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FOREWORD

The papers contained in this RECORD examine various economic concerns that affect transportation systems. The papers cover a wide range of economic topics and will be of interest to those concerned with the economics of transportation.

The first paper explores the impact of tourism on a regional economy, that of Oregon. It is both conceptual and empirical insofar as quantitative measures are available for the Oregon economy. Its intent is to illuminate public policy decisions and give direction to research appropriate to their implementation. Farness gives careful consideration to distinguishing between resident and nonresident effects—a distinction that is generally not made in tourist impact studies.

Hibbard and Miller discuss the economic impact of the environmental impact statement. They contend that the key to the use of the environmental impact statement is an understanding of the relation between effects considered by economic analysis and other project impacts. Much of the paper develops the rationale for categorizing effects of highway improvements by explaining which are included in benefit-cost analysis and which must be evaluated separately.

Gruver presents a discussion of a detailed highway user economic analysis of field-inventoried section data combined with an investment level analysis and the associated computerized models. He describes the benefit-cost, cost-effectiveness, and investment analyses conducted by using the data collected by individual states for the 1972 National Highway Classification and Needs Study as input. In addition, a summary of the national study results is presented, which shows the proposed benefit-cost ratio.

In another paper, Hibbard and Miller examine the application of traditional benefit-cost analysis, frequently used to evaluate construction projects, as a means to analyze nonconstruction activities of highway agencies for the purposes of improving resource allocation within and between programs. Drawing from three examples of maintenance projects and from the parks and bicycle trail programs, the authors demonstrate that difficult-to-value variables such as safety, recreational experiences, and benefits to bicycle riders can be evaluated with benefit-cost analysis. The optimum frequency for maintenance projects is also examined.

Roess presents data concerning operating costs of bus and rail systems collected from operating agencies and the American Transit Association. Operating cost models were prepared for individual rail rapid transit systems and bus systems. The use of these models in economic comparisons of highway and other transit alternatives is discussed and illustrated. Data deficiencies are discussed, and recommendations concerning accounting formats are made.

The paper by Winfrey and Lipka is an analysis for the economy of transportation to be expected on the proposed trans-Java highway. The analysis involves several procedures that have rarely if ever been reported in the literature. These features include calculating vehicle running costs on the basis of a distribution of vehicle speeds rather than using one specific average speed, including the changes in vehicle speeds as a running cost item, estimating highway construction costs and vehicle running costs for segments of the highway as opposed to one estimate for the entire length of the proposed project, calculating rates of return for segments of the proposed highway, calculating the rate of return for each year for each highway segment, using seven classes of vehicles with separate costs for gasoline- and diesel-fueled vehicles, making the complete analysis for six levels of design (traffic service) as contrasted to use of one design, and applying the analysis to the network of existing highways affected by the trans-Java highway.

BENEFITS AND COSTS OF TOURISM: A REGIONAL POINT OF VIEW

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This paper explores the impact of tourism on a regional economy. It is both conceptual and empirical insofar as quantitative measures are available for the Oregon economy. Its intent is to illuminate public policy decisions and give direction to research appropriate to their implementation. Inasmuch as the objective of regional policy is to promote the welfare of the residents of the region, careful consideration is given to distinguishing between resident and nonresident effects—a distinction not generally made in tourist impact studies. Also, contrary to most studies, the costs associated with tourism are given explicit consideration. And, in addition to the gross effects, attention is directed to redistribution effects among residents of a region. The fiscal effect appears to be adverse in Oregon; that is, the costs incurred by the state to provide facilities and services (parks, highways) used directly by tourists are greater than the taxes collected directly from them (user fees, state gasoline tax). Financial capital is sufficiently mobile that it is affected little by growth or nongrowth of the tourist industry. Labor, on the other hand, is not so mobile, and there appears to be a small labor benefit. Despite the fact that the jobs pay little, are seasonal, and offer limited opportunities for upward mobility, they do match the needs of a part of the labor force. Owners of natural resources have the most to gain from tourism, but their gains are partially offset by losses to resident consumers who pay higher prices for products of fixed-quantity natural resources. The local fiscal effect is unknown. The low capital-labor ratio in tourist industry activities and the low wages of the industry tend to result in low property tax revenue generated per worker in the industry. Whether this results in an adverse fiscal effect on local government depends on the characteristics of its labor force. Because of the difficulties in assigning weights to the various effects and in handling redistribution effects, it is difficult to arrive at a consensus.

•THOUGHTS on the subject of costs and benefits of tourism have tended to be confused or at least incomplete because of two types of error, failure to account for the geographic distribution of effects (in-region and outside-of-region) and failure to account for costs as well as benefits. If the point of view is the welfare of the residents of a subject region it is necessary to distinguish resident effects from nonresident effects. And if the objective is a comprehensive accounting of the effects of tourism it is important to recognize the existence of costs. In addition to conceptual shortcomings, considerations of self interest are involved; consequently a third factor, interpersonal, in-region, redistribution effects also should be given explicit attention.

The term tourists as used here refers to nonresidents of a region who visit it for pleasure-oriented reasons. And hereafter the term state will be used in place of region; however, the analysis is applicable to regions not defined by state boundaries.

STATE FISCAL IMPACT

Analysis of the state fiscal impact is limited to direct costs and benefits, i.e., costs incurred in providing facilities and services used directly by tourists and payments by tourists made directly to state government. Some of the funds expended are federal in origin, but, inasmuch as their magnitude is not related to the presence of out-of-state visitors, for purposes of this paper they are viewed the same as revenue derived from Oregon residents. Also it is true that indirectly state revenues increase as a result of higher taxes paid by businesses and households that directly and indirectly serve tourists. But if these are allowed then it also would be necessary to take into account the government costs of providing incremental public goods and services to them. Data are not available to make these calculations, and the effect of ignoring them is to treat these revenues and expenditures as if they were fully offsetting. In the section on the local fiscal impact, indirect fiscal consequences are taken into account.

The facilities and services that state governments provide tourists include highways, parks and roadside rest areas, police, and litter removal services. Both monetary benefits and costs are incurred. State taxes (gasoline, sales, hotel-motel) and park user fees are the principal sources of revenue. Costs arise from land acquisition; construction, maintenance, and operation of facilities; and provision of various services. Additional but avoidable costs are generally incurred in tourist advertising and information programs. The relationship between all of these costs and revenues provides one measure of whether the region is encouraging or discouraging the tourist industry through its expenditure and revenue policies.

The measurement of tourist-related expenditures and revenues involves both data and conceptual problems. Those posed by highway investments are perhaps the most complex.

Highway Costs and Benefits

The response to out-of-state tourist traffic can range from no response—i.e., to build no new capacity with the result that all costs to state residents are incurred in the form of increased congestion costs—to construction of enough new capacity to fully accommodate the additional traffic and thus avoid increased congestion costs to resident drivers. (Congestion costs include increased travel time, selection of second best recreational alternatives, a higher incidence of accidents, psychic costs due to discomfort and inconvenience, and so forth.)

The Oregon experience appears to fall between the two polar cases. The amount expended on highways does not appear to have varied significantly as a result of the volume of out-of-state traffic; however, the selection of projects appears to have been affected. Because tourist automobile traffic is concentrated by season and route, traffic peaks for many highways have been quite different from those that would have occurred in the absence of tourists. Additional capacity has been built to accommodate these peaks at the cost of forgone construction on routes used predominantly by resident traffic. In this case there are no direct net monetary highway costs; hence, any revenue from the Oregon gasoline tax would tend to ensure an excess of highway-generated revenue over costs and would seem to imply an arrangement favorable from the standpoint of residents.

Of course, this conclusion is correct only insofar as congestion costs to residents are ignored or are less than the amount of highway-generated taxes collected from nonresidents. Although it is not possible to accurately measure congestion costs, it is possible to indicate the per capita magnitude of these costs that would be necessary to offset the tax revenues collected. For 1972 it is estimated that out-of-state travelers paid Oregon gas taxes of $7,322,000. (Oregon does not have a state sales tax or state hotel-motel tax; hence, gasoline tax revenue is the only revenue that can be classified as highway generated.) This amounts to less than $4.00 per capita, which indicates that the congestion costs need amount to only $4.00 per person before adverse highway effects are experienced by Oregonians as a result of out-of-state visitors. If the value of time per vehicle in road use is $3.00 an hour for passenger vehicles and $6.00 per hour for trucks as is commonly assumed, the number of hours in lost travel time alone necessary to exhaust the tax benefit is relatively small. It is true that premature construction would result in excess capacity during much of the year and that some resident user benefits would result from off-season use of these highways; however, benefits from what is largely redundant capacity are assumed to be small relative to the congestion costs.

If the response to out-of-state visitors is to build net additional highway capacity, the resultant costs should be identifiable and measureable. Implementation of the measures, however, requires information that is not generally available, particularly traffic count data for out-of-state light vehicles. Conceptually what is required is the identification of (a) improvements that are premature from the standpoint of resident and commercial traffic, (b) the costs of such improvements, (c) the number of years the improvements occurred in advance of justifying resident and commercial traffic, and (d) an appropriate interest rate or opportunity cost of capital. The cost of premature projects is not the actual construction cost but rather interest costs or opportunity costs of committing resources premature to resident needs.

Although Oregon generally does not appear to have built any net additional capacity in response to tourist traffic (rather it has reallocated highway funds), estimates have been made as if a net increase in expenditures occurred. Twelve projects involving expansion from two to four lanes were chosen to estimate the monetary costs that would have been incurred by Oregonians if they had expended funds that otherwise would not have been committed in the absence of tourists. The improvements cover 255 miles or approximately 5 percent of all primary roads in the state. The various projects were judged to be premature by from 1 to 16 years. That is, in the absence of out-of-state light vehicles, the volume of domestic traffic alone was estimated to not reach a level sufficient to justify these improvements until 1 to 16 years after the improvements occurred because of the presence of out-of-state light vehicles. An interest rate of 6 percent was arbitrarily selected, and interest costs were calculated for each project for each year of premature construction. Summing over the various projects gave an estimated interest cost for 1972 of approximately $4,500,000. Because the calculations were for only 5 percent of the primary roads (roads with a high volume of out-of-state vehicles) and because no consideration was given to nonprimary roads or improvements other than expansion from two to four lanes, a conclusion that the total highway costs incurred as a result of out-of-state visitors exceeded state gasoline taxes collected, $7,322,000 for 1972, is not particularly heroic.

State Park Costs and Benefits

State park costs and revenues arising from out-of-state tourist users are more readily identifiable, particularly if overnight use is important, fees are collected, and the origin of the user is recorded. In Oregon these conditions prevail, and, in conjunction with various expenditure data, tourist-related costs and revenues have been calculated. Given various assumptions regarding the assignment of costs between resident and nonresident users, the annual net subsidy (costs in excess of user fees collected) to out-of-state visitors for the three fiscal years 1969 to 1971 (1) ranged from $1,302,078 to $8,968,917.

If allowance is made for other direct state costs such as policing and litter control for which there are small or no revenue offsets, there is strong evidence to conclude that Oregon has pursued a policy of subsidizing tourists and indirectly the Oregon tourist industry. This is not necessarily desirable or undesirable. Such a judgment depends on the significance of this subsidy for the levels of tourist activity, the consequences for resources (human, natural, and capital) owned by Oregonians, the local fiscal impact of tourism, redistribution consequences of tourism, and the difficult-to-quantify amenity consequences.

It also should be noted that the Oregon case is probably not significantly different from that of other states. Just as Oregonians appear to subsidize out-of-state visitors, Oregonians are probably subsidized when they travel in other states. This is not to say that it all balances out. States that have a favorable net balance of trade on the tourist account will receive subsidies smaller than those granted visitors to their states. And, even where the subsidies do balance out, income redistribution effects should be considered inasmuch as it is exeedingly unlikely that they would balance for each individual.

BENEFITS TO STATE HUMAN AND INVESTMENT (FINANCIAL) CAPITAL

Within areas of unrestricted labor and capital migration, it has been conventional to assume a high degree of labor and capital mobility. Under this assumption and the additional assumption of full employment, the consequence of more or less economic activity in any particular region is not assumed to significantly affect the welfare of either labor or owners of investment (financial) capital; the next best alternative to employment within the state is assumed to be virtually equally remunerative. Hence benefits from state growth or nongrowth have been ignored. With respect to financial capital, the assumption of full mobility is reasonably valid and can therefore be disregarded in the measurement of tourist benefits. However, with respect to labor, this assumption is not appropriate. Labor is not perfectly mobile, and a favorable employment effect from tourism is a distinct possibility. A measure of such benefits is elusive however.

As indicated earlier, the employment benefit to residents is the difference between wages received as a result of tourist-induced employment and the benefits (wage and leisure) derived from the next best nontourist alternative uses of labor. Resident is defined as of a particular point in time. Both out-migration and in-migration are possible over time. Yet from the standpoint of state policy, which is presumably directed to maximizing the welfare of residents, the only population that counts is the constituent population as of the decision-making point in time. Policies that induce in-migration bring direct employment benefits to nonconstituents, and these should not be included in the labor benefits. On the other hand, if out-migration occurs, the employment loss is not equivalent to the full decrease in wages inasmuch as the policy point of view is in terms of the one-time-constituent who in most instances would have an alternative income earned outside of the state.

The employment benefit is not equivalent to total wages received directly as a result of tourist employment and indirectly through linked and induced employment. This overlooks possible benefits of alternative employment and leisure activities in the absence of tourist employment opportunities. Nor is the employment benefit the difference in total state payroll that would occur with and without a tourist industry. This overlooks employment possibilities outside of the state and nonwage benefits from increased leisure. For state residents the alternatives to work in the state tourist industry and indirect tourist-induced activities include (a) nonwork with associated leisure benefits, (b) work in the state in non-tourist-related activities, and (c) work outside of the state. Each presumably is an inferior alternative. How inferior and therefore how large the net labor benefits of tourism are depend on the degree of labor mobility and the value placed on leisure. Benefits to labor that migrates into the state as a result of tourist expansion should not be included in the calculation of benefits to state labor as a result of expaneded tourism. On the other hand, if there are social costs as a result of unemployment or underemployment and if tourism increases the level of employment, an additional benefit must be included.

Information is not available to measure the net labor benefits of tourism to a state economy. When estimates of labor impact are made they are gross estimates and tend to be in terms of employment. Also they tend to be exaggerated relative to other basic industries (industries that engage in production for nonregion residents) because of tourism's high visibility and the difficulty of separating in-state from out-of-state components. Another source of exaggeration arises from the assumption that the indirect and induced effects of a tourist job are equivalent to those of the average basic job. (Basic jobs are jobs engaged in production for nonresidents; hence, they bring purchasing power into a region, which, in turn, through the expenditure process induces additional jobs engaged in production for the local market.) This is incorrect. In the case of the Oregon economy tourist jobs constituted between 7 and 9 percent of all basic jobs between 1962 and 1968. However when correction was made for differences in wage levels, direct tourist jobs accounted for between $4\frac{1}{2}$ and 5 percent of total basic job remuneration (tourist jobs paid between 55 and 58 percent of the average basic job). Assuming that the economy-wide average multiplier is valid for tourism, then the total employment effect, direct, indirect, and induced, was $4\frac{1}{2}$ to 5 percent of total state employment.

As indicated by the rates of remuneration, these jobs are not necessarily ideal either. Not only are the rates of pay low, but the jobs tend to be seasonal, geographically dispersed, and limited in opportunities for upward mobility. Of course, a certain number of such jobs are desirable insofar as labor force skills, seasonal and geographic labor availabilities, and job preferences match job opportunities. Beyond this number, further expansion of the industry in its traditional pattern would seem to be undesirable. Upon absorption of a resident labor force of students, other part-time job seekers, and low-skilled members of the labor force, growth in the industry will tend to exercise a downward influence on a state's per capita income level. This may occur either through in-migration of new labor force members—a result that is not the objective of policies to maximize benefits to the initial population—or through entrapping residents, primarily new entrants to the labor force, in these jobs. Indeed, if public policy can and is used to influence the pattern of economic growth, from the standpoint of employment opportunities, beyond some level of activity, further growth of tourism is not an appropriate policy.

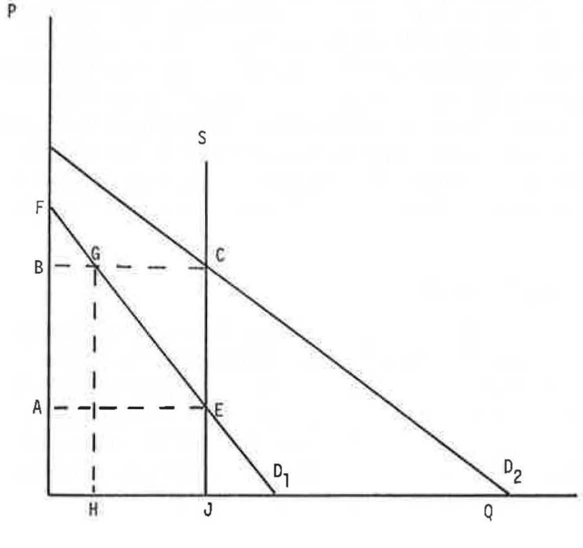
BENEFITS TO NATURAL AND FIXED CAPITAL AND REDISTRIBUTION CONSEQUENCES

The one who stands to benefit most from tourist expansion is the owner of natural resources and in some instances underutilized fixed-capital resources that are dependent on in-region demand.

In the case of privately owned natural resources, e.g., residential and recreational land, the effect of tourist growth is to increase demand for those resources as shown in Figure 1 by the shift from D_1 to D_2. If market pricing prevails, the result is an economic rent of ABCE. This is the gain to owners of natural resources. It does not represent the net gain to residents of the region however. For one thing, ownership rights may reside with nonresidents. More importantly, there are accompanying losses to regional consumers.

