Highway Engineering Economy Analysis

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•HIGHWAY ENGINEERING ECONOMY, including value analysis, economic analysis, cost-benefit analysis, and cost-effective analysis, is often wrongly used, poorly understood, and poorly applied. It suffers also from the lack of much necessary input information. For example, the performance of traffic on the highway, the running cost of motor vehicles as affected by highway design and traffic, the rate and cost of traffic accidents, and the economic and social consequences of highway improvements all require added research to assemble the performance and cost data needed in highway economy studies. Although research on the relationships between the motor vehicle and the highway was started about 1920, the area has never been thoroughly and systematically covered. The result is that today more information is missing than is available.

Analysis of the economy of highway improvements was begun well over 100 years ago. Though few people realize it, the subject is to be found in school texts and in engineering handbooks printed in the mid-1800's. As an example, consider the following 5 quotations published in 1853 in a book on road-making by Gillespie (1):

> Any unnecessary excess of length causes a constant threefold waste; firstly, of the interest of the capital expended in making that unnecessary portion; secondly, of the ever-recurring expense of repairing it; and thirdly, of the time and labor employed in travelling over it. It will therefore be good economy to expend, in making topographical examinations for the purpose of shortening the road, any amount less than not only that sum which the distance thus saved would have cost, but, in addition, that principal which corresponds to the annual cost of the repairs and of the labor of draught which would have been wasted upon this unnecessary length (p. 26).
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> A perfectly level road is thus seen to be a most desirable object; but as it can seldom be completely attained, we must next investigate the limits to which the slopes of a road should be reduced if possible, and determine what is the steepest allowable or maximum slope (p. 38).
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> A minimum of expense is, of course, highly desirable; but the road which is truly cheapest is not the one which has cost the least money, but the one which makes the most profitable returns in proportion to the amount which has been expended upon it (p. 65).
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> The more nearly, however, the road is made to approximate towards "what it ought to be," the more difficult will it be to satisfy the demands of economy. Some medium between these extremes must therefore be adopted, and the choice of it must be determined by the amount and character of the traffic on the road which it is proposed to make or to improve. For this purpose an accurate estimate is to be made of the cost of the proposed improvement, and also of the annual saving of labor in the carriage of goods and passengers which its adoption will produce. If the latter exceed the interest of the former, (at whatever per centage money for the investment can be obtained) then the proposed road will be "what it ought to be as to its cost." From these considerations it may be truly cheaper to expend ten thousand dollars per mile upon a road which is an important thoroughfare, than one thousand upon another road in a different locality (pp. 65-66).
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> From these considerations it is also seen that a line ought not to diverge from the direct course between its extremities, and thus increase its distance, for the sake of the trade of a small town, for whose benefit the time and fare of all the passengers and freight on the whole line would thus be taxed. It would be preferable to make a branch track to the town (p. 271).

Gillespie dealt with real live horsepower or mulepower that cost at that time 75 cents per day per animal. This interesting book by Gillespie is proof that the art of road-building was born long before the coming of the motor vehicle; unfortunately, the art is still not as skillfully practiced as desired, particularly from the standpoint of economy of highway design and use, including both economic and social factors.

There is a need for a systematic fore-planned attack on the vacuum of data required to improve the economic analysis of highway transportation investments. The information needed can be obtained through well-directed research and observation. Its use in planning, particularly in economic analysis, will return a high payoff in studies of transportation.

NEEDS FOR BASIC INPUT INFORMATION

Traffic Performance

Data on speed distribution, speed changes, and, to a certain extent, traffic composition are almost completely lacking in the form needed by the analyst in computing the relative economy of different highway designs and special facilities. Information is especially lacking for urban streets. The motor vehicle running costs are markedly influenced by the speed of the vehicle and the extent and number of speed changes. Therefore, the analysis of alternative designs requires reliable information on speed and speed changes with respect to the basic type of highway, i.e., whether it has 2, 4, or 6 lanes, and with respect to the amount and composition of traffic. Speeds and speed changes need to be determined for the full year and for all vehicles, not solely for free-running vehicles. Likewise, a knowledge of the volume and kinds of vehicles for each hour of the year is needed so that speeds and numbers of vehicles can be put together in computing motor vehicle running costs on a yearly basis.

Motor Vehicle Running Cost

NCHRP projects will furnish information on fuel consumption, tire wear, and other factors for a range of highway designs and traffic conditions. It will still take some effort, however, to put these data in the proper form for use in highway engineering economy studies. In addition to knowledge of the specific performance of vehicles under specific elements of highway design, knowledge must also be obtained of the running costs for general conditions such as rolling grades, urban streets, and general classes of traffic volumes and kinds of vehicles. For example, fuel consumption is perhaps better expressed on a rise-and-fall basis for a rolling grade such as that found in southern Iowa than it is by gallons per mile on specific plus-and-minus grades. On the other hand, specific fuel consumption can be used for the longer grades in mountainous country.

