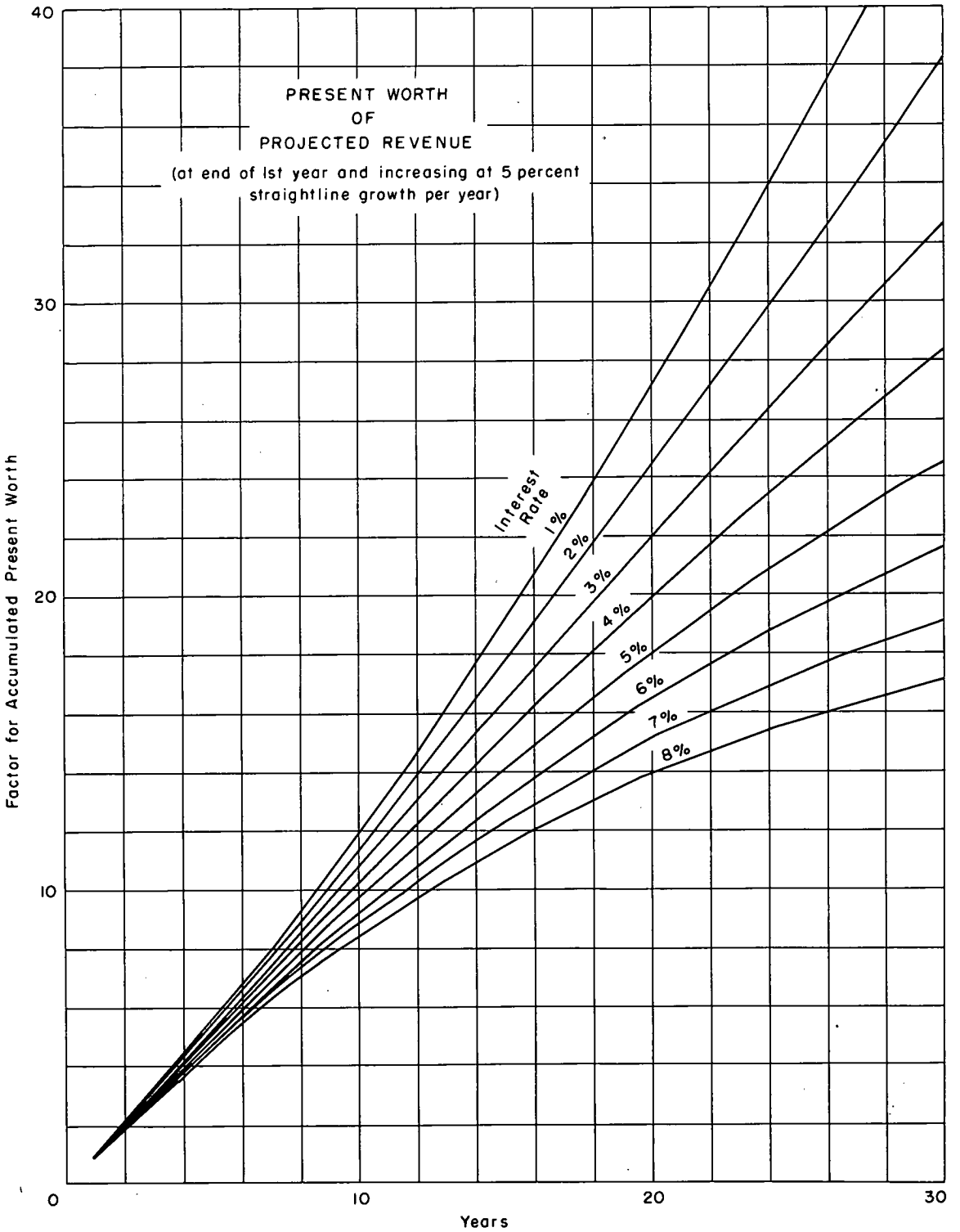
Projections of traffic on a national basis show an expected growth of 4.7 percent from 1956 to 1976 and an expected growth of 4.9 from 1956 to 1986, deviating slightly from a straightline growth.

When there is a consistent and continuous growth the computation of continuous compounding and continuous present worth may be the ideal approach, but in traffic and revenue growths there are seasonal fluctuation and erratic growths which do not justify such refinement in the mechanics of computing.

PRESENT WORTH OF PROJECTED REVENUE: INTEREST RATE 6%

Year	Traffic or Revenue [1]	PW Factor	PW	Accumulated PW Factor
1	1.05	0.9434	0.9906	0.9906
2	1.1	0.8900	0.9790	1.9696
3	1.15	0.8396	0.9655	2.9351
4	1.2	0.7921	0.9505	3.8856
5	1.25	0.7473	0.9341	4.8197
6	1.3	0.7050	0.9165	5.7362
7	1.35	0.6651	0.8979	6.6341
8	1.4	0.6274	0.8784	7.5125
9	1.45	0.5919	0.8582	8.3707
10	1.5	0.5584	0.8376	9.2083
11	1.55	0.5268	0.8165	10.0248
12	1.6	0.4970	0.7952	10.8200
13	1.65	0.4688	0.7735	11.5935
14	1.7	0.4423	0.7519	12.3454
15	1.75	0.4173	0.7303	13.0757
16	1.8	0.3936	0.7085	13.7842
17	1.85	0.3714	0.6871	14.4713
18	1.9	0.3503	0.6656	15.1369
19	1.95	0.3305	0.6445	15.7814
20	2.0	0.3118	0.6236	16.4050
21	2.05	0.2942	0.6031	17.0081
22	2.1	0.2775	0.5828	17.5909
23	2.15	0.2618	0.5629	18.1538
24	2.2	0.2470	0.5434	18.6972
25	2.25	0.2330	0.5242	19.2214
26	2.3	0.2198	0.5056	19.7270
27	2.35	0.2074	0.4874	20.2144
28	2.4	0.1956	0.4694	20.6838
29	2.45	0.1846	0.4513	21.1351
30	2.5	0.1741	0.4353	21.5704

[1] Traffic or revenue figures show growth in place at end of year computed on a straight-line growth of 5%. No consideration is given to extra value of revenue flowing in during year. "Continuous compounding" might be used to obtain the "true" value but refinement is unjustified, inasmuch as receipts of revenue are not uniform throughout the year, and more especially due to the fact that the error of estimate of revenue may greatly exceed the small error introduced by ignoring present worths of daily receipts.


PRESENT WORTH
OF
PROJECTED REVENUE
(at end of 1st year and increasing at 5 percent straightline growth per year)
Interest Rate
1%
2%
3%
4%
5%
6%
7%
8%
Factor for Accumulated Present Worth
0
10
20
30
40
Years
0
10
20
30

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