Assume that D_1 represents resident demand, D_2 total demand including nonresident demand, and S represents the supply schedule of a resource for which there is a fixed quantity. In the absence of nonresidents, residents would consume J of the resource and pay A per unit. The consumer surplus to residents would be the area AEF. Consumer surplus is the difference between what buyers are willing to pay, which is pre-

Figure 1. Welfare effects of out-of-state tourism through increased demand for privately owned resources of fixed supply.



sumably indicative of the benefits derived from a good, and what they in fact pay. [For a discussion of the concept see any theory text (2).] With the addition of nonresident demand, residents reduce their consumption to $\bar{H}$ for which they must pay a price of B. Their consumer surplus decreased by ABGE. The gain in rent to property owners is larger than the loss in consumer surplus by GEC. The analysis also applies to fixed-supply resources for which demand is indirectly increased as a result of the expansion of tourist-oriented activities.

If the ownership of the resource resides with residents of the state and if the potential for making some individuals better off without making others worse off is a sufficient condition, expansion of tourist demand can be said to increase the welfare of residents of the state. Inasmuch as compensation by gainers (resource owners) to losers (consumers) will not occur in the absence of intervention by government, the result is a redistribution from a state's consumers to its resource owners. If the resources are partially or wholly owned by nonresidents, then a part or all of the redistribution is from consumer residents to resource-owning nonresidents. This, of course, need not be a matter of particular concern. Changes in market forces regularly effect new equilibriums that alter the welfare positions of individuals. In the case of tourism, however, what is involved may not be entirely market forces. State governments through various expenditure and pricing policies (taxes, user fees, and the like) relating to highways, parks, and travel information programs may influence the level of nonresident demand. If this is the case, the formulation of such policies should give explicit consideration to the redistribution consequences.

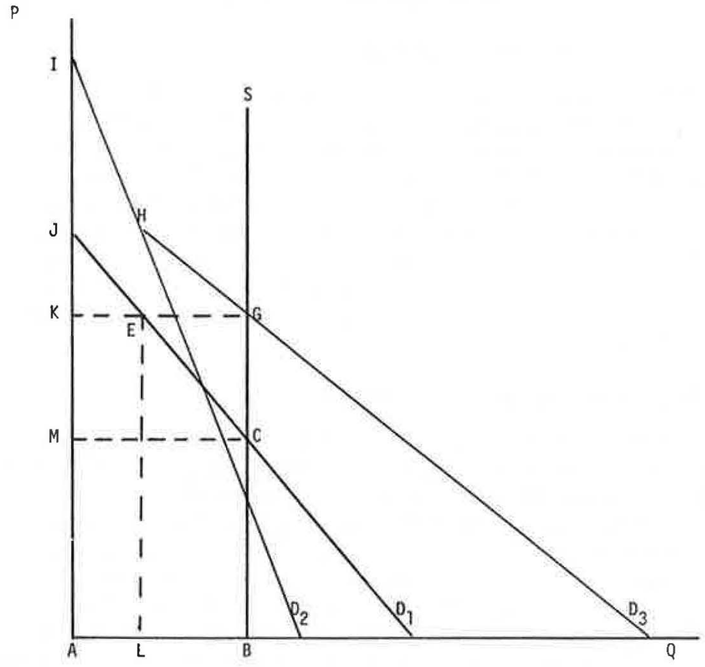
When fixed resources, say amenity-producing resources such as wilderness areas or water resources, are publicly owned, shifts in demand through increased tourism also can be expected to reduce the welfare of resident consumers except in instances in which the resource is available in sufficient quantity that neither rationing (price or nonprice) nor congestion costs occur as may still be the case of wilderness resources in certain northern Rocky Mountain states. If rationing is necessary and is not accomplished through pricing (and nonprice rationing is generally the case), the gain in resource value (as evidenced by what users are willing to pay for it) is unrealized, and indeed depending on the rationing outcome the actual consumer surplus enjoyed by users may be even less than in the resident-use only case. In Figure 2 D_1 is resident demand, D_2 nonresident demand, D_3 total demand, and S the supply schedule of a resource for which there is a fixed quantity.

If allocation of supply were made to those placing the highest value on the product (to individuals willing to pay a price of M or higher), the resident consumer surplus would be ABCJ in the absence of nonresident users and ALEJ in the presence of nonresident users (assuming that allocation is made to individuals willing to pay a price of K or higher). Total consumer surplus would increase to ABGHI, whereas the resident share would decrease. Rationing other than by price would most certainly alter this outcome inasmuch as some allocation would be made to individuals unwilling to pay prices as high as M or K. Total consumer surpluses would be smaller as a result of a different mix of users. How different would depend on the workings of the rationing system. Despite such ambiguities, it is safe to conclude that, unless the rationing system was peculiarly perverse, the effect of introducing nonresident demand would be to reduce consumer surplus of residents. Thus, in the absence of a price system and a zero increase in resource rents to the state, the result of nonresident users is a decrease in welfare to residents of the state.

LOCAL FISCAL IMPACT

At the local community level there is also a fiscal impact. Social overhead facilities and government services are required by tourist-serving enterprises and the labor force of these enterprises. Revenue is derived from taxes and fees, mainly property taxes on the land and improvements of the commercial enterprises and residential property (owned and rented) of the tourist labor force. The match between costs and revenues depends on a number of variables including the character of the community, the types of tourist enterprises, and the characteristics of the labor force.

Figure 2. Welfare effects of out-of-state tourism through increased demand for publicly owned resources of fixed supply.



Costs will be smaller if a community has excess social capital and residential housing, for example because of stagnation or decline in its other basic industries, and therefore the community will not need to construct new schools, water systems, sewage treatment plants, residential streets, public buildings, and so forth.

The enterprises (motels, golf courses, summer resorts, convention centers) vary by the level of demand for public facilities and services, the seasonality of demand, and their capital intensity. Low levels of demand for public facilities and services are preferred over high levels. The smaller the seasonal fluctuations of the enterprises are, the less the off-season idle social overhead capacity will be. The more capital intensive the enterprise is, the higher the real property values and hence tax revenue per worker will be.

The labor force varies by rates of pay, seasonality of work, age, marital status, number of school-aged children per worker, geographic origin of worker, and so forth. The higher the wage rate is, the more valuable the residential property is and therefore the higher residential property tax revenues are. The fewer the number of school-aged children per worker is, the smaller is the educational impact. This is particularly important inasmuch as education cost is the major item in local budgets. The more stable the employment and the milder the seasonal employment variations are, the smaller the community welfare needs are. If the worker already resides in the community, the smaller are the needs for additional social capital.

An adverse local fiscal impact shifts support of tourist expansion to commercial and residential property owners not directly related to the tourist industry, whereas a favorable local fiscal impact, in effect, constitutes a subsidy from the tourist industry to the rest of the community. Tourist communities, of course, vary widely, and generalization is tenuous, particularly in the absence of any systematic studies. A number of characteristics are fairly universal however. Capital-labor ratios tend to be fairly low relative to other basic industries. Rates of employee pay are low, and therefore the value of residential property per worker is low. Both tend to contribute to a low per-worker property tax. Whether this results in an adverse fiscal impact depends on the expenditure side and the extent to which nonproperty taxes and fees collected directly and indirectly from tourists are used. Here generalization is not possible.

OTHER COSTS AND BENEFITS

There are, of course, effects of tourism other than those discussed. Two in particular might be noted. Environmental quality may be affected, with the direction of change generally adverse to the resident population. Also benefits may result from expanded consumer choice caused by available facilities and services that were tourist induced, and possibly prices may be lower for certain facilities and services because of scale effects or lower off-season rates as a result of off-season marginal pricing. These and other effects have been treated less sytematically because of difficulties of measurement or because of a judgment that they are of lesser improtance. Nonetheless, they should not be overlooked in a tourist impact study, particularly since their importance may vary widely among states.

PUBLIC POLICY IMPLICATIONS

The case for promotion, neutrality, or discouragement of tourism depends on the total impact of the industry on the welfare of the residents of the region. As indicated, the effects are diverse and are not unambiguously favorable or unfavorable when redistribution effects are involved. Therefore, the case for tourist promotion (tourist information and advertising programs and the less than full cost pricing of facilities and services used by tourists) is supported (a) if tourist encouragement policies work, (b) if the state fiscal impact is favorable, (c) if the job impact is favorable, (d) if the local fiscal impact is favorable, (e) if the redistribution impact is viewed favorably (redistribution from resident consumers to resident or nonresident natural resource owners), (f) if there are no adverse environmental consequences, and (g) if the region has an unfavorable balance of tourist payments; hence residents receive a larger tourist subsidy when traveling outside of the region than nonresidents receive when traveling within the region.

Obviously the case for promotion does not necessitate that all these conditions be met. Yet, when some are adverse, a system of weights is necessary; and, if all effects are not quantifiable in dollar terms and redistribution effects are involved, a concensus policy is not likely to be achieved. The case for discouragement is supported by the opposite of these conditions.

Alternatively, a policy of neutrality might be followed, particularly inasmuch as the totality of effects is not fully known and appropriate weights for different effects are difficult to agree on. By one definition of neutrality, governments could dispense with all tourist promotion and price all public services and facilities used by tourists at their full cost including highways. The effect on tourism would then depend on whether present prices (taxes and user charges) are higher or lower than costs and whether the demand for facilities and services is somewhat elastic in the relevant price ranges. It may be either that prices (taxes and user charges) paid by tourists for state facilities and services are reasonably close to the full costs of producing them or that the change in prices necessary to cover full costs would have little or no effect on tourist activities and that travel promotion and information programs do not influence the number of visitors. Then policies of encouragement, discouragement, or neutrality as defined above would be equally ineffective in influencing levels of activity (although the state fiscal impact would vary). If encouragement or discouragement were desired, either sizable subsidies or penalty overcharges would be necessary insofar as the pricing mechanism (taxes and user charges) was utilized.

Unfortunately at this time we have insufficient information to be assured of making wise decisions. In this paper an attempt has been made to isolate the effects that should be measured. Insofar as data for Oregon are available, the direction and magnitude of certain effects for one state have been reported. The data are incomplete however, and no definitive judgment can be made. Insofar as evidence is available, it indicates (a) a state fiscal subsidy to tourists, (b) a small favorable employment effect (based on an assumption of a high degree of labor mobility and some leisure benefits from nonwork), (c) a favorable real property effect from the standpoint of resource owners and an unfavorable effect from the standpoint of consumers, (d) an unknown local fiscal effect (there is no reason to believe it to be strongly favorable), and (e) probably an adverse environmental effect. If this is correct, it is not a strong case for promotion of the industry. Indeed, if the state is determined to promote economic growth, other industries should be investigated and their impact compared with tourism.

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DISCUSSION

L. B. Wallerstein, Environmental Development Division,
Federal Highway Administration

With the increasing policy of no growth or slow growth on the part of states such as Oregon, because of environmental and other considerations, the tourist industry, despite its relatively low wage level, takes on increasing economic importance because it does provide some seasonal economic input without the traumata of permanent economic development.

The following comments on this paper deal primarily with economic concepts.

Although the author places the economic emphasis on employment caused by the tourist industry, he does not touch on the economic multiplier and accelerator effects of this employment or on the economic impact of goods and services, stemming from the tourist industry, purchased within the state other than the economic impacts caused by increased employment.

The Office of Management and Budget usually uses 8 or 9 percent as an opportunity cost. Also, the opportunity cost concept is not really the interest concept as indicated, although the concept of interest may be a facet of opportunity cost or one kind of opportunity cost. If the author's figures are recalculated at 8 or 9 percent, the related data derived may differ considerably from that derived by using the 6 percent figure.

The relationship between full employment and wage levels should be clarified, inasmuch as, contrary to the author's contention, full employment usually results in high wage levels because of supply and demand factors.

The author overlooks the possibility of out-of-staters coming in to be employed in Oregon's tourist industry and the impact this would have on the economy of the area.

In his discussion of per capita income level, the author neglects the question of the impact on per capita income level if there was no tourist industry and if people went on welfare instead of working in this industry.

In summary, I think that overall this is an extremely valuable paper, and I recommend that it be read by all persons in the highway community concerned with the economic considerations of the highway program and by those concerned with relationship between the tourist industry and the highway program in particular.

ECONOMIC ANALYSIS AND THE ENVIRONMENTAL OVERVIEW: SUGGESTIONS FOR PROJECT RECOMMENDATIONS BY LOCAL GOVERNMENTS

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Recent trends in transportation planning and in federal and state legislation are leading to greater public participation in transportation project evaluation. Although these trends represent an opportunity, they also obligate citizens and local governments to evaluate the multitude of social, economic, and environmental factors involved in project evaluation, even though they have limited experience and few resources for doing so. The paper suggests a framework for organizing potential project impacts, which emphasizes (a) the development of an environmental overview before project recommendations are made and (b) an understanding of the relationship between the effects considered in the overview and those included in traditional economic analysis. Effects on road users and nonusers are analyzed to determine whether they are treated explicitly or implicitly in benefit-cost analysis or whether they should be placed in such categories as (a) natural resources and environmental quality, (b) community impacts, (c) leisure and recreation, and (d) economic effects. A technique for rating and weighting the project effects is outlined in order to facilitate the formulation of project recommendations. The paper should be useful to local governments either in providing an approach to be implemented or as a point of departure for developing a system that is responsive to specific local needs.

•RECENT TRENDS in transportation planning and in federal and state legislation are leading to greater public participation in evaluating transportation projects. In Oregon, for example, the Action Plan, state land use legislation, state legislation to divert motor vehicle revenue to public transportation investments, and a proposed $150 million bond sale all invite or require public involvement in the project selection process. The result is an opportunity for citizen groups and local government agencies to explicitly incorporate their preferences into project recommendations and for state transportation agencies to respond to a variety of local needs in a systematic way when they select from the recommendations.

The opportunity, however, carries with it an additional obligation. It is necessary for citizens and local governments to evaluate numerous social, economic, and environmental factors (SEEF) even though they have limited experience and few resources for doing so. Whereas environmental impact statements have frequently been the tool for clarifying and evaluating SEEF, local governments do not have the capabilities for analyzing project effects in the depth required for detailed impact statements. Furthermore, whereas an impact statement is useful in presenting information for corridor and design hearings, it is unnecessary and, in fact, impractical to prepare one for each project recommendation. In some instances, a local government recommendation will be made at the project concept level with no well-defined corridor. In these cases, an involved impact statement would be impossible. Nevertheless, some consideration of SEEF is essential at an early stage. Consequently, guidance is necessary if project effects are to be measured and evaluated in a meaningful manner.

This paper suggests to local governments a framework for organizing the myriad of potential project impacts. The key to the approach is the development of an environmental overview and an understanding of the relationship between the effects considered in the overview and those included in traditional economic analysis. Ideally, it would be used in conjunction with systems planning, but the approach is also useful if a comprehensive plan does not exist.

BENEFIT-COST ANALYSIS AND THE ENVIRONMENTAL OVERVIEW

Ideally, a local government unit evaluates prospective highway projects with reference to how well they correspond to specific regional objectives. Unfortunately, however, most local governments have not generated a set of operational objectives to which highway improvements can be related. Furthermore, many project effects are not easily measured in comparable units. Consequently, a productive approach is to organize project impacts according to those factors that can be evaluated in dollar terms and that are included in benefit-cost analysis (to the extent that the state of the art permits) and those that pertain to other social or community goals. In this framework, project effects should be scrutinized to determine which are considered in benefit-cost analysis and which should be treated in an environmental overview, taking care not to double count any factors.

Road-User Benefit-Cost Analysis

The benefits of highway projects occur primarily because of highway use; road users are the initial beneficiaries of both reductions in cost and improvements in road quality. Savings to automobile and truck operators in terms of shorter or faster trips, reduced operating costs, and safer travel (to the extent that they can be measured) are included in traditional road-user analysis. These benefits are compared with costs to the highway agency to arrive at an index of project desirability.

Road-user analysis is not used to analyze general benefits and costs to the community, impacts on wildlife and natural resources, or air and noise pollution effects; environmental impact statements have typically focused on these variables. Because the analysis compares only some of the benefits from highway construction with some of the costs, the result cannot be considered sufficient in itself for choosing projects. However, the analysis does provide important but frequently misinterpreted information about the nature and magnitude of the factors usually treated in an environmental impact statement. An understanding of the relationship between road-user benefit analysis and all costs and benefits from highway projects reveals that road-user analysis is a more powerful tool than would first appear to be the case.

The most frequent analytical errors (2, 3, 4) committed in evaluating highway projects are (a) failing to recognize that most of the new economic activity that does arise is implicitly measured by road-user analysis and (b) counting too many observed effects as net increases in economic activity, not realizing that they are possibly offset by unobserved effects.

Transferred Benefits—The savings or benefits to road users represent real income gains that are "consumed" in a variety of ways, including more time on the job, increased convenience and leisure, additional break time for drivers, and more or faster trips for housewives. Many observed effects in the area of a highway project are results of these real income gains that are transferred or passed on to land owners, apartment landlords and tenants, and sellers and purchasers of goods as the economy adjusts to the change in the transportation network. Too frequently, road-user savings and transferred benefits are lumped together as total benefits from a project. Benefits are overstated whenever the analyst includes both transferred benefits and road-user savings.

It is possible to invent many cases of overcounting to illustrate this point. For example, a highway improvement might reduce the cost of grain to a farmer who uses it to feed his cattle from which milk and meat are produced and sold. If the analyst were to count the transportation savings and the value of the grain, milk, and meat, he would arrive at huge benefits and an impressive benefit-cost ratio. All these effects represent only one benefit that is passed from one stage of production to another.