Cost of Traffic Accidents

The large volume of data published on traffic accidents does not contain combined data on accident costs and accident frequencies related to elements of highway design. Kihlberg and Thorp (2) and Jorgensen (3) report on research that is a step leading in the right direction.

System Data

For urban transportation studies, motor vehicle performance including running costs should be compiled and reduced to forms applicable to system analyses.

Value of Travel Time

Travel time has a widely varying value for both passenger automobiles and the occupants. Haney (4), Thomas (5), and Lisco (6) have developed a technique and statistical procedure by which acceptable values of time can be determined. The next step is to apply these procedures to many other types of highways, to geographical locations, and to specific conditions in order to develop a range of values of time for specific applications.

IMPROVEMENTS IN PRACTICES OF ECONOMIC ANALYSIS

The Literature

Some writing was done in the 1920's on the subject of highway economic analysis, and since about 1950 many valuable contributions have been made to the technical literature. Unfortunately, however, highway officials and analysts are not applying this knowledge very widely. Individual economic analyses are still widely deficient in the principles and procedures of analysis, and are themselves not always understood. Additional education and practice are needed in this field to bring the level of performance up to an acceptable quality. Perhaps a series of workshops should be conducted across the country to achieve this improvement.

Relationship of Road User Consequences to Nonuser Consequences

In the past several years, many individuals have proposed some form of numerical rating system for evaluating or ranking general economic and social consequences. Some have wanted to combine road user consequences and nonuser consequences into one numerical index or ranking among alternatives as a means for indicating relative economic feasibility. Because road user factors are reliably priced on the market and because nonuser factors are most difficult to price on the market and vary widely from place to place, it seems to be unwise to combine these consequences into a single index, even if it could be done. No doubt advances can and will be made in developing guidelines, interpretations, and techniques that will aid the decision-maker in reaching his decision by some process of subjective evaluation of the nonuser factors. Decision-makers need a better understanding of how to use the results of the economic analysis as one of many tools and guides to the decision.

IMPROVEMENT OF PROCEDURES OF ECONOMIC ANALYSIS

Engineering Economic Procedures

Procedures to determine the economy of highway improvements are patterned after those developed for private industry. In general, these procedures are satisfactory, but some phases need additional study and some concepts need further development. These include the handling of terminal value, selection of the discount rate, identification and quantification of benefits, development of applications to systems analyses, and the handling of the increase in traffic volume as opposed to the existing traffic volume. Greater emphasis is needed on separating the analysis for economic evaluation from the analysis for project formulation.

The Engineer Versus the Economist

The literature in the economic and engineering fields indicates several differences in concept, theory, and application of economic analysis. It would be helpful if these two professions could get together and reach an understanding, even though they do not reach an agreement. One of the factors that leads to disagreement is that the function and use of highways are different from the function and use of those things for which capital expenditures are made by private industry. Most of the economists writing on this subject view the problem under the mantle of private business and monetary profit. This approach leads to statements hardly applicable to highways. Other factors needing discussion relate to the willingness to pay versus what is actually paid and the economic transfers, offsets, and adverse consequences. There are no accepted guides by which those nonuser consequences can be isolated and the economic worth of a proposed highway facility measured.

SUMMARY

This paper has briefly summarized the state of highway economic analysis from two standpoints: (a) the need for added meaningful data to fill the gaps in existing knowledge and (b) the need for more advanced approaches to analysis. It should be clear that much work must still be done.

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Discussion

Tillo Kuhn

I am very interested in international development work and would like to know the degree of standardization for vehicle costs on any particular road. How can we keep present motor vehicle running cost tables up to date as time goes on and as new road and vehicle designs come along?

Robley Winfrey

I do not like the use of the word standardizing unless you mean standardizing on a quality basis. We can measure fuel consumption, and we can measure tire consumption under certain conditions only; but other expenses of the vehicle, particularly general maintenance expenses, are most difficult to measure and to allocate to a specific feature of highway design or to a specific condition of traffic. So we have to attack the updating problem by working the basic tables out by theoretical methods through energy equations and power requirements. Another difficulty, however, is in getting the necessary traffic performance for the economic analyses. For example, we do not know speed distributions of traffic. We have been unable to measure many speed changes in urban traffic that increase fuel consumption and increase tire wear. These changes can and should be measured, but we have not found the right kind of reasonably priced instrumentation to do enough driving to get at this problem. In my book, Economic Analysis for Highways, I used a good deal of mechanics, dynamics, and other theory because I wanted to allocate fuel, tires, engine oil, vehicle maintenance and minor repairs, and vehicle depreciation to roadway surface, distance, plus grades, minus grades, horizontal curvature, and changes in speeds. When we are able to fill in the parameters for that sort of matrix, then I think we have a good representation of motor vehicle running costs as affected by those elements of the highway and traffic. Given these, we can adjust the vehicle running costs very easily, particularly as the prices change.