Relocations of Economic Activity—Highway improvements and the consequent user benefits often create conditions conducive to increased commercial activity in the area of the project. Before this increase is characterized as a net benefit, whether and where the economic activity would have taken place without the highway must be known. Frequently, apparent increases in economic activity are erroneously included as benefits only because the researcher fails to view the project from a perspective that is broad enough to include all project effects, not just those occurring in its close proximity. That is, frequently a gain to one firm is a loss to another. For example, construction of a bypass might result in a strip of restaurants, bars, and gas stations, while there is accompanying decline in commerce and land values on the "old road." Although the corridor may reflect more prosperous conditions, the overall level of economic activity may not have changed. Just as with transferred benefits, there is a danger of overcounting if apparent benefits are accepted uncritically.

The Environmental Overview

The environmental overview encompasses analyses of the "other" SEEF arising from project construction. It provides a mechanism by which projects can be evaluated before priorities are formulated. Later, if the highway agency selects a project for construction, an environmental impact statement that analyzes the same effects in more detail or from a different perspective can be prepared, if necessary. For small projects with few effects on nonusers, the project proponents would need to do no more than explain that no adverse impacts are expected. Major projects, of course, would require more elaborate investigation. In no case, however, does the overview represent a detailed analysis of the anticipated effects. Rather, it highlights the major potential problems so that local area recommendations can be based on a recognition of their existence and an evaluation of their importance.

The general categories given below represent a possible classification of effects for the overview. They are presented here as a suggested rather than a definitive list; the subcategories are not all-inclusive but are indicative of how the factors might be organized. It would be extremely difficult to devise a set of categories that are applicable to projects in both urban and rural areas and that are accepted by all potential users.

1. Natural resources and quality of the environment
   a. Fish and wildlife
   b. Vegetation
   c. Earth
   d. Water
   e. Air
   f. Noise
2. Community impacts
   a. Land use
   b. Neighborhood effects
   c. Services and utilities
   d. Schools and churches
3. Leisure and recreation
   a. Parks and open space
   b. Monuments and historical sites
   c. Recreation areas or activities made available
4. Economic effects
   a. Use of unemployed resources
   b. "Opening-up" effects (reorganization of inputs or economies of scale)
   c. Effects of construction expenditures
   d. Structures affected and not taken

Whatever classification scheme is adopted, it is imperative that the categories be clearly defined and not overlap so that persons using them will not be confused about their meaning and will understand that each effect is included under only one heading. If such a system is not used, it is likely that citizens and local government representatives will be overwhelmed by the number and variety of project consequences and may mentally classify and evaluate them in different ways.

The section that follows indicates how project effects can be grouped into these or similar categories.

CLASSIFICATION OF PROJECT EFFECTS

Local governments should understand which project effects are explicitly and implicitly measured by benefit-cost analysis and which effects must be included in the various categories of the environmental overview. Regardless of how many categories are used or how they are defined, essentially the same effects must be analyzed. Project impacts are viewed as being either developmental (because of or during construction) or operational (related to the volume of highway use). Within these general classifications, effects on both road users and non-road users are examined.

Developmental Effects

Developmental effects can usually be separated into those that are compensated and those that are uncompensated. If compensation is paid for a project impact, the payment will be included in the cost component of the benefit-cost analysis and, consequently, should not be counted again. If compensation is not paid, then the effects should be considered in one of the categories of the environmental overview.

Compensated Effects—Highway agencies compensate the owners of private property (including land, structures, and improvements) acquired for highway investments and pay for costs associated with relocation. Thus, for an environmental overview, it is not necessary to describe such specific effects as business structures and residential units removed because they are already included as right-of-way costs. Details concerning the property taken and relocations can be included as supporting information for the benefit-cost analysis, however. The risk of overemphasizing these effects by counting them twice is especially great because they appear to be both dollar costs and "real" losses in structures and residences.

Uncompensated Effects—Many of the uncompensated effects described below have the potential to become compensated because, if they represent acute problems, a highway agency will have to take steps to minimize them. The costs of these steps are included in the benefit-cost calculation.

Uncompensated effects on people or property should be considered in the environmental overview. Several categories of effects are discussed so that it can be shown which impacts are included in benefit-cost analysis and which should be treated in the environmental overview. Three types of impacts are analyzed.

1. For highway users, the construction process can result in increased operating costs, reduced comfort and convenience, and additional trip time arising from construction delays and detours. Usually, these effects are negligible when compared with total benefits and costs from a project and, consequently, are ignored. If they are counted, they are included in the benefit-cost calculation and need not be considered separately. There are also costs that drivers impose on each other related to congestion, air and noise pollution, and visual disamenities. These are assumed to be either related to comfort and convenience or treated explicitly when air, noise, and visual pollution are evaluated.

2. Non-road users are sometimes affected by the presence of men and equipment used in the construction process. Noise, dirt, and unsightly machinery and materials are among the potential adverse effects on nonusers. Also, though a home is not physically altered by highway construction, the homeowner might consider himself worse off if a highway now passes near his doorstep. Such losses are not compensated and represent costs (or gains if one prefers the situation with the new highway) for which one is paid (or pays) nothing. Generally, these effects are also small when compared with the total impact of the project. Consequently, there is justification for treating these effects as negligible or, if the effects are substantial, for including them in the environmental overview either as a community impact or as an effect on the quality of the environment.

3. Some highway projects disrupt the environment in ways that ultimately affect common property. There are impacts on natural resources and environmental quality such as air, soil, water, vegetation, and wildlife and on the items included in the leisure and recreation category such as parks, open space, and historical sites and monuments. In most cases, the effects are considered to be negative, but it is possible that monuments and historical sites can be made accessible, parks can be created, or undesirable species can be eliminated. In either case, the effects should be considered in the environmental overview.

A review of the compensated and uncompensated developmental effects reveals that the environmental overview is concerned only with impacts on nonusers. When efforts are made to minimize these impacts, the costs of these efforts become part of the benefit-cost analysis. In such cases, descriptions of these effects should serve only as supporting information in benefit-cost analysis rather than as components of the environmental overview.

Operational Effects

The most important effect of a highway project is that for which it is intended: enabling the highway user to move himself and his goods faster, cheaper, safer, and more comfortably and conveniently. Of course, there are other effects related to highway use that accrue to nonusers both within and outside the corridor.

Proper evaluation of the effects on users and nonusers requires that the analyst distinguish between diverted and generated traffic. Although the causes of diverted and generated traffic may be the same, the evaluations of the two sources of traffic as impacts of the highway improvement should be very different. When traffic is diverted, the effects of that traffic are diverted too. Thus, an appropriate evaluation of the consequences of a highway improvement includes the changes in effects on the roads from which the traffic is diverted, as well as the effects of the diverted traffic on the improved highway.

It should be noted that the offsetting effects on the highways from which traffic is diverted frequently go unnoticed. Traffic that is diverted to the improved highway tends to come from several highways in the system; thus, traffic reductions are dispersed over many roads and the traffic increase is concentrated on the improved road. Also, traffic reductions on the rest of the highway system may actually never be apparent if they are offset by normal traffic growth.

User Effects—Highway projects benefit users primarily by (a) reducing vehicle operating costs, (b) reducing travel time, (c) reducing the frequency and severity of traffic accidents, and (d) increasing the comfort and convenience of traveling. Standard benefit-cost analyses usually include estimates of a and b and sometimes c. Increased comfort and convenience and some elements of improved driver safety, however, have not yet been adequately measured. Eventually, perhaps, values can be assigned to these factors, and they can be incorporated into benefit-cost analysis. Until then, road-user benefit-cost measures will continue to be imperfect.

Nonuser Effects—Highway investments typically increase traffic flows, which, in turn, have effects on nonusers both in the proximity of the corridor and in other areas. These impacts are felt specifically by those owning property and those living or operating businesses in the affected areas and generally by the entire regional population.

Highway improvements and the consequent user benefits often create conditions that are conducive to more economic activity in the area of the project. However, as was pointed out earlier, much of the apparent increase in activity may simply be diverted along with the traffic from other areas in the network or may represent a result of road-user savings already included in benefit-cost analysis.

There is no a priori reason to expect a net gain or loss for the land component of property values or in the tax base. In contrast, the value of structures in the aggregate might be expected to decline in response to highway construction. This is the case when relatively durable and immobile structures become inefficiently located because of the change in the highway network. Eventually, perhaps, gains and losses in the value of structures can be treated in an expanded benefit-cost framework, especially inasmuch as they are measurable in dollar terms. Until then, these results of highway improvements should be included as economic effects in the environmental overview.

Most highway construction projects cause or at least permit some negative environmental effects in the operational stage, although their net effect is probably smaller than expected. The primary reason for the overstatement of adverse air, noise, or visual effects is that much of the observed traffic on the improved facility is diverted from other highways and the effects of the traffic are diverted along with it. For example, polluted air along the improved corridor may be offset by cleaner air along other highways in the system.

Of course, any additional traffic on the entire highway system caused by the highway improvement will tend to accelerate the deterioration of the physical environment. The relevant question is not how much environmental damage appears on the improved highway, but how much of the damage would not have occurred anywhere on the highway system in the absence of the improvement.

As a result of their construction, improvement, and use, highways affect the structure and activities of neighborhoods and communities. If there is generated traffic, the net impact will be greater. Also, there can be important effects from traffic diversion from less populated to more populated areas or from areas without structured neighborhoods to organized communities. Although the traffic still carries its effects with it, more people may be exposed to them.

Community effects are not likely to be great for the majority of projects that involve only grading and paving or widening of existing roads. New highways, on the other hand, can be expected to have consequences for public services, school districts, and community interaction. Because these impacts are not included in benefit-cost analysis, they should be evaluated as community impacts in the environmental overview.

Some projects, usually new construction, act as catalysts in tapping an area's development potential, providing economies of scale, or causing unemployed resources to be used. Whereas many of the observed benefits to an "opened-up" area are either relocated activities or are included in the benefit-cost analysis, the net effects from such investments should be noted. With this type of effect, especially, care must be taken to avoid double-counting. These effects should only be counted when it is clear that they are entirely dependent on the new highway.

Opening-up effects may not be so important now or in the future as they were in the past. When areas are penetrated by new highway construction, the new project is less likely to be a better investment than an alternative use of funds, assuming that the best opening-up project presumably would have been chosen previously. In these cases, the movement of raw materials, goods, and services will be facilitated, but the increased mobility and its related benefits are merely experienced in one area rather than in another where the alternative investment would have been undertaken.

Summary of Developmental and Operational Effects

Many publications that address impacts of highway construction compile long lists of project effects. Frequently, these listings include practically everything that happens in the immediate area of the project, whether or not the impacts can be traced to the project, and ignore effects resulting from the project but not taking place in the corridor. Furthermore, in the attempt to be comprehensive, overcounting of effects is common.

A typical collection of effects and items to which effects are related is given in Table 1. By way of a summary, these variables are classified according to how they fit the organizational framework just discussed.

RATING AND WEIGHTING PROJECT EFFECTS

The organizational scheme just outlined provides a systematic framework within which local governments can review highway project impacts. Although the effects expressed in dollars are relatively easy to understand, many of the SEEF included in the environmental overview are subject to a number of interpretations. When local governments generate priorities based on these data, it is convenient for them to have at their disposal some means of rating (estimating the magnitude of the impacts) and weighting (evaluating their importance) project effects (5, 6, 7). A general approach to weighting and rating is suggested below.

Assigning Weights to Project Effects

Although it is nearly impossible to assign weights to a heterogeneous collection of project effects, such weights are assigned implicitly and often unsystematically whenever projects are recommended. If weights are not explicit, then the decision-making rationale is not clear. Consequently, either decision-makers tend to impute their personal preferences, or technicians usurp the role of decision-makers by assigning their own values.

Two weighting processes are recommended: The relative importance of categories in the environmental overview should be established, and user benefits, as expressed in the benefit-cost ratio, should be compared with the nonuser effects summarized in the environmental overview.

A simple procedure for establishing the relative importance of categories in the environmental overview is to allocate 100 points to each member of a citizen committee, for example, and have them assign these points according to their perceptions. Once each member "votes," the numbers can be averaged and the results discussed. The discussion will very likely affect a second round of voting. The averages from the second round could be accepted as representing the valuations of each class of effects, or more rounds could be undertaken before the final averages are accepted. Table 2 gives a hypothetical result of the process.

A similar procedure could be followed to determine the relative importance of user benefits shown in benefit-cost analysis and nonuser effects shown in the environmental overview. Assuming that an allocation such as 40:60 resulted, the 60 points could be assigned to the weighted categories from Table 2 as given in Table 3.

The result would be weights that represent the collective preferences of the group. Whereas experience in applying the weighting scheme would likely lead to modifications, establishing some weights tends to confine discussions concerning project priorities within reasonable bounds.

Rating Project Effects

Because a common denominator such as dollars cannot be assigned to all project effects, the use of a relative scale appears to be the most practical approach to the rating process. For example, a scale of -3 to +3 could be used to express the estimated magnitude of each category of effects (Table 4).

Even with limited experience, both the benefit-cost analysis and the categories of the environmental overview could be assigned a heavy, moderate, slight, or negligible rating for each project, within bounds of accuracy required for the recommendation process. The values corresponding to the general ratings can be multiplied by the weights for the categories as previously determined, and a total could be assigned to each project (Table 5). There are some conceptual problems in establishing rating scales for all factors. This is certainly true with respect to benefit-cost analysis and other factors in which the relationship between estimated or measured results and the rating might not be linear. Generally, however, at this stage in project evaluation assumed linearity is not a big problem. For purposes of the example, it is assumed that a benefit-cost ratio of 1.3 is equivalent to a rating of +1.

In Table 5, the negative nonuser effects outweigh the benefit-cost ratio of 1.3 and the positive impact on leisure and recreation, and the project receives a score of -8. If all projects under consideration are subjected to the same procedure, they can be ranked according to their scores.

Although the ranking process can be very useful to local governments, it should not be expected that projects could be selected directly from the rankings. There are several reasons for this. First, the procedure is probably not accurate enough to distinguish between projects that have very close total scores. Because the scores are products of several processes, all of which have some degree of error, the final numbers are accurate only within a given range. It should be possible, however, to conclude

Table 1. Proposed treatment of effects of highway improvements.

Type of Effect	Impact	Effect	Proposed Treatment
Developmental	Disruptions during construction	On users	Benefit-cost analysis
		On nonusers	Evaluated in environmental overview as natural resource effect or community impact
	Acres taken, buildings taken, jobs lost or relocated	Compensated	Benefit-cost analysis
	Structures affected but not taken	Uncompensated	Evaluated in environmental overview as community effect if residential and economic effect if business
	Earth and erosion, fish and wild life, vegetation, parks and space, monuments and historical sites	Compensated and uncompensated	Supporting information in benefit-cost analysis if compensated; natural resource or leisure and recreation categories of environmental overview if uncompensated
Operational	Driving time, operating cost, accident reduction	User benefits	Benefit-cost analysis
	Safety, comfort and convenience	User benefits	Not yet valued in benefit-cost analysis
	Noise and air pollution	User and nonuser effects caused by users	Evaluated in environmental overview as natural resource effects
	Congestion	User effects caused by users	Benefit-cost analysis or not yet valued in benefit-cost analysis
	Commercial: agricultural, industrial, sales, taxes, employment, property values	Usually transferred and relocated effects	Results of effects treated in benefit-cost analysis; should not be evaluated in environmental overview; if net impacts, then treated below as "opening-up" effects
	Community: neighborhood changes, schools, churches, public services	Some net effects but often transferred and relocated	Net effects only; included in the environmental overview as community impacts
	Opening up: developmental potential, unemployed resources, effects of construction expenditures	Net economic effects if clearly an addition to economic activity	Evaluated as economic effects in environmental overview

Table 2. Hypothetical results of assigning weights to project effects.

	Citizen				
Category	No. 1	No. 2	No. 3	No. 4	Average
Natural resources and quality of the environment	35	30	50	45	40
Community impacts	20	25	20	35	25
Leisure and recreation	10	20	5	5	10
Economic effects	35	25	25	15	25

Table 3. Assigning weights to environmental overview categories.

Category	Value[a]	Weight (value × 0.60)
Natural resources and quality of the environment	40	24
Community impacts	25	15
Leisure and recreation	10	6
Economic effects	25	15

[a]Value from Table 2.

Table 4. Relative scale for rating project effects.

Magnitude	Value	
Heavy	+3	Favorable
Moderate	+2	Favorable
Slight	+1	Favorable
Negligible	0	
Slight	-1	Unfavorable
Moderate	-2	Unfavorable
Heavy	-3	Unfavorable

Table 5. Sample scoring of a project.

Effects	Description of Effects	Weight	Rating	Score (weight × rating)
Benefit-cost analysis	1.3	40	+1	40
Natural resources and environment	-Slight	24	-1	-24
Community impacts	-Moderate	15	-2	-30
Leisure and recreation	+Slight	6	+1	6
Economic effects	Negligible	15	0	0
Total				-8

that projects in the 75 to 80 range are better than those in the 50 to 55 range.

Second, there may be special circumstances that suggest that a project is better or worse than its score. Each project with extenuating circumstances should be supplemented by remarks indicating their importance. For example, if there are severe environmental problems that are not expressed adequately by a -3 rating, it may be decided to defer a project with a high score. Alternatively, a project that would significantly reduce fatalities at a dangerous interchange may have a low benefit-cost ratio (given existing imperfections in the measurement of accident costs) and a negligible environmental impact—resulting in a score near zero—but still be considered desirable.

Finally, funding requirements may cause a change in the ranking. For example, it might be considered desirable to substitute a project for which a greater share of federal funds can be used for one with a higher ranking that receives a higher proportion of state funds. Similarly, it may be possible only to maintain a given section requiring major reconstruction until federal funding is available.

Although considerable work remains to be done to gain a commitment on the environmental overview concept and on rating and weighting techniques, the approach offers an opportunity to enhance local government project recommendation procedures to keep up with the demands of federal and state legislation. Whether the discussion in this paper is used as a basis for project recommendations or as a point of departure for the development of a local government project evaluation framework, some efforts in this direction could be valuable. The framework presented or a similar approach would help to (a) systematize the consideration of SEEF, (b) advance the time in the selection process at which important project effects are considered, and (c) increase the opportunity for local groups to express their preferences and their evaluations of project impacts.

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DISCUSSION

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This paper presents some new wine in old bottles and some old wine in new bottles. While I disagree with some of the authors' concepts about the shifting or relocating of environmental impacts, I do find the work to be informative and timely. It presents tools to aid local governments in reaching more viable decisions relative to highway programs. This is especially useful because the tools suggested are rather elementary and relatively easy to use, and these characteristics take on increasing importance in these days of scarce money. The particular relevance of this paper is made increasingly so because of the surge of new regulations relevant to the highway programs such as the National Environmental Policy Act and the inclusion of environmental requirements in federal highway legislation. It discusses economically related environmental considerations for both user and nonuser in easily understood language.

In summary this is a useful, nuts and bolts, how-to-do-it paper that should prove useful not only to local governments, but to other levels of government as well.

HIGHWAY USER INVESTMENT STUDY

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A discussion of the highway user investment study, a detailed highway user economic analysis combined with an investment level analysis, and associated computerized models are presented. The purpose of this paper is to point out data and procedures necessary for analyses of this nature and areas needing improvement. In a national application, data collected by individual states for the 1972 National Highway Classification and Needs Study were used as input. However, a large number of data necessary for the study were not provided by the needs study, and the methods of handling these data deficiencies are discussed. A summary of the national study results is presented, which shows that the proposed 1970-1990 investments in arterial and collector highways yield a benefit-cost ratio of 2.1 and reduce the total expected number of fatal accidents by 32,703. Finally, recommendations are made on areas needing research, and conclusions are drawn on the general applicability of the computer models to similar studies at the state level.

•THE HIGHWAY user investment study (HUIS), a support study for the 1972 National Highway Needs Report to Congress, was developed to satisfy two objectives: (a) to provide Congress with explicit information on the effectiveness of future highway investments in achieving Department of Transportation goals of economic efficiency and safety in transportation and (b) to develop analysis models that, in addition to use in national studies, could be adapted to state-level economic analyses of highways and investments.

This paper discusses HUIS and its computer programs (1) and, in doing so, points out the data and procedures necessary for economic analyses of this nature and those data and procedural areas needing improvement in either quality or quantity (Table 1). Because this is the first detailed highway user investment study to be developed for national application, highway departments will find it interesting and useful.

HUIS consists of economic and investment analyses. Each of these is discussed below.

ECONOMIC ANALYSIS

The Model

The economic analysis model incorporates the more or less typical approach to highway economic analysis in that each highway section proposed for improvement is defined in terms of vehicle operating costs, travel time, and accident parameters in both the before and after conditions. The savings resulting from the proposed improvement are compared to the capital cost of the improvement to determine the relative worth of the investment. However, there are at least three points about this analysis that are noteworthy: (a) large numbers of deficient highway sections can be processed (approximately 200,000 were processed for the national study); (b) many parameters are used to define the before and after conditions on these sections; and (c) both benefit-cost and cost-effectiveness approaches are used.

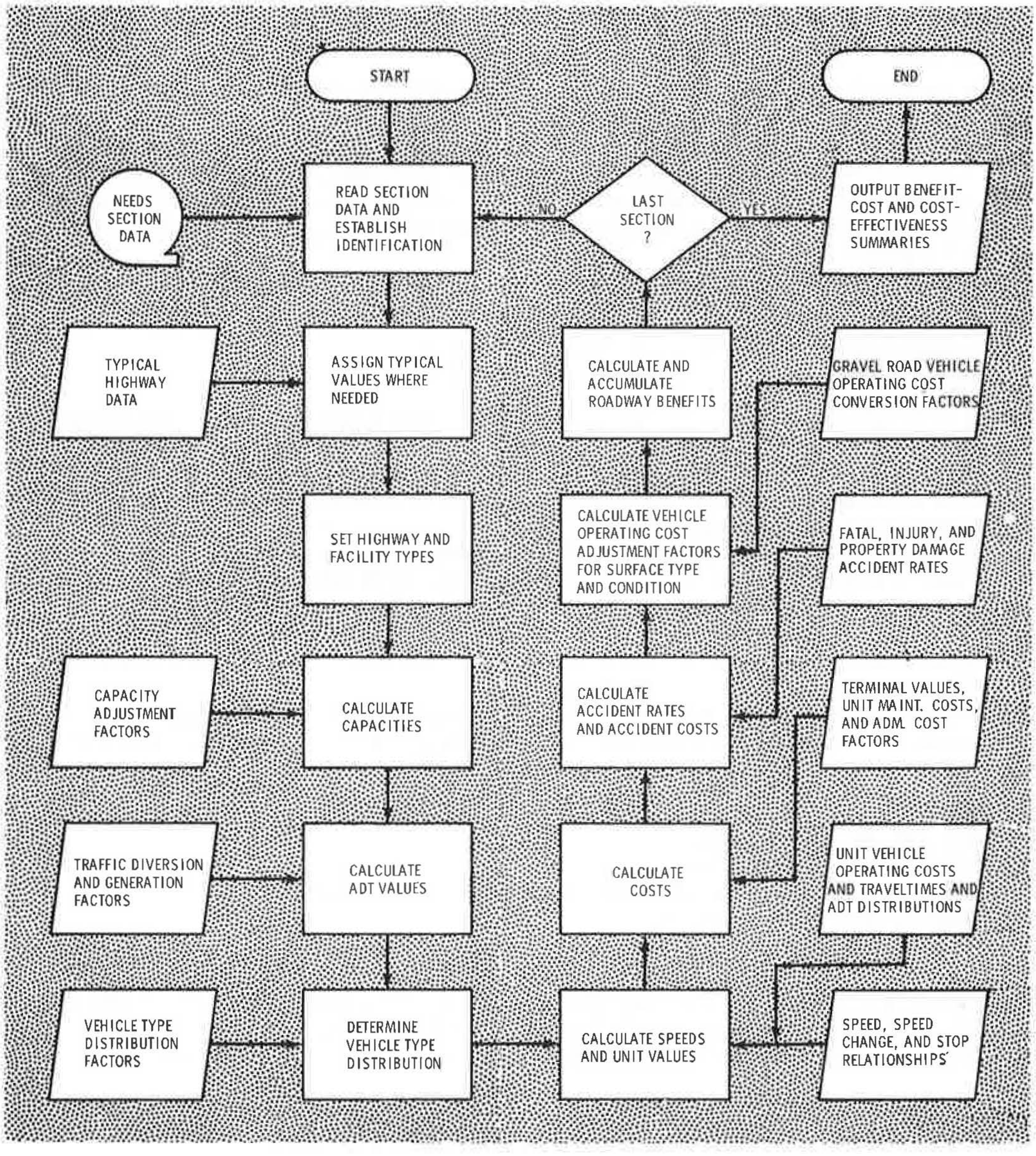
In both the benefit-cost and cost-effectiveness approaches, user savings are calculated for a section for each of the 21 years from the year of improvement through the design year to account for the effects of changing ADT. Annual user savings are calculated from the following formulas:

Table 1. Input data from needs study.

General	Existing Condition	Improvement	Cost
Section identification	No. of lanes	Type and year made	Right-of-way
1968 and 1990 functional classes	Lane, median, and shoulder width	Functional class design standard	Grading and drainage
Rural/urban connector class[a]	Degree of access control	No. of lanes	Surface and base
Roadway deficiency type	Average highway speed	Degree of access control	Structures
Roadway and structure deficiency periods	Passing sight distance[b]	No. and type of railroad crossings	Other
Section length	Terrain type[b]	No. of new structures	Unit maintenance cost
	Type of development	Improvement and design year ADT	Administration cost factor
	No. of signalized intersections		
	Type of signalization[a]		
	Typical percentage of green time		
	Peak-hour parking and directional operation[a]		
	1969 and 1990 ADT		
	Percentage of trucks		
	Capacity		
	Surface type and condition		
	No. and type of railroad crossings		
	No. of structures		

[a]Urban only. [b]Rural only.

Figure 1. Economic analysis process for roadway improvements.



$$\text{Benefit-cost savings} = (\text{value}_E - \text{value}_I)(\text{effective ADT}_I) + (\text{value}_E - \text{value}_{EAI})(\text{effective ADT}_{EAI})$$

$$\text{Cost-effectiveness savings} = (\text{value}_E)(\text{ADT}_E) - (\text{value}_I)(\text{ADT}_I) - (\text{value}_{EAI})(\text{ADT}_{EAI})$$

where E, EAI, and I = data associated with the existing, existing-after-improvement, and improved conditions of a section.

Value is the annual unit user value (e.g., vehicle operating cost, number of fatal accidents) for a specific year and a specific highway condition. Effective ADT is the average daily traffic for a specific year and highway condition reduced by an amount equal to one-half the diverted and generated ADT. The reduced ADT effectively gives diverted and generated ADT one-half the savings realized by the original ADT and thus accounts for consumer surplus.

In the benefit-cost approach the following annual unit values are considered:

1. Vehicle operating costs, travel times, and travel time costs for speed change cycles, stopping and idling, and curves and grades; and
2. Numbers of fatal, injury, and property-damage-only (PDO) accidents and associated costs.

In this approach all benefit and cost components are discounted (an interest rate of 10 percent was used in the national study) from the year in which they occur back to 1970 to convert all future dollars to present dollars. Benefits consist of annual user cost savings plus annual savings in maintenance and administration costs. The sum of these benefits for the study period is compared to the difference between the initial capital investment and the end-of-study-period terminal value to give the relative worth of a proposed highway improvement.

In the cost-effectiveness approach the following annual unit values are considered:

1. Travel times for speed change cycles, stopping and idling, and curves and grades;
2. Numbers of fatal, injury, and PDO accidents; and
3. Number of speed change cycles and stop cycles.

In this approach the savings are not discounted. User savings for the study period are compared to the initial capital investment to assess the relative effectiveness of the highway improvement. This approach provides the decision-maker with the means to evaluate the estimated numerical changes (e.g., fatal accidents eliminated) resulting from the proposed highway improvement.

Finally, the model aggregates the benefit-cost and cost-effectiveness data for all sections into summaries by state, interstate location, 1990 functional highway class (hereafter referred to as functional class), rural-urban connector designation, deficiency time period, and initial deficiency type. The model results are reported on an aggregated basis inasmuch as the general nature of some of the input data precludes reporting on a section basis.

The economic analysis model requires highway section data (Table 1) of the type and in the format of the section data reported by individual states as a requirement of the National Highway Classification and Needs Study (2) (hereafter referred to as the needs study); the model also requires supplemental data as follows:

1. Regional listing of states,
2. Vehicle type distributions,
3. Typical existing highway data for new location improvements,
4. Capacity adjustment factors,
5. Urban area sizes,
6. Traffic diversion and generation factors,
7. Typical percentage of improved highway with passing sight distance ≥ 1,500 ft,
8. Typical average highway speeds for improved highways,
9. Percentage ADT and v-c ratio for 6 ADT segments for HUIS facilities,

10. Speed, speed change, and stop equations,
11. Vehicle operating costs and travel times,
12. Vehicle operating cost adjustment factors for surface type and condition,
13. Daily train frequencies,
14. Capital cost terminal values,
15. Total accident, injury, and fatality rates, and
16. Accident conversion factors for injuries and fatalities.

Control parameters such as interest rate, values of automobile and truck travel time, and costs of fatal, injury, and PDO accidents are also necessary.

Needs Data

As an initial step of the needs study, a 1990 highway functional classification plan, including both existing roads and streets and proposed highways, was developed based on projected 1990 population, land use, and travel.

Needs for the arterial and collector classes were determined by using randomly sampled homogeneous sections and by comparing the conditions of existing roads and streets to appropriate minimum tolerable conditions. Those sections not meeting the tolerable conditions in 1970 were identified as backlog needs. The future adequacy of sections tolerable as of 1970 was examined in 5-year increments to 1990, and the sections becoming deficient in one of the 5-year periods were identified. In addition, the adequacy of existing structures and at-grade railroad crossings was determined.

After deficient sections were identified, necessary improvements and improvement years were established. Coincident with establishing needed improvements, the corresponding cost of the improvements was established.

Figure 1, a flowchart of the economic analysis process for roadway improvements, shows the major computational areas and related supplemental data inputs.

For HUIS the main identification parameters are state, location, functional classification, rural-urban connector class, deficiency time period, and initial deficiency type. Each deficient section identified is processed in one of four improvement categories: normal, railroad crossing, spot, or major structure.

Normal Improvements

New location, reconstruction of existing alignment, major widening, minor widening, resurfacing, and resurfacing plus shoulder improvements are considered normal roadway improvements.

Typical Highway Data—Although most of the required data were reported in the needs study, data on the existing condition are supplemented for sections requiring location improvements for which no existing condition data are reported and for low-volume collector sections. The reported improvement data are supplemented for those sections requiring improvements that change the existing average highway speed (AHS) and percentage of highway with passing sight distance (PSD) greater than or equal to 1,500 ft. Typical rural, small urban, and urbanized values were developed through an in-house study of existing roads and streets.

For new location improvements in which no data on existing highway condition exist, the following typical data are assigned based on functional class, area characteristics, and proposed improved highway type:

1. Number of lanes,
2. Highway type,
3. Surface type and condition,
4. AHS,
5. PSD, and
6. ADT-capacity ratio.

For low-volume collector sections typical existing AHS, PSD, and ADT-capacity ratio are assigned based on existing highway type (and, in urban areas, location and population). Typical AHS and PSD are assigned to the appropriate improved highway conditions based on improvement design standard and rural terrain type respectively.

Highway and Facility Types—Highway types are established for the existing and improved conditions of a section based on the number of lanes, median width, and degree of access control associated with the conditions. Because similar highway types have similar geometrics and speed characteristics, facility types for (a) selecting unit vehicle operating costs and travel times and (b) determining automobile running speeds also are established.

Highway Capacity—Existing (1970) capacity was reported for all sections except low-volume collectors and new location improvement sections for which no existing condition data were reported. An existing capacity for these sections is calculated as a function of the assigned typical ADT-capacity ratio and the 1990 ADT.

Highway capacity after improvement is calculated for each section by using modified Highway Capacity Manual (3) procedures and can be no less than the existing capacity with the exception that resurfacing improvements are assumed to produce no change in the existing capacity.

ADT—Two, three, or four ADTs were reported for each deficient section. The HUIS model uses these ADTs to establish an ADT growth function, defined by improvement year and design year ADTs and an annual ADT growth rate or increment, for each before and after condition. The possible ADT growth curve combinations range from a single linear, positive exponential or negative exponential curve, representing the ADT growth on all section conditions, to independent linear or positive exponential curves for each section condition. The final number of curves for a given section depends on the number and logicality of the reported ADTs and whether the reported improvement year and design year ADTs included diverted or generated traffic.

For a new location improvement the determination of ADT growth patterns is complicated by the fact that the existing highway may not be abandoned after the improvement is made. For HUIS the existing highway is assumed to be kept in service if the improved ADT is lower than the corresponding existing ADT.

The amount of diverted and generated traffic for each "after" improvement condition is also determined through use of diversion curves and fixed percentage generated ADT factors for the existing-after-improvement condition.

Maximum Allowable ADT—A maximum allowable ADT is calculated for each existing highway condition and any improved highway condition not specifically designed to carry design year traffic. The need for this maximum allowable ADT is based on the fact that projected ADTs often exceed the reasonable daily capacity of a highway, which, because of the nature of travel, is often much less than the theoretical daily capacity of 24 times the hourly capacity. Any traffic exceeding the maximum allowable ADT for a given highway condition is assumed to use alternative routes and to experience operating conditions and costs similar to those on the section being analyzed. These maximum allowable ADTs are calculated as a function of the appropriate capacity and a maximum ADT factor. Maximum ADT factors were developed for several categories of rural and urban facility types by using automatic traffic recorder data from several states.

Vehicle Types—The traffic stream for each section comprises five vehicle types—4-kip passenger vehicle; 5-kip commercial delivery truck; 12-kip single-unit truck; 40-kip gasoline powered, multiunit truck; and 50-kip diesel-powered, multiunit truck. A vehicle type distribution is defined by using the percentage of trucks furnished on a section basis and individual state truck weight study data.

Speeds, Speed Change, and Stop Cycles and Unit Operating Costs and Travel Times—Speed data, unit vehicle operating costs, and unit travel times are determined for both the improvement and design years for each highway condition for each section. Unit values are obtained for each remaining year in the analysis period by interpolation between these end point values.

Average automobile running speeds, the theoretical average running speeds at which an automobile can cruise under given traffic conditions without experiencing significant fluctuations in speed due to internal or external interference, are calculated by using modified Highway Capacity Manual (3) operating speed relationships. Average running speeds for single-unit and multiunit trucks are calculated as functions of the automobile speed.

The number and magnitude of speed change cycles per vehicle-mile are calculated for automobiles, single-unit trucks, and multiunit trucks (trucks experience speed change cycles only if their initial speed is greater than the speed slowed to by an automobile during its speed change). The number of stops per mile for each vehicle is calculated as a function of the number of automobile speed changes. The speed change and stop relationships were developed from raw, unreported data collected by Claffey (4).

Unit vehicle operating costs and travel times for curves and grades, idle engine, and speed change and stop cycles are developed for the five vehicle types. The basic source of these values was Winfrey's vehicle operating cost and travel time data (5) updated to 1969 and modified to reflect the effects of curves and grades.

Varying operating conditions throughout a day were accounted for by developing ADT distributions for several rural and urban facility types from state automatic traffic recorder data and by dividing them into six unequal segments with homogeneous operating conditions. Average running speeds, speed change and stop cycles, and related vehicle operating costs and travel times are determined for each segment. Finally, the data for each ADT segment are weighted to obtain daily values.