Clarkson Oglesby

Present costs have to be projected to some period in the future. Do we have any techniques that have been proven for projecting future traffic in either a developed or a developing nation?

Martin Wohl

I do not think we can really forecast well, and this is very crucial. We cannot assess the benefits or costs unless we know how many people and what kinds of vehicles

are going to use the facilities consistently and what service and performance conditions will be desired. Even if we agree on how to carry out economic analysis, we still have the problem of forecasting; in a sense, it underlies everything we and a lot of other people do.

Wilson Campbell

There are many factors that influence traffic forecasts that forecasters cannot control. But I think that we can forecast reasonably well, on a 24-hour basis, traffic volumes on particular roadways in urban areas. It always makes me nervous when we have to provide design data, including specific turning movements, for 10 o'clock on Thursday morning in 1985. We do it just because there is no other information, and we recognize that the design engineer has to have numbers to determine the number of lanes and interchanges needed and other design features. We qualify our forecasts, however, by specifying the limits of accuracy so that he can use some judgment in his traffic engineering and design technique. I agree that forecasting is far from perfect, but we have come an amazingly long way during the past 10 years.

Marvin Manheim

One of the critical gaps in the analysis of proposed transportation technologies is an understanding of the fundamental relationships between the basic physical technological aspects of transport and its true economics. Therefore, we need basic power resistance relationships in order to segregate the effects of fixed facilities from vehicle effects, from operating-decision effects, and from traffic effects in such a way as to trace out the cost ramifications of each.

William Adkins

Forecasting is always somewhat inexact. On the other hand, perhaps the forecasters and the planners may have to give thought to the use of measures such as police power or land use zoning to control the amount and composition of traffic to ensure that forecasts are more or less met. As an example, when a bottling company turned 100 trucks loose on a rather high-capacity freeway during the peak hour, the effect was amazing, especially on the number of speed changes and time losses. If we had had the sense to keep this one bottler off the freeway, traffic would have been more like that forecast. Another less drastic example is ramp metering.

Clarkson Oglesby

In Great Britain there has been quite a bit of talk about road pricing and parking pricing to control the amount of traffic. Do you see this concept as being applicable in the United States?

Paul Wagner

Our attitude is that when a legal vehicle enters the highway the driver should be allowed to do anything he wants so long as it does not interfere with the rights of others. This idea of trying to control vehicles in order to plan the economy is not in line with our present thinking. We are trying to provide highways for the public's desires as they exist today; we are not trying to change those desires.

Tillo Kuhn

There are two defects in the pricing literature: (a) pricing is only a portion of the total economic decision; and (b) the influence of pricing on the road user may be very slight, because the user may not conceive what his total cost is or his sensitivity to cost may be very slight. So my inclination would be to organize the pricing problem within the broader context of systems analysis. The literature would have us believe that some loops in the road and a little pricing will solve all problems. In my opinion this is not so.

Paul Roberts

We already control the system in a number of ways. Lane markings, signs, and, of course, gasoline tax are forms of control.

Marvin Manheim

These comments imply that a bundle of options can be manipulated in any transportation problem. These options range from a choice of basic technology to the design of the network, location of links and their characteristics, design of the vehicle, and operating policies such as pricing and access control. In one context where state legislation does not allow segregation of traffic or control over access, or where the state decides that there is no real choice of technology, the key set of options to manipulate will be the detailed characteristics of the link, such as grade and horizontal curvature. In another context, e.g., in a developing country where the range of technologies is very wide, the decision may be to shift the technology from a rubber-tired vehicle on pavement to an off-the-road vehicle. In the urban context, the only available option may be user pricing schemes, e.g., parking charges and tolls. We need to be concerned with the full spectrum of options and should not be extreme advocates of either pricing policy or new technology as the answer to every transportation problem.

Robley Winfrey

The highway engineer is often blamed for all the ills of highway transportation. He should not shoulder that blame, because he has not had control of how the highway is to be used. He designed it for one kind of use, and because the public chose to use it differently we have transportation problems. What we need is a reconciliation of viewpoints. There are private interests, local interests, community interests, and national or state interests; they are not all compatible because they value certain concepts or certain goals differently. That is why the engineering economy aspects should be kept separate from the economic and social aspects.

Tillo Kuhn

Our task is to serve up particular choices, to prepare well-designed and well-researched options. In this process we must also document the social, aesthetic, and other consequences together with the road user, dollar-priced consequences. Therefore, we can say to a decision-maker, "Here is a system that has certain design characteristics with regard to speed and capacity and one that has various social and economic consequences."