Initial Capital Investment and Terminal Values—The initial capital investment is the sum of right-of-way, grading and drainage, surface and base, structures, and other miscellaneous costs. All capital expenditures for a section are assumed to be made on the first day of the improvement year. Terminal value is calculated as a function of the individual cost items.

Maintenance and Administration Costs—For the cost-benefit comparison, annual maintenance costs for the existing and improved section conditions are calculated as a function of an average annual per mile maintenance cost that varies by highway type and functional class (and pavement type for two-lane roads or streets).

The annual administration cost for the improved condition is calculated as a function of annualized roadway costs, annual maintenance cost, and an administration cost factor that varies by functional class and location (and, in urban areas, population). The annual administration cost for the existing condition is calculated as a function of the annual maintenance and administration costs of the improved condition and the annual maintenance costs of the existing condition.

Roadway Accident Rates—Relationships between total accident, fatality, and injury rates and ADT for several facility types were developed by using existing accident data. These relationships and the number of fatalities and injuries per fatal and injury accident per state are used to determine the fatal, injury, and PDO accident rates for the before and after conditions of a section in both the improvement and design years.

Pavement Condition Adjustment Factors—To more accurately reflect vehicle operating costs, we calculate annual adjustment factors to convert unit vehicle operating costs, developed for high types of pavements in good condition, to unit operating costs on the existing and improved highway conditions. These factors are calculated as a linear function of Winfrey gravel and stone surface vehicle operating cost conversion factors (5), running speed, pavement type, pavement life, remaining pavement life, improvement year, and study period year.

For the existing highway condition, the pavement life is set based on the existing surface type, and the remaining pavement life as of 1970 is set based on the existing surface type and its condition in 1970. Pavement life and remaining pavement life for the improved highway condition are equal. They start as of the improvement year and are set based on the proposed improvement and an assumed improved pavement type.

Benefits—When benefits (described previously) are calculated, if the maximum allowable ADT is reached on a given highway condition, unit values are held constant from that year through the design year. In addition to benefits from roadway improvements, benefits associated with concurrent railroad crossing improvements are additive and are calculated by using the procedures described below.

Railroad Crossing Improvements

Railroad crossing improvement benefits consist of accident reductions and resulting accident cost savings and vehicle operating cost, travel time and travel time cost savings resulting from reductions in the number of speed change and stop cycles.

The same procedures used to determine unit values and benefits for normal improvements are used to determine unit values and benefits for railroad crossing improvements. However, annual maintenance and administration costs for railroad crossings are calculated as a function of the number of crossings and their protection types. One other procedural difference is that ADT growth on both the existing and improved highway conditions of the section is linear and is defined by the 1969 and 1990 ADTs with maximum allowable ADT constraints being applicable.

Railroad Crossing Operating Conditions—Vehicles required to stop at railroad crossings consist of those stopping for trains, based on the time a train occupies a crossing, train frequencies, and non-Poisson vehicle queuing theory, and those required to stop because of (a) state laws requiring all vehicles to stop at at-grade railroad crossings, (b) stop signs at crossings protected by crossbucks, and (c) legal requirements concerning trucks carrying hazardous materials. Idling times for vehicles required to stop for trains are based on the number of vehicles stopped and the vehicle arrival and departure rates. Because of the roughness of many railroad crossings those vehicles that do not have to stop are assessed a speed change cycle with a magnitude of one-tenth of the initial vehicle speed.

Accident Rates—Improvement and design year fatal, injury, and PDO accident rates are based on the expected annual numbers of vehicle-train and nontrain-vehicle accidents at each crossing type.

Spot Improvements

Spot improvements are defined as reconstruction of a minor (less than 41 percent) portion of a highway section. Thus it is assumed that the operating conditions before and after the improvement are the same, the only benefits deriving from accident reductions. Accident benefits are calculated by assuming linear ADT growth, defined by the 1969 and 1990 ADTs for a collector section or the improvement and design year ADTs for an arterial section, and by using normal improvement accident benefit procedures.

If concurrent railroad crossing improvements are being made to the section, the benefits are additive.

Major Structure Improvements

Major structure improvements are assumed to be necessary only where a restriction to travel, such as a major river, exists. The vehicle operating cost, travel time, and accident benefits from this type of improvement result from reduced travel distance, which is assumed to be 2 miles in an urban area and 20 miles in a rural area. Benefits are calculated by using a constant rural or urban speed and normal improvement procedures.

Improvements to the Economic Analysis Model

As a result of the experience gained from the development and use of the economic analysis model, certain desirable changes became apparent: improved input data and analysis procedures and new input data and analysis procedures. The amount and degree of change are somewhat dictated by the proposed use of the model. In other words if the model is to be used for system-level investment decisions (as was the case with the national HUIS analysis) only minimal change is needed. But, if the model is to be used to evaluate individual highway sections or projects, the amount of change required is maximized.

Improved Input Data and Analysis Procedures—Although the comprehensive procedures developed for this study have proved to be sound and adequate, there is room for improvement in the input data and analysis procedures. As constituted, this analysis does not consider changes in section length resulting from highway improvements. Though using the same length may be quite sufficient for a national- or state-level investment analysis, it is not sufficient when an individual highway improvement is evaluated.

A second area worthy of attention concerns information relating to ADT. In either a system or project economic analysis, ADT is one of the most significant inputs. Specific areas of concern include traffic projection, traffic assignment procedures, methods of calculating diverted and generated traffic, daily and yearly ADT distributions, temporal distributions of vehicle types, treatment of ADTs on intersecting roads and streets, and consideration of the system effects of individual project improvements.

Finally, attention needs to be given to those factors that affect vehicle speeds, vehicle operating costs, and accidents. Whereas the economic analysis data and procedures are adequate for system investment decisions, available data are rather limited. Data collection and analysis and research effort are needed in the following areas: road user effects of horizontal and vertical curvature, pavement type and condition, capacity, passing sight distance, average highway speed, and roadside obstacles and interferences; accident rates for roads, railroad crossings, and spot improvements; maintenance and administration costs; vehicle operating costs and characteristics for current model vehicles; methods of calculating user costs at intersections, railroad crossings, and structures and isolated reconstruction and resurfacing improvements; and relationships to estimate vehicle speeds and speed change and stop cycles.

New Input Data and Analysis Procedures—One area of needed new input data and associated analysis procedures is the socioeconomic effects of highway improvements. It is important that noise, air pollution, and relocations (people and businesses) be evaluated along with user costs.

New procedures also need to be developed to determine the optimum timing of construction, including stage construction projects. Procedures aiding decisions on when a construction project should be started to get the maximum benefit or whether to build the final product in one or more stages could maximize the taxpayer's return on each dollar invested in highways.

Finally, new input data and analysis procedures to measure the negative and positive effects of improving a highway section would be a desirable addition to models of this nature.

INVESTMENT ANALYSIS

The Model

The investment analysis model determines functional classes and deficiency areas (e.g., intolerable operating speed of v-c ratio or poor surface condition) associated with an administrative system in which to invest money in order to optimize benefits (e.g., user savings, fatal accident reductions, or total accident reductions) realized under different levels of investment constraints.

Assume, for example, that for specified functional classes and deficiency areas the benefit to be optimized is economic benefits. Sections associated with a given time period are ranked in descending order of benefit-cost ratio. Then within the maximum and minimum expenditure constraints the available funds are invested in consecutively lower benefit-cost projects until the funds for the time period are depleted. Those sections not funded in one time period are made a part of the next time period ranking.

The investment analysis model requires the following inputs:

1. Administrative systems consisting of one or more functional classes;
2. Data output from the economic analysis model consisting of initial capital investment, present worth of costs, present worth of benefits, total number of accidents eliminated, and number of fatal accidents eliminated for each deficient section on the administrative systems;
3. Maximum expenditures for each administrative system in each time period; and
4. Minimum expenditures for each functional class within an administrative system and for each deficiency area within each functional class.

Improvements to the Investment Analysis Model

The procedures for analyzing sections deferred from one time period to another need improvement, and the capacity of priority ranking of sections should be added. Further work in these areas would greatly enhance the capabilities of this model and would provide the decision maker with more meaningful investment-level analysis and priority programming tools.

NATIONAL HUIS RESULTS

Any interpretation of the national study results should be prefaced by the knowledge that (a) only costable user effects—i.e., vehicle operating cost, travel time, and accident savings—resulting from highway improvements were considered, leaving other, often significant, economic and noneconomic decision-influencing effects to be evaluated by other means; and (b) the results were generated based on what improvements were necessary to bring the highway sections up to a uniform national set of geometric standards, where the determination of improvement type was not necessarily the result of an economic evaluation. Thus it is important to recognize that the study results were not intended to be used as the sole criterion for making decisions. The great value of these results lies in the fact that a relatively uniform basis was used for all states in determining the economic consequences and cost-effectiveness of proposed highway improvements, thus making reliable interstate and intrastate comparisons possible.

Economic Analysis

Benefit-Cost Results—Overall 1970-1990 highway investments in arterial and collector sections, given in Table 2, returned an average of $2.1 in benefits for each dollar invested. As might be expected, the urban investments tended to carry the rural investments with the average benefit-cost ratios for rural, small urban, and urbanized areas being 0.4, 1.9, and 4.0 respectively.

On a functional class basis Interstate investments yielded high b-c ratios (4.5 to 4.8) in all locations. Excluding the Interstate systems the b-c ratios on rural functional classes ranged from 0.2 to 0.5, whereas the b-c ratios on small urban functional classes ranged from 0.9 to 2.3 and on urbanized functional classes from 2.1 to 4.8. Four of the five rural functional classes had b-c ratios less than 1.0, whereas only one urban category, small urban collectors, had a b-c ratio less than 1.0. As expected, the b-c ratio decreased in going from arterials to collectors. It should be emphasized that these are average functional class b-c ratios, and, though most of the rural functional classes have b-c ratios less than 1.0, 20,977 (29 percent) of the 72,577 rural sections requiring improvement had b-c ratios greater than or equal to 1.0.

On a national basis the total benefit of $374.6 billion consisted of $263.6 billion in time savings, $112.1 billion in vehicle operating cost savings, $2.6 billion in accident savings, and a negative savings of $3.6 billion in maintenance and administration costs. As in most studies using discounting techniques, these results were sensitive to changes in the interest rate and, as can be seen from the results, to assumed values of time. The study results were rather insensitive to the value of a human life.

Cost-Effectiveness Results—Data given in Table 3 show that, if all the needs study improvements were made, fatal accidents would be reduced by 33,000, injury accidents by 4,259,000, and PDO accidents by 9,611,000. In terms of cost-effectiveness ratios, 0.1 fatal accident, 13 injury-producing accidents, and 30 PDO accidents would be eliminated for each million dollars invested. Proposed improvements in rural areas produced the greatest reduction in fatal accidents, whereas urban improvements produced the greatest reduction in nonfatal injury-producing and PDO accidents.

For each $1,000 invested $1,497 in vehicle operating cost savings and 1,230 hours of time savings were realized. In both cases urban area savings were greater than rural area savings.

Investment Analysis

Because of the rigid reporting dates associated with the 1972 Highway Needs Report to Congress only minimal use was made of the investment analysis model. However, the following general conclusions were reached after the results of the limited applications were evaluated:

Table 2. HUIS benefit-cost summary (present worth in millions of dollars).

1990 Functional Highway Classification	Benefits: Accident	Benefits: Unit Operating Cost	Benefits: Time	Benefits: Maintenance and Administration Cost	Benefits: Total	Costs	Net Present Worth	Benefit-Cost Ratio
Rural								
Interstate	-7	4,651	791	-34	5,401	1,123	4,278	4.8
Other principal arterial	690	-2,237	12,895	-788	10,560	24,748	-14,188	0.4
Minor arterial	224	393	11,029	-351	11,295	24,628	-13,333	0.5
Major collector	17	4,282	3,605	-169	7,735	19,377	-11,642	0.4
Minor collector	1	2,580	1,788	-439	3,930	21,546	-17,616	0.2
Subtotal	925	9,669	30,108	-1,781	38,921	91,422	-52,501	0.4
Small urban								
Interstate	-	210	56	-3	263	59	204	4.4
Other freeway and expressway	55	725	2,827	-34	3,573	1,532	2,041	2.3
Other principal arterial	24	3,765	6,407	-78	10,118	3,764	6,354	2.7
Minor arterial	2	1,799	2,649	-45	4,495	2,992	1,413	1.5
Collector	-2	854	1,168	-28	1,992	2,355	-363	0.9
Subtotal	79	7,353	13,107	-188	20,351	10,702	9,649	1.9
Urbanized								
Interstate	71	5,354	5,200	-43	10,582	2,389	8,193	4.3
Other freeway and expressway	1,281	37,952	105,737	-716	144,254	29,961	114,293	4.8
Other principal arterial	149	25,698	51,465	-339	76,973	18,419	58,554	4.2
Minor arterial	78	19,647	45,181	-402	64,504	18,630	45,874	3.5
Collector	-15	6,432	12,795	-148	19,064	9,119	9,945	2.1
Subtotal	1,564	95,083	220,378	-1,648	315,377	78,518	236,859	4.0
Total	2,568	112,105	263,593	-3,617	374,649	180,642	194,007	2.1

Table 3. HUIS cost-effectiveness summary.

1990 Functional Highway Classification	Initial Capital Investment (millions of dollars)	Accident Reduction[a]: Fatal No.	Fatal Rate	Injury No.	Injury Rate	PDO No.	PDO Rate	Total No.	Total Rate	Vehicle Operating Cost Savings: Dollars (million)	Rate[b]	Time Savings: Hours (million)	Hours/ Thousand Dollars
Rural													
Interstate	3,747	-1	0	-25	-7	-46	-12	-72	-19	24,354	6,499	1,676	447
Other principal arterial	43,569	38	1	907	21	1,688	39	2,633	60	-16,427	-377	13,839	318
Minor arterial	40,432	12	0	247	6	578	14	837	21	-5,053	-125	11,923	295
Major collector	30,634	0	0	-24	-1	1	0	-23	-1	11,867	387	3,167	103
Minor collector	34,875	-1	0	-14	0	-25	-1	-40	-1	8,218	236	1,449	42
Subtotal	153,257	48	0	1,091	7	2,196	14	3,335	22	22,959	150	32,054	209
Small urban													
Interstate	172	0	0	6	32	14	84	20	116	1,383	8,040	153	892
Other freeway and expressway	3,011	0	0	108	36	252	84	360	119	2,957	982	4,256	1,413
Other principal arterial	6,966	-3	0	41	6	172	25	210	30	15,480	2,222	8,847	1,270
Minor arterial	5,823	-1	0	11	2	13	2	23	4	7,402	1,271	4,375	751
Collector	4,351	0	0	-5	-1	-21	-5	-26	-6	3,640	836	1,835	422
Subtotal	20,323	-4	0	161	8	430	21	587	29	30,862	1,519	19,466	958
Urbanized													
Interstate	5,730	5	1	194	34	497	87	696	122	30,113	5,255	8,831	1,541
Other freeway and expressway	61,262	10	0	2,448	40	6,342	104	8,800	144	187,017	3,053	181,096	2,956
Other principal arterial	31,638	-10	0	207	7	297	9	494	16	101,705	3,215	72,655	2,296
Minor arterial	34,857	-12	0	201	6	128	4	317	9	84,879	2,435	66,349	1,903
Collector	16,789	-4	0	-43	-3	-279	-17	-326	-19	27,203	1,620	18,022	1,073
Subtotal	150,276	-11	0	3,007	20	6,985	46	9,981	66	430,917	2,868	346,953	2,309
Total	323,856	33	0	4,259	13	9,611	30	13,903	43	484,738	1,497	398,473	1,230

[a]Numbers in thousands; rates in number per million dollars.
[b]Dollars saved for each $1,000 invested.

1. To maximize user benefits requires that the overall investment be reduced from the level sufficient to overcome all identified needs to the level that would exclude the funding of sections yielding negative user savings. The exact level of investment necessary to maximize benefits would depend on the systems being analyzed.

2. The relative investment in urban areas increased as the investment level was reduced from that necessary to overcome all needs, further illustrating that urban systems yield relatively higher user benefits.

3. Specifying that certain funds be invested in specific federal-aid systems yielded lower total benefits than allowing unconstrained investment in the economically "best" projects.

RECOMMENDATIONS AND CONCLUSIONS

Work is under way in the areas of indirect effects, priority programming of section improvements, and the application of the models to state use. Improvements in these areas should greatly enhance the usefulness of the present models.

It is recommended that research be done in the areas of indirect effects; priority programming; and speed, speed change cycle, and stop cycle factors. In addition, it is recommended that research be done on how to treat projects not funded at one point in time but deferred to another point in time, such as in the investment analysis model.

In conclusion, the HUIS models, making use of large amounts of field-inventoried data plus unreported supplemental data, provide one of the most detailed and comprehensive highway user investment analysis tools yet developed. The two HUIS models, in their present form, provide valuable tools to aid in (a) evaluating different investment levels and the consequences of limited budgets, (b) evaluating alternative systems, (c) realigning systems along functional or administrative lines, and (d) establishing matching funds ratios. Thus the current HUIS models are good investment analysis tools for state use. And with the recommended improvements in input data and procedures it is to be expected that the models will be even better national decision-making tools.

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APPLICATIONS OF BENEFIT-COST ANALYSIS: THE SELECTION OF "NONCONSTRUCTION" PROJECTS

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The traditional benefit-cost framework, frequently used to evaluate construction projects, is used to analyze "nonconstruction" activities of highway agencies for the purpose of improving resource allocation within and between programs. Drawing from three examples of maintenance projects and from the parks and the bicycle trails programs, the authors demonstrate that difficult-to-value variables such as safety, recreational experiences, and benefits to bicycle riders can be evaluated with benefit-cost analysis. In the hypothetical cases of safety benefits from shoulder paving, multiple benefits from pothole patching, construction of parks for campers and day users, and bicycle route construction for commuters, the values of benefits required to justify the investments are calculated. The optimum frequency for maintenance projects is also examined. The conclusions are that techniques exist to improve project selection within many programs and that a better understanding of the versatility of benefit-cost analysis will lead to its more frequent use.

• A CONTRACT was entered into by the Oregon State Highway Division and Oregon State University (OSU) for OSU to provide the analytical framework, economic analysis, and, in some cases, data to improve resource allocation in the highway division. Essentially, the study was designed to indicate what contribution economics could make to decision-making on a variety of organizational levels. The research resulted in a six-section report (1) that treated topics as general as intermodal resource allocation and as specific as the selection of highway projects.

This paper draws partially on sections of the report that deal with the role of economics in evaluating highway division programs and with allocating resources to specific "nonconstruction" activities. A generalized benefit-cost framework is applied to problems that are frequently not evaluated by such analysis. If employed successfully, the suggestions offered in the paper will facilitate comparisons among projects in particular programs (e.g., within the maintenance section) and between projects in different programs (e.g., between the construction and maintenance sections).

After a discussion of the role of economics in evaluating public investments, the general benefit-cost framework is outlined. Within this context, the application of economic analysis to activities in the maintenance, parks, and bicycle route programs is examined.

THE ROLE OF ECONOMICS

Central to most definitions of economics is the concept of allocating scarce resources to alternative ends. That is, economics is generally perceived as a discipline concerned with deciding how to use a limited amount of time, money, labor, machinery, or other scarce resources to best achieve an objective or set of objectives. This concept can be applied within wide limits. Broadly defined, economics is a science of decision-making. It is concerned with benefits and costs (or advantages and disadvantages) of alternatives and is relevant to all of man's activities. In this context, to say that one is applying economics to decision-making really means that he is considering all relevant factors, both positive and negative, before making a decision.

Very narrowly (and inappropriately) construed, the term economics is used to signify the undertaking of an activity with the lowest monetary outlay. For example, when there are several alternate highway investments and the least expensive one is chosen, the choice is sometimes mistakenly referred to as one "determined by economics."

Economics, however, is not limited to a consideration of costs or quantifiables; the discipline is equally concerned with benefits and with nonmonetary, unquantified variables. Viewed in this way, economics provides a framework within which the inputs of all other relevant disciplines can be combined and expressed so as to assist the decision-maker in an otherwise very difficult task.

ECONOMIC ANALYSIS IN HIGHWAY AGENCIES

The need to organize and evaluate effects (i.e., benefits and costs) of highway projects is widely recognized, especially with the recent emphasis on developing Action Plans and preparing environmental impact statements. This recognition could be expected to lead to an intensified application of economic analysis and, more specifically, of benefit-cost techniques, but this does not seem to have taken place. Casual observation suggests that economics has not been used so frequently as possible for several reasons:

1. Economic analysis, as mentioned above, is seen as a means of determining the "least cost" approach to constructing a project. This decision, which really does not require an economist at all, can be made after the more important questions of project feasibility or desirability have been answered. When the discipline is interpreted so narrowly, it is understandable that it is not viewed as very helpful in evaluating the numerous project effects that are possible.
2. Highway agencies often lack the interest or expertise to correctly apply economic analysis and benefit-cost techniques. Other project selection tools such as sufficiency and deficiency indexes have been more popular (2, 3).
3. Traditional benefit-cost analysis (frequently treated as the equivalent of economic analysis) compares only some road user benefits with highway agency costs. It is too restrictive to include most project impacts. It is usually not understood, however, that many observed economic effects can be traced to road user benefits. In most cases, road user benefits represent a large share of the actual net gain from a highway project (4).
4. Some analysts have responded to the apparently narrow benefit-cost framework by trying to include other effects such as indirect economic benefits; a frequent by-product of this approach is double-counting. The result is an expanded benefit-cost ratio that is difficult to interpret, is often "stacked" to make a project look worthwhile, and lacks credibility.
5. The interest in displaying all project effects in large matrices is growing. This represents a potentially productive approach, but there are still many problems with rating and weighting effects to arrive at a decision concerning project selection. The intuitive appeal of showing all effects, though, has led to a reduced interest in the narrower benefit-cost framework.

The result of these factors is less frequent use of economics, even though its organizational contribution could be valuable, and of benefit-cost analysis, although it is still one of the best evaluation techniques for considering many kinds of projects. There is no doubt that benefit-cost methodology can improve project selection and that it is a great deal more flexible than is usually thought to be the case—notwithstanding problems with multiple objectives and project effects that are difficult to evaluate.

It appears that the organizational constraints of the past and the narrow categorical funding arrangements for highway programs are changing. The movement to departments of transportation and broader federal funding requires increased use of project selection techniques that facilitate comparison between types of programs and alternate transportation modes.

BENEFIT-COST ANALYSIS

Before we consider several adaptations of benefit-cost methodology to highway agency programs, it is useful to describe the general analytical framework. Ideally, according to the benefit-cost criterion, projects would be undertaken as long as the present value of project benefits was at least as great as the present value of project costs. That is, a project passes the benefit-cost test if

$$\frac{B_1}{(1+r)} + \frac{B_2}{(1+r)^2} + \ldots + \frac{B_n}{(1+r)^n} \geq \frac{C_1}{(1+r)} + \frac{C_2}{(1+r)^2} + \ldots + \frac{C_n}{(1+r)^n}$$

where B_i is the benefit enjoyed by society in the ith year, C_i is the cost borne in the ith year, n is the last year in which the project generates either benefits or costs, and r is the rate at which society discounts time. In most real-world agencies, the budget is fixed; therefore, projects should be selected so that the sum of the difference between the discounted benefits and discounted costs over all projects is maximized.

Passing the benefit-cost test is not sufficient to make a project worthwhile when all benefits and costs cannot be quantified; nonquantified effects can and often do outweigh the measurable impacts that are treated in the standard benefit-cost calculations. Even in these cases, however, benefit-cost analysis facilitates the organization and evaluation of other benefits and costs.

The possibilities of applying the benefit-cost framework to a variety of investments are elaborated below. The examples represent cases in which there is uncertainty about the benefits, because of either the value of the benefit per beneficiary, the number of beneficiaries, or a combination of these factors. It is demonstrated that unlike projects can be compared to a greater extent than is usually recognized.

MAINTENANCE PROJECTS

Although benefit-cost analysis is frequently applied to construction investments, it is seldom used to evaluate maintenance projects, even though the objectives and functions of the programs are very similar. Examples are given of how typical maintenance projects might be evaluated with standard benefit-cost techniques.

Case 1: Treatment of Safety Benefits From a Shoulder Paving Project

Benefit-cost analysis is rarely used in cases where the important project effects are difficult to evaluate in dollar terms. Shoulder paving is such a case in that its primary purpose is a rather elusive benefit: highway safety.

Our behavior, individually and as a society, confirms that we place some positive, but finite, value on added safety. The problem of including safety effects in the conventional benefit-cost analysis is that one must place a specific value on a unit of safety, (e.g., on accidents prevented or on a life saved). Resistance to the selection of a particular value causes many analysts to reject a benefit-cost framework. Unfortunately, however, this does not eliminate the need to consider safety effects in project selection; it simply means that the implicit value for safety will vary widely from project to project.

The alternative suggested here is that the benefit-cost analysis be "reversed" so that the solution becomes the value that would have to be placed on safety benefits to justify selection of the project. In the example, safety benefits are expressed in terms of an annual dollar figure. Existing accident data allow the answer to be further refined.

The advantage to this approach is that the decision-maker need not select a precise value for safety benefits; rather, he must decide only whether the likely safety benefits are worth more than the cost of the project, a variable that can be estimated with some degree of precision.

Consider the following hypothetical project to replace gravel shoulders with pavement along a 10-mile section of highway. Assume that (a) the highway has annual traffic of 1,000,000 vehicles or 10,000,000 annual vehicle-miles, (b) the initial cost of the paving project is $100,000, (c) the additional annual maintenance cost for the highway strictly due to shoulder pavement is $5,000, (d) the project life is 20 years, and (e) the discount rate is 8 percent. The problem can be stated as

$$\$100{,}000 = \frac{X - \$5{,}000}{(1 + 0.08)} + \frac{X - \$5{,}000}{(1 + 0.08)^2} + \ldots + \frac{X - \$5{,}000}{(1 + 0.08)^{20}}$$

where X is the minimum dollar value of increased safety per year that the paved shoulders must provide to justify the maintenance project. Solving for X yields $15,185.

An examination of accident data allows more detailed statements about the safety benefits that would be needed to justify undertaking the projects. Given a cost per accident of $2,186 (based on accident data on the Oregon state rural system), there must be 6.95 fewer accidents per year along this section of highway to yield a benefit-cost ratio of one. Given an average accident rate of 2.55 per million vehicle-miles, 25.50 accidents would have been expected along the 10-mile section of highway each year. To reduce this number by 6.95 accidents constitutes a reduction of 27.3 percent.

Other general maintenance functions can be evaluated in the same manner. The essential feature of the proposed procedure is that it requires explicit consideration of the major benefit, increased safety, even though it is difficult to measure. Of the other eight general maintenance functions of the Oregon State Highway Division, four seem to be undertaken primarily for a single benefit that has been troublesome to measure. As with shoulder paving, installation of guardrails and maintenance of traffic control facilities are primarily intended to increase safety on the highway system. Among the other functions, care of roadside vegetation and roadside cleanup are undertaken mainly for the comfort and convenience of the road user. As in the shoulder paving case, the benefits required to justify projects carried out for these functions can be expressed in various ways that may ease the decision-making problem. For example, the required value per passing vehicle for roadside cleanup could be calculated. These calculations of required benefits allow the decision-maker to postpone the valuation problem until it is expressed in a manner that may be more meaningful for him and then to compare unlike projects more rationally.

Case 2: Treatment of Multiple Benefits From a Pothole Patching Project

The difficulty in estimating the effects of many maintenance projects does not lie mainly in valuation; these effects tend to be the standard benefits corresponding to fast, safe, and efficient travel. The methodology of valuing them is reasonably well formulated, but rather in measuring the amount of effects. This second case illustrates how the investigator can use the benefit-cost framework to calculate a set of benefit packages that would justify undertaking the maintenance project. Even if he cannot measure the effects, the analyst can restate the selection problem in a way that facilitates project selection.

Consider the following example (Fig. 1). Assume that (a) a pothole patching project on 10 miles of highway with a lifetime of 1 year will cost $10,000 and (b) the roadway involved has annual traffic of 1,000,000 vehicles. (In this example, the benefits to road users are not discounted for the length of time between cost and benefit because the period involved is so short.)

User benefits include time saved, reduced vehicle operating costs, and increased safety. Time saved is assumed to be worth $3.00 per hour per vehicle, and each accident prevented is estimated to be worth $2,186.

Figure 1 shows benefits that are required for a benefit-cost ratio of unity. If no accidents are prevented by the project, time and vehicle operating savings must be worth project costs of $10,000 to justify the investment. This amounts to $0.001 per vehicle-mile or 1.2 seconds per vehicle-mile. Thus, a savings of 1.2 seconds per vehicle-mile or $0.001 in vehicle operating cost per vehicle-mile or any linear combination of the two will yield total benefits from the project equal to the total cost of $10,000. If benefits are estimated to be at any point above the line labeled 0 accidents prevented, the estimated benefit-cost ratio exceeds unity; the opposite holds for any

Figure 1. Multiple benefits from a patching project.

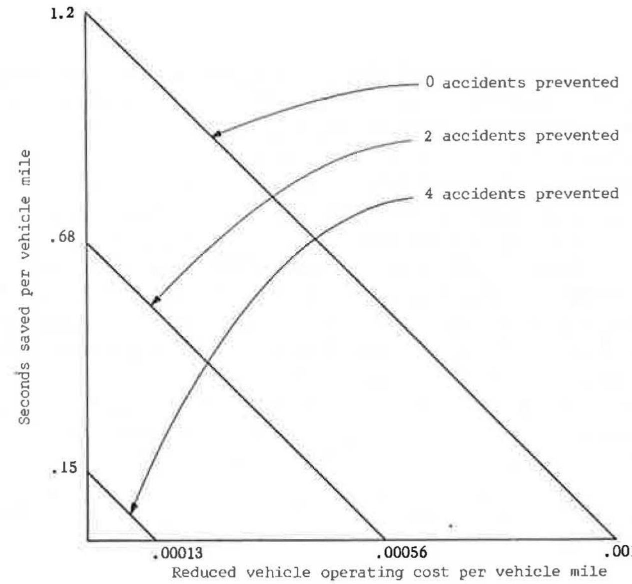

Figure 2. Required values for overnight campers and picnickers to justify park development.

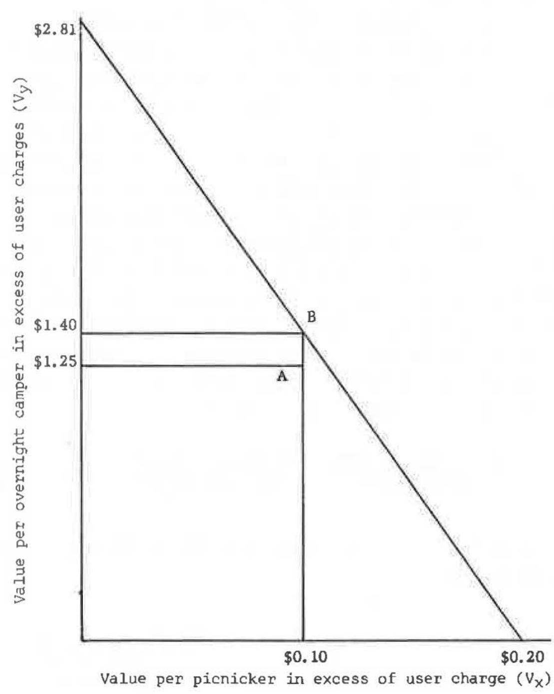

Table 1. Benefits of bicycle routes and expenditures justified per mile.

Path Length (miles)	Average Trip Length (miles)	Commuters	Present Value of Benefit (dollars)	Expenditure per Mile (dollars)
4	2	100	21,300	5,325
		500	106,500	26,600
		1,000	212,500	53,100
5	3	100	9,000	1,800
		500	44,900	9,000
		1,000	89,000	17,800
7	5	100	37,300	None justified
		500	186,700	
		1,000	374,700	

pair of values below that line. If accidents prevented are estimated to be greater than zero, the necessary time and operating cost savings for a benefit-cost ratio of one would be reduced. This is reflected in Figure 1 by required benefit lines down and to the left of the 0 accidents prevented line. For example, if two accidents would be prevented by the pothole patching project, the combination of time and savings benefits for a benefit-cost ratio of unity is described by the line labeled 2 accidents prevented.

As in case 1, the decision-maker must consider whether the actual benefits are likely to be as large as the required benefits depicted in Figure 1. The proposed technique does not select projects; it merely recasts the properties necessary for wise decisions in ways that are more intelligible. It assists the decision-maker; it does not replace him. Still, its role is sufficiently illuminating that it may help to ensure that the best projects will be selected and the worst will be omitted.

Many of the maintenance functions are similar to pothole patching in that they yield benefits of more than one type that are difficult to measure. Project selection and evaluation for any of the functions that can be so characterized may be facilitated by the procedure suggested for pothole patching. Functions that definitely involve the full range of standard road user benefits are repair of roadway surfaces, snow removal, and sanding.

Case 3: Selection of Optimum Frequencies for Maintenance Projects

For most of its functions, a maintenance section probably has a set of strategies that can be adopted to achieve the highway benefits for which the program is intended. In general, the feasible strategies can be ordered from very frequent but inexpensive tasks to much less frequent but major maintenance projects. For example, the maintenance section may be able to choose between patching a highway each year or carrying out a major overlay every 10 to 12 years. Benefit-cost analysis can be useful in selecting the optimum frequencies for different maintenance tasks.

In this case, it is assumed that road user benefits of a constant amount per year, \$1,000, can be obtained through either of two maintenance strategies. In one strategy, the highway agency must spend \$100 per year for each of the 20 years that the highway is expected to yield services for a total of \$2,000. In the second strategy, the agency spends \$4,000 for maintenance at the end of the tenth year of operation; nothing is expended in the other years. As in case 1, an 8 percent discount rate is used to convert costs and benefits to present value terms. (Problems related to the comparability of benefits in the twentieth year for the two cases are ignored.)

The problem can be stated as follows:

$$PV_1 = \frac{\$1,000 - \$100}{(1 + 0.08)} + \frac{\$1,000 - \$100}{(1 + 0.08)^2} + \ldots + \frac{\$1,000 - \$100}{(1 + 0.08)^{20}} = \$8,836$$

The present value of the net benefits of the highway, if it is maintained once at the end of the tenth year, is

$$PV_{10} = \sum_{1}^{20} \frac{\$1,000 - M_t}{(1 + 0.08)^t}$$

$$PV_{10} = \$7,965$$

and

$$M_t = \$4,000 \text{ for } t = 10$$
$$M_t = 0 \text{ for } t \neq 10$$

The calculations for this example show that the policy of undertaking some maintenance annually is superior to the policy of undertaking a major maintenance project in the tenth year. The present value of the net benefits of the highway with annual maintenance is $8,836, and the present value of the net benefits for the 10-year maintenance policy is $7,965. Thus, following the annual expenditure method gives net benefits of $871 over the less frequent maintenance approach.

This particular example is not intended to suggest that more frequent maintenance is always better than less frequent maintenance. This, too, can be overdone. For this example, it might be concluded that a maintenance pattern of every 2 or 3 years would yield a present value in excess of the present value that was obtained for annual maintenance expenditures. In fact, it is appropriate to consider several reasonable maintenance patterns to be sure that the optimum frequency for any type of maintenance project has been determined.

The type of investigation suggested here could be used for all general maintenance functions. Still, it may be more important to determine the best frequencies for some maintenance functions than for others; this would seem to be particularly the case if a failure to maintain at one frequency means that the highway agency will need to undertake an entirely different maintenance activity. This characterizes the maintenance functions that "protect the investment." Maintenance of highway drainage facilities, inspection and repair of structures, and repair of roadway surfaces are all functions designed to protect the investment. For each, better maintenance frequencies may be discovered or confirmed by investigating alternatives, as this third case suggests.

PARKS AND RECREATION

In Oregon, the state parks and recreation program is included under the jurisdiction of the highway division. Benefit-cost analysis has not been used in making decisions in this program even though there is a definite similarity between selecting and developing land for recreational purposes and choosing highway construction projects. In fact, the use of benefit-cost analysis for the parks program may be less controversial than its use for highways because the impact of park construction and use on nonusers is usually relatively small. For the most part, the benefits derived from a park accrue to users, and the costs are reflected in highway division expenditures on land acquisition, development, and maintenance of the park.

The primary problem in using benefit-cost analysis in the park program is in estimating the dollar value of the recreational experiences enjoyed by park users. The proposed analytical strategy to cope with this problem is to solve for the user benefits that would be necessary to justify the project rather than the ratio of benefits to costs. Given the relatively accurate estimates of the number of prospective park users and the nature of their use, the corresponding required value per use can be determined.

Consider the following example. The following assumptions are made:

1. Land acquisition cost is $1,000 per acre,
2. Campsite development cost is $4,000 per site,
3. Picnic site development cost is $1,000 per site,
4. Annual use per picnic site is 3,300 people,
5. Annual use per campsite is 350 people,
6. Annual user charges equal annual maintenance and operation cost,
7. Park life is 25 years,
8. Discount rate is 8 percent, and
9. A 100-acre park site accomodates 20 campsites and 30 picnic sites.

The land for this park would cost $100,000 (100 acres × $1,000 per acre), and the development cost would be $110,000 (20 campsites × $4,000 per campsite + 30 picnic sites × $1,000 per picnic site); total acquisition and development cost is $210,000.

The only other cost associated with the proposed park would be for operation and maintenance. Assumption 6 above is that these costs are just equal to park user fees. Thus, the appropriate benefit-cost test in this case compares park benefits in excess of park user charges with acquisition and development costs of $210,000.

Given the assumptions above, 175,000 campers will stay overnight and 2,475,000 people will use the picnic facilities in the proposed park over the next 25 years. Other things being equal, though, the value of a camping experience or a picnic in the park is worth less the longer society must wait for them. The appropriate adjustment is to discount recreational experiences for this waiting time. At an 8 percent discount rate, the present time equivalent of the 175,000 nights that campers would spend in the park over the next 25 years is 74,723. Similarly, the present time equivalent of the 2,475,000 picnickers who would use the proposed park is 1,056,802.

The benefit-cost test determines whether these use levels are worth $210,000 plus the park user fees. The solid line in Figure 2 shows the possible combinations of values in excess of fees for picnic and camping uses that would be required for a benefit-cost ratio of unity, given the levels of use mentioned above. Any pair of values above the solid line would give predicted user benefits in excess of costs and, therefore, a benefit-cost ratio in excess of unity. Conversely, any pair of values below the line yields a benefit-cost ratio of less than one. For example, suppose that the value per picnicker in excess of any user charge is known or judged to be more than $0.20. In this case, the proposed park would pass the benefit-cost test even if the value per overnight camper is zero. In contrast, the benefit-cost ratio would be less than unity if the values per camper and picnicker are $1.25 and $0.10 respectively (A in Fig. 2). A $0.10 value per picnicker would require a $1.40 value per camper to justify the park through equating the values of benefits and costs (B in Fig. 2).

BICYCLE ROUTES

In 1971, Oregon was placed in the forefront of bicycle route legislation when a law was passed that called for no less than 1 percent of the funds received by the highway commission (from federal or state sources) to be expended for footpaths or bicycle routes. According to this law, each highway construction, reconstruction, and relocation project must include bicycle routes or footpaths unless

1. They are contrary to public safety,
2. The cost of the trails is disproportionate to their use, or
3. The sparsity of population or other factors indicate no need.

These qualifications effectively leave the highway division without guidelines on where bicycle routes should be placed and what quality of routes should be constructed. Economic analysis provides some direction.

For simplicity, in the example it is assumed that all bicycle route users are commuters (5). The analysis of bicycle commuters is similar to the standard benefit-cost approach for highway construction. Conventional assumptions concerning the value of time and vehicle operating costs are used, and commuter trips of several lengths are treated. It is assumed that bicycle riders would have to be diverted from automobiles to the new bicycle route; then the difference between a person's costs as an automobile driver and a bicycle rider is compared.

Because there is only minimal knowledge on how many riders might be expected, the approach is to calculate the changes in time costs and operating costs for an assumed number of commuters for several bicycle route lengths. It can then be determined how many bicycle riders are required to justify the construction of bicycle routes of various lengths.

Table 1 gives the present value of the benefits to commuters, assuming a 20-year life for bicycle routes and an 8 percent discount rate. The other assumptions are as follows:

1. The bicycle route has a 20-year life,
2. Automobile operating cost is 11 cents per mile,
3. Bicycle operating cost is 2 cents per mile for commuters on the 2- and 3-mile trips and 1.5 cents per mile on the 5-mile trip,
4. The value of time is 3.9 cents per minute ($3.00 per hour per car),
5. Automobiles travel 20 mph for the 2- and 3-mile trips and 25 mph for the 5-mile trip,
6. Bicycles travel at 10 mph,
7. The automobile driver requires 5 minutes more to park and walk than does the bicyclist,

8. Average automobile occupancy is 1.3 people,
9. Users of bicycle paths of 4, 5, and 7 miles have average one-way trip lengths of 2, 3, and 5 miles, and
10. There are 120 workdays on which it is possible to ride a bicycle.

The expenditure per mile indicates the expenditure justified per mile to just balance the 20-year benefits, i.e., that would yield a benefit-cost ratio of one.

Generally, the analysis indicates that as many as 750 bicyclists would need to use a bicycle route to justify an expenditure of approximately $40,000 per mile (the average cost of a path) and that only a shorter route would be feasible. As the length of a bicycle route increases, more bicyclists would be required. It seems unlikely, based on these calculations, that a route of more than 5 miles would be economically justified. Ridership on constructed bicycle routes has averaged approximately 30 a day, hardly enough to justify construction of routes.

The analysis, of course, does not pretend to represent all of the benefits (or costs) from bicycle riding. Dealing with what is known or can be reasonably assumed, however, shows how much the nonquantifiables must be worth if the bicycle path is to be justified. For a 5-mile bike route with 100 commuters per day, for example, an expenditure of only $9,000 is justified. With an average construction cost of $40,000 per mile, it would require $200,000 to build the bicycle route. Consequently, the additional benefits to society must be valued at approximately $190,000 if the bike route is to be constructed.

CONCLUSIONS

The major conclusion emerging from the foregoing analysis is that it is not necessary to throw up one's hands so soon. Techniques and data exist to improve decisions that are now based primarily on judgment and intuition. To the extent that such investments as maintenance projects, parks, and bicycle routes can be quantified, there is a more rational basis on which to compare all agency activities when allocating funds.

Progress should be made in quantifying more project effects and in displaying and evaluating all consequences of highway agency investments. It is important to recognize, however, that it is not necessary to wait for these developments before improving project selection techniques; the framework already exists to enhance decision-making. Only an effort to use it is required.

ACKNOWLEDGMENT

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OPERATING COST MODELS FOR URBAN PUBLIC TRANSPORTATION SYSTEMS AND THEIR USE IN ANALYSIS

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Data concerning operating cost of bus and rail systems were collected from operating agencies and the American Transit Association. Operating cost models were prepared for individual rail rapid transit systems and bus systems. The use of these models in economic comparisons with highway and other transit alternatives is discussed and illustrated. Data deficiencies are discussed, and recommendations concerning accounting formats are made.

• AFTER FAILING to produce a compromise bill in 1972, Congress passed a bill in 1973 that permitted some diversion of Highway Trust Fund moneys to construction of mass transit facilities. At the same time the Environmental Protection Agency authorized the enforcement of strict antiautomobile regulation in major urban areas as a means for cities to meet federal clean-air standards by 1976.

Since 1956, when the Federal-Aid Highway Act of that year created the Highway Trust Fund and authorized the construction of the 41,000-mile Interstate System, the focal point of transportation planning in the United States has been the movement of people and goods via automobile. Even in urban communities of considerable density, the automobile has played an ever more important role in urban travel. Transit ridership declined from its peak of 23.2 billion in 1954 to 10.9 billion in 1956 and, by 1971, had fallen to 6.8 billion.

However, the increasing congestion in most major cities and the general realization that the automobile cannot efficiently meet the travel demands of dense urban corridors have sparked a renewal of interest in new transit facilities and the revitalization of existing properties. Thus, the early 1970s have seen the construction of the first new rapid transit systems in the United States for more than 2 decades in south Jersey (Lindenwold-Philadelphia), San Francisco (BART) and Washington, D.C. With these already operating or under construction, other new systems are planned for Baltimore and Atlanta, and extensions for New York. Many cities have taken new approaches to bus service with startling success: express bus services (N.Y.C.), bus rapid transit (Shirley Highway), and minibus service (Washington, D.C.). The federal government has fueled this interest by providing $10 billion in federal funds for up to two-thirds subsidy of capital expenses for new or improved transit facilities over a 12-year period ending in 1982. A 1973 act increased the subsidy limit to 80 percent. Other federal programs have provided money for demonstration projects involving new transit technology or novel applications of existing technology.

The transportation planner can no longer be merely a highway planner. However, whereas vast amounts of data documenting pertinent aspects of highway operation, construction, and maintenance exist, there is a distinct lack of such data for other transportation modes. This is especially true where economic data are concerned. Automobile operating costs have been well documented by the American Association of State Highway Officials (1) and others (2, 3). These sources provide the planner with the data and procedures for estimating all quantifiable aspects of highway cost and methodologies for comparing alternative highway plans on an economic basis. Similar data for public transportation are needed to enable the planner to evaluate alternative public transport plans and to compare transit and highway plans on an economic basis.

The major objective of this study, and the prime result of this report, is a series of unit cost models that make possible the estimation of costs for public transit systems for rail rapid transit and bus transit. The models deal primarily with operating cost, and other aspects are added as separate items.

DATA ACQUISITION

Two main sources of data were tapped for this study: the American Transit Association (ATA), to whom most operators send yearly budget figures (4), and the operators of the transit properties themselves.

For data concerning rail rapid transit facilities, the transit operators provided copies of their 1971 budget reports. Although such data were available from ATA in summary form, the breakdown and categorization of cost items appeared to be inconsistent from system to system and, in several cases, only partial data were available. Another complication was that many operators of rail rapid transit facilities also operate bus systems. In such cases, many cost items, e.g., administrative costs, are given only for the total system and are not allocated separately to the rail and bus systems. In most cases, it was also not possible to separate labor and nonlabor costs, an unfortunate situation that prohibited close examination of each of these items separately.

Along with the operating budgets of rail rapid transit systems, each operator was asked to provide certain system characteristics to permit the computation of unit costs. These data include the total number of revenue track-miles in the system, number of revenue route-miles, number of annual car-miles and car-hours of operation, number of stations, and so forth.

Data for bus systems were obtained directly from ATA summaries, which exist for several hundred public and private operations in various parts of the country. These summaries, unlike those for rail rapid transit systems, are relatively uniform in their breakdown of cost categories. This is due to two prime factors: Bus costs are not so complex nor do they involve so many categories as rail rapid transit; and the ATA summaries are in general similar to forms that interstate operators regularly file with the ICC, and the format is fairly standard for all companies.

A representative sample of data from 20 bus companies was selected for detailed analysis and unit cost treatment. At a later date, it is hoped that these data can be examined closely for all systems reporting to ATA. In this regard, all of the ATA data for years up to 1970 are on computer file at the Institute for Defense Analysis, which uses the data for other types of economic analyses than those presented here (5). It is hoped that these computer files may be used by others to further the type of research described here.

URBAN PUBLIC TRANSPORTATION COST ELEMENTS

In classical economic analysis of highway systems, several cost items must be considered to make up the total cost of the highway transportation network. The cost to build the highway is a capital expense, borne directly by the government (state, federal, municipal) and indirectly by road users and others through taxes. Highway maintenance is an annual cost item, also borne by governmental units and indirectly by taxpayers. The highway transportation cost, however, must also include those items borne directly by the road user: vehicle operating cost (gas, oil, tire wear, maintenance), vehicle depreciation, and travel time. These road user costs may be computed on an annual basis by using AASHO data tabulations (1) or those of Winfrey (3). The total cost of a highway transportation system is the sum of capital, maintenance, and road user costs. Of course, capital expenses must be "written off" or represented as an equivalent annual cost to conform to the same units as other items. This is done by applying the cost over the entire service life of the physical facility with consideration of interest. Mechanically the capital cost or capital investment is multiplied by an appropriate capital recovery factor, which depends on the service life of the facility in years and the market rate of interest.

For public transportation systems, the situation is slightly different in that the transit property owner directly bears capital costs, maintenance costs, and operating costs. The only costs borne directly by the user are travel time and fare. Of these, the fare is not considered inasmuch as it is used (together with various subsidies) to pay for operating and maintenance costs. To include it, then, would be a "double-counting" of certain costs. This is entirely analogous to Winfrey's strong argument for the exclusion of gasoline and other road user taxes from road user cost (these moneys are used by the government to build and maintain highways).

For public transportation systems, therefore, three cost elements must be considered: capital expenses (construction of trackbed, other physical plant, purchase of equipment), operating and maintenance expenses, and user costs (travel time).

Capital and Construction Costs

Capital and construction costs include the construction of rights-of-way, stations, maintenance facilities, and control systems and purchase of rolling stock for rail rapid transit systems. For bus systems, the purchase of buses and the construction of maintenance and terminal and station facilities constitute most capital cost. For rapid transit systems, the major cost elements involve the construction of physical facilities over which vehicles travel. For bus systems, which use public rights-of-way in practically all cases, the major cost element is the purchase of buses. In some cases, buses will operate on private rights-of-way providing a service called bus rapid transit. In such cases, the cost of the right-of-way and structure must, of course, be included.

The size and extent of physical facilities required by rail rapid transit cause the initial costs for such systems to be extremely high. For example, the BART system in San Francisco, which opened its first section for service in September 1972, will have cost \$1.4 billion by its completion, and the completion cost for the 95-mile Washington, D.C., system is estimated at \$3 billion. Costs for the provision of bus services are of a different order of magnitude, involving the purchase of vehicles ranging from \$30,000 to \$40,000.

Also to be considered is the fact that a rail rapid transit system may require a decade or more to construct, whereas bus services, particularly where there are existing bus companies, may be provided in a period of weeks with little or no disruption of surroundings during the preparation period.

The great advantage of the rail rapid transit system, and the one that will most often justify the large initial cost of such services, is capacity. A single train with a single motorman can carry more than 2,000 persons; a bus carries up to 80 persons with one driver. Rapid transit systems can carry over 60,000 persons per hour on a single track; bus routes rarely carry more than 10,000 persons per hour, which requires 125 buses per hour, quite a traffic problem in most areas.

Operating Expenses

Despite the high initial cost of rapid transit systems, the critical financial plight faced by rail and bus operators alike is operating costs. Because of the nature of the services, public transportation is extremely labor-intensive. Labor costs in the strongly unionized transportation industry have skyrocketed in recent years and, with them, the operating costs of transit services. In the case of rail rapid transit 80 percent to 90 percent of all operating expenses are directly attributable to labor as direct salaries and wages and various employee benefits.

It is unfortunate, but data and procedures for estimating transit operating costs are neither so plentiful nor so formalized as corresponding procedures for private vehicle operating costs. There is a degree of variability introduced because of the great importance of labor expenses to the total operating cost outlook. Labor expenses may vary widely from city to city, depending on area of the country, unions, and other unpredictable factors. This makes it difficult to generalize costs from system to system. The estimate of public transit operating costs often involves case-specific techniques and data.

Despite the difficulties involved, several general approaches to the estimation of transit operating costs exist. The two most popular methods are the unit cost method and the regression method. Both methods make use of the same basic predictive formula.

$$OC = A(VM) + B(VH) + C(PV) + D(RP)$$

where

OC = annual operating cost,
VM = annual vehicle-miles of operation,
VH = annual vehicle-hours of operation,
PV = number of vehicles in use during peak periods,
RP = annual (or daily) revenue passengers, and
A,B,C,D = constants of calibration.

The difference between the unit cost and regression methods is the way the constants of calibration are determined. In the regression method, standard multiple regression techniques are used with a set of existing cost data.

The unit cost technique is used here and has produced results that are in general as good as or better than the regression technique. Although less analytic, the unit cost approach is more rational and more closely matches actual operating characteristics. The method entails separation of operating costs into subcategories such as vehicle maintenance, track maintenance (rail only), fuel or power, and transportation expenses. A determination of which of these costs relates best to which parameter must then be made. Table 1 gives a breakdown of cost elements by their respective base parameters as recommended in a study conducted for the Washington Metropolitan Area Transit Authority (6).

The model is simply calibrated by using an existing set of data. Costs are stratified into those relating to vehicle-hours, vehicle-miles, peak-period vehicles, and revenue passengers. Dividing the totals by the number of vehicle-hours, vehicle-miles, or so on gives the desired constants of calibration.

The unit cost model has been applied with great success to specific transit companies. Calibrated with past data, the model has been used to predict future costs for service alterations for the company in question. No universally applicable calibration has been accomplished because of the wide variation in unit costs among various systems.

One essential requirement for calibration of a unit cost model is a set of data that can be categorized as shown in Table 1. Unfortunately, even with the variability in operating costs among different systems, there is more variability in the way these are reported. The accounting systems used by public transit operators vary widely, and a breakdown as indicated in Table 1 may not be possible. In such cases, judgment must be used to effect the best possible separation of costs according to their principal underlying variable. In some accounting systems, considerable detail is lacking, and two- or three-variable unit cost models may be necessary. Where this is so, the loss of variables will negatively affect the accuracy of the model's predictions.

User Costs

The third category of costs to consider in public transportation is user costs. The user of a public transportation facility experiences two direct costs: travel time and fare.

Travel time is handled the same as vehicular traffic; a unit cost per person-hour must be assumed. For vehicular analysis, AASHO (1) assumed a cost of \$0.86/person-hour or \$1.55/vehicle-hour. This value is quite conservative, and higher values could be justifiably used. Various studies have resulted in travel time values of \$1.40 to \$3.40 per person-hour. Whichever value is used must be used for all alternatives being compared. If a transit line is being compared to a highway system and the AASHO road user cost tables have been used without modification to estimate

Table 1. Allocation of transit cost elements for unit cost model.

Item	Vehicle-Hours	Vehicle-Miles	Peak-Hour Vehicles	Revenue Passengers
Equipment maintenance and garage expenses				
Supervision		X		
Maintenance of service equipment			X	
Maintenance of buildings and grounds			X	
Maintenance of revenue equipment		X		
Tires and tubes (buses only)		X		
Other		X		
Transportation expenses				
Supervision	X			
Operators' wages	X			
Fuel and oil or power		X		
Station expenses			X	
Other	X			
Traffic and advertising		X		
Insurance and safety				X
Administrative and general				
Officers' salaries			X	
Employee wages			X	
Legal expenses			X	
Welfare expenses	X			
Other			X	

Source: (6).

Table 2. Total operating costs (in dollars) for selected rapid transit systems, 1971.

Coat Category	NYCTA	TTC (Toronto)	MUCTC (Montreal)	SEPTA (Philadelphia)	CTA	CTS (Cleveland)	PATCO (Lindenwold)
Maintenance of way and structure	77,701,000	2,919,720	2,522,708	1,897,709	15,278,035	459,355	672,273
Maintenance of equipment	83,711,000	3,244,494	2,503,693	2,680,480	9,770,516	804,914	831,235
Power	49,632,000	2,134,227	3,435,689	2,110,509	5,816,565	557,939	595,934
Conducting transportation	141,458,600	3,515,213	3,869,086	7,562,681	31,134,198	1,473,567	1,455,469
Administration	9,008,075[a]	652,000[a]	1,651,423	431,355[a]	3,030,858[a]	378,377[a]	205,572
Miscellaneous	142,436,700[b]	868,511[b]	775,030	4,996,916[b]	2,252,455	1,011,686[b]	529,734
Total	503,947,375	13,339,165	14,757,629	19,679,630	67,282,627	4,685,838	4,287,255
Annual car-mile	359.8×10^6	22.74×10^6	18.37×10^6	13.39×10^6	51.48×10^6	4.27×10^6	2.92×10^6
Annual car-hour	19.51×10^6	1.194×10^6	1.102×10^6	—	—	0.134×10^6	0.122×10^6
Peak-hour vehicle	6,127	—	261	—	995	117	70
Annual rev. pass.	$1,258 \times 10^6$	98.49×10^6	65.86×10^6	50.34×10^6	105.6×10^6	15.29×10^6	8.66×10^6

[a]Estimated from totals for bus and rail. [b]Includes employee benefits.

Table 3. Unit costs for use in models of rail rapid transit costs.

System	Maintenance of Way[a]	Maintenance of Equipment[a]	Power[a]	Conducting Transportation[b]	Administration[c]	Miscellaneous[d]
NYCTA	0.216	0.232	0.138	7.250	1,470.23	0.113
CTA	0.297	0.190	0.113	—	3,046.09	0.021
SEPTA	0.142	0.200	0.158	—	—	0.099
CTS	0.107	0.189	0.131	10.998	3,233.90	0.066
PATCO	0.199	0.246	0.176	11.930	2,936.74	0.061
TTC	0.128	0.142	0.094	2.944	—	0.009
MUCTC	0.138	0.136	0.187	3.511	6,327.29	0.012
Avg U.S.	0.192	0.211	0.143	10.059	2,669.22	0.072
Avg Canada	0.133	0.139	0.140	3.228	6,327.29	0.011

[a]In dollars per car-mile. [b]In dollars per car-hour. [c]In dollars per peak-hour vehicle. [d]In dollars per revenue passenger.

highway costs, then the AASHO value of \$1.86/person-hour must be used to evaluate travel time for the transit system. If the Winfrey tables (3) are used to estimate highway costs and a travel time value of \$2.00/person-hour has been assumed, it must be used as well for the transit cost estimates.

There is much debate among economic analysts on the treatment of travel time. All agree that it most often is the single most heavily weighted factor in an economic comparison. The use of a flat rate for the travel time value is justifiably challenged. To equate the value of 100 persons saving 1 minute of travel time to 1 person saving 100 minutes is not reasonable, even though the total in both cases is 100 person-minutes. These issues, however, are not the subject of this paper.

OPERATING COST MODELS

Rail Rapid Transit

The principal difficulty faced in predicting transit operation costs is the wide variability in unit costs from system to system. This will be illustrated in the sections that follow. However, it will also be seen that capital costs for these systems also vary widely from place to place. This variability is particularly true of rail rapid transit. Construction costs are dependent on a wide variety of surface and subsurface conditions, particularly where tunneling is concerned. Equipment cost varies with the type of equipment purchased—air-conditioned or not air-conditioned, automated or not automated, sound-insulated or not, and so on. Operating costs, as discussed, vary with labor rates but also with age of equipment, condition of track bed, operating speed, and so forth.

It is not the purpose of this paper to treat construction or equipment costs in detail. Rapid transit construction costs range from \$10 to 20 million/mile for tunnels, \$2 to 5 million/mile for elevated structures, and \$1 to 2 million/mile for surface rights-of-way, exclusive of land purchase. Stations cost an additional \$2 to 3 million if underground and \$½ million if elevated or at grade. Detailed reports on construction costs, including tunneling (10), are available in the literature.

Rolling stock costs vary with the size of the car, the type of unit (single cars, married pairs, four-car units), performance criteria, and passenger amenities. The new New York City Transit Authority R-44 car costs approximate \$¼ million per car. Costs for other rapid transit cars are detailed in the literature (11-15).

ATA, to which most transit operators belong, publishes an annual summary of costs, revenues, and operating statistics for rail and bus systems. Although highly useful for bus systems, the ATA summaries on rail transit are of limited utility. For rail systems, data are missing for several whole systems and for certain cost categories in other systems. Further, the breakdown of cost elements appears to be inconsistent among systems in the ATA summaries. For this reason, data presented here were extracted from the annual budget summaries of the various transit operators directly.

This is a difficult analysis task. No two operators employ the same bookkeeping systems, nor are cost accounts readily comparable. Many large municipal systems that operate both bus and rail transit have overlapping and combined accounts, particularly for administrative aspects. One such system, the Massachusetts Bay Transportation Administration, kept only combined accounts, making it impossible to extract rail or bus unit costs for that system. Estimates had to be used to divide administrative costs into rail and bus for the Chicago Transit Authority (CTA).

Most operating budgets, however, make it possible to stratify data into six major categories:

1. Maintenance of way and structures—maintenance of stations, including labor and material costs;
2. Maintenance of equipment—maintenance of rolling stock, maintenance garages, fare collection equipment, and so forth;
3. Power—costs for purchase and generation of power;
4. Conducting transportation—motormen, conductors, station agents, traffic managers, dispatchers;

5. Administration—office and executive staffs, personnel, public relations; and
6. Miscellaneous—insurance and taxes.

Total operating costs for each of these categories, as well as other statistics of interest, are given in Table 2. The data in this table were extracted from operating budgets of seven U.S. and Canadian transit systems for the year 1971 (16-21).

To apply these data to an appropriate unit cost model requires that the various cost categories be assigned to the proper unit of determination. If Table 1 is used as a guide, the following assignment should be made:

Cost	Category
Maintenance of equipment, maintenance of way and structures, power	Vehicle-miles
Conducting transportation	Vehicle-hours
Administration	Peak-period vehicles
Miscellaneous	Revenue passenger

Some general comments can be made. Canadian and U.S. systems should not be directly compared. Price structures, particularly for labor, are drastically different in the two countries and preclude meaningful comparison. Where inconsistencies within categories are observed, these may generally be traced to characteristics of the rapid transit systems.

An examination of unit costs versus all possible units confirms the recommendations of Table 1, and the cost assignments recommended were used. Table 3 gives the data used in the formulation of unit cost models for rail rapid transit.

Unit cost models may now be developed for each system and for U.S. and Canadian averages. Where individual unit values are missing because of lack of data, the appropriate average will be used as a reasonable approximation. When these models are used for predictions of operation costs on new systems or proposed extensions to existing systems, care must be taken in the choice of models. If the characteristics of the proposed system are similar to one of the existing systems, the model for that system might be adopted. For example, a proposal for a new high-speed automated line might appropriately make use of the PATCO model for the Lindenwold line. If the characteristics of the proposed line are not well defined, average models should provide useful estimates within a reasonable range of error. Operating costs for extensions to existing systems should be estimated by using the model for the system in question. Unit cost models are given in Table 4.

The estimates that can be made by using these unit cost models are based on 1971 price levels. Such estimates should be adjusted to reflect inflation. Costs can be updated by using the national average inflation rate, which has been about 7 percent over the decade of the 1960s and early 1970s. For the approach, resultant cost estimates would be multiplied by 1.07^x, where x is the number of years between the time of the estimate and 1971.

Ideally, trend data for the various rapid transit operators should be investigated. Unfortunately, such data are not readily available. A previous work by Lang and Soberman (22), however, does contain data on unit rail costs for 1960. Four systems can be compared: New York, Cleveland, Chicago, and Philadelphia. Table 5 gives the comparison of unit costs on a per car-mile basis.

In 11 years, rail transit costs have more than doubled! This is due mainly to rising labor rates and particularly to a great rise in employee benefit costs. Approximately 85 to 95 percent of all operating costs are directly and indirectly labor-related. Based on the average total operating cost per car-mile, a compound inflation rate of 7 percent is indicated. Inasmuch as this agrees with national average inflation rates, a factor of 1.07^x might be used. This factor should be adjusted if government controls initiated in 1972 succeed in reducing the inflation rate. In general, the factor would be $(1 + i)^x$, where i is the average inflation rate over x years.

It should be noted that, for use in economy studies, inflation rates are ignored. However, capital costs for all alternatives must be based on price levels for the same year.

Table 4. Unit cost models for prediction of rail rapid transit operating costs.

System	Model
NYCTA	OC = (0.216 + 0.232 + 0.138)CM + 7.250CH + 1,470.23PC + 0.113RP = 0.586CM + 7.250CH + 1,470.230PC + 0.113RP
CTA	OC = (0.297 + 0.190 + 0.113)CM + 3,046.09PC + 0.021RP = 0.600CM + 10.059CH + 3,046.090PC + 0.021RP
SEPTA	OC = (0.142 + 0.200 + 0.58)CM + 10.059CH + 2,669.22PC + 0.099RP = 0.500CM + 10.059CH + 2,669.220PC + 0.099RP
CTS	OC = (0.107 + 0.189 + 0.131)CM + 10.998CH + 3,233.90PC + 0.066RP = 0.427CM + 10.998CH + 3,233.900PC + 0.66RP
PATCO	OC = (0.199 + 0.246 + 0.176)CM + 11.930CH + 2,936.74PC + 0.061RP = 0.621CM + 11.930CH + 2,936.740PC + 0.061RP
TTC	OC = (0.128 + 0.142 + 0.094)CM + 2.944CH + 6,327.29PC + 0.009RP = 0.364CM + 2.944CH + 6,327.290PC + 0.009RP
MUCTC	OC = (0.138 + 0.136 + 0.187)CM + 3.511CH + 6,327.29PC + 0.012RP = 0.461CM + 3.511CH + 6,327.29PC + 0.012RP
Avg U.S.	OC = (0.192 + 0.211 + 0.143)CM + 10.059CH + 2,669.22PC + 0.072RP = 0.546CM + 10.059CH + 2,669.220PC + 0.072RP
Avg Canada	OC = (0.133 + 0.139 + 0.140)CM + 3.228CH + 6,327.29PC + 0.011RP = 0.412CM + 3.228CH + 6,327.290PC + 0.011RP

Note: OC = annual operating costs, CM = annual car-miles, CH = annual car-hours, PC = no. of peak-period vehicles, and RP = annual revenue passenger.

Table 5. Unit rapid transit costs (in dollars per car-mile) for 1960 and 1971.

Category	Year	NYCTA	CTA	SEPTA	CTS	Average
Maintenance of way and structures	1960 1971	0.132 0.216	0.082 0.297	0.108 0.142	0.057 0.107	0.095 0.191
Maintenance of equipment	1960 1971	0.098 0.232	0.099 0.190	0.069 0.200	0.041 0.189	0.077 0.203
Power	1960 1971	0.113 0.138	0.098 0.113	0.091 0.158	0.044 0.131	0.087 0.135
Conducting transportation	1960 1971	0.265 0.393	0.298 0.605	0.309 0.565	0.251 0.345	0.281 0.477
Other	1960 1971	0.090 0.421	0.090 0.496	0.088 0.405	0.063 0.326	0.083 0.412
Total	1960 1971	0.698 1.401	0.667 1.307	0.665 1.469	0.456 1.097	0.622 1.319

Table 6. Unit operating costs for publicly owned bus systems, 1970.

City	Annual Bus-Miles	Annual Bus-Hours	Peak-Hour Buses	Annual Revenue Passengers	Maintenance (dollars per bus-mile)	Conducting Transportation (dollars per bus-hour)	Fuel (dollars per bus-mile)	Admin. (dollars per peak-hour bus)	Misc. (dollars per revenue passenger)	Total (dollars per bus-mile)
Chicago	89,326,082	10,006,568	2,224		0.228	6.387	0.034	10,607.47	—	1.277
New York	67,958,432	8,854,103	2,187	409,000,904	0.419	7.818	0.034	11,383.34	0.017	1.939
Los Angeles	57,478,555	4,438,067	1,325	142,059,393	0.157	6.283	0.029	4,485.50	0.057	0.915
Philadelphia	37,248,271		1,256	140,902,696	0.202	—	0.033			
Detroit	37,029,607	2,919,662	930	108,296,614	0.131	6.939	0.028	15,202.05	0.012	1.123
Cleveland	23,222,679		652		0.125	—	0.028		—	0.737
Atlanta	19,425,505	1,500,337	462	48,345,963	0.103	5.448	0.024	4,128.97	0.032	0.725
Kansas City	10,179,235	901,169	270	16,870,798	0.145	5.405	0.024	2,590.09	0.055	0.806
South Jersey	1,109,459	156,580	45	7,187,798	0.378	4.120	0.040	2,315.07	0.013	1.177
Wichita	1,417,458	134,069	52	2,063,270	0.081	3.200	0.027	1,507.41	0.078	0.525
Average					0.197	5.700	0.020	6,527.48	0.038	1.025

Table 7. Unit costs for privately owned bus systems, 1970.

City	Annual Bus-Miles	Annual Bus-Hours	Peak-Hour Buses	Annual Revenue Passengers	Maintenance (dollars per bus-mile)	Conducting Transportation (dollars per bus-hour)	Fuel (dollars per bus-mile)	Admin. (dollars per peak-hour bus)	Misc. (dollars per revenue passenger)	Total (dollars per bus-mile)
New Jersey (Newark area)	82,933,427	6,379,079	1,871	165,544,793	0.150	6.030	0.024	5,243.73	0.075	0.9065
Oakland-San Francisco	23,987,889	1,683,595	638	48,064,026	0.109	7.238	0.022	3,842.57	0.046	0.8329
Buffalo	13,347,376	1,228,522	420	46,469,696	0.219	5.261	0.028	3,823.07	0.049	1.020
New York	3,779,291		137	26,369,925	0.240	—	0.037	5,561.35	0.040	1.519
Jacksonville	5,314,077	501,616	131	12,398,820	0.126	3.361	0.027	2,831.47	0.044	0.644
Long Beach	5,041,010	418,471	98	11,180,240	0.080	4.243	0.017	4,794.10	0.034	0.568
Charlotte City	3,149,090	383,112	116	9,081,782	0.122	2.967	0.036	1,533.82	0.051	0.722
Hempstead	1,527,272		44	4,127,384	0.236	—	0.037	5,050.41	0.055	1.044
Twin Cities	2,186,613	178,960	68	4,442,892	0.115	3.513	0.024	1,331.26	0.034	0.587
Utica	1,222,397	112,655	43	3,539,382	0.192	4.667	0.028	2,373.72	0.033	0.829
Average					0.159	4.659	0.028	3,639.05	0.046	0.862

Local Buses

The bus is the "underrated star" of urban public transportation. Although much attention, including research, planning, and publicity, has been given to the development and operation of rail transit systems, the urban bus has been quietly carrying the overwhelming majority of public transit users. Corridor demands sufficient to justify the construction of rail rapid transit facilities exist in only a few of the nation's largest urban centers. Whereas rail systems exist in only six U.S. cities, bus services are provided in virtually every municipality of 50,000 population or more and in many smaller urban and suburban areas.

The provision of bus services is many times less expensive than comparable first costs for rail systems. This is understandable, considering that buses may make use of public rights-of-way, whereas rail services require the construction of extensive right-of-way facilities. Also, whereas each purchase of rapid transit rolling stock requires a special vehicle design and incurs the plant set-up costs to manufacture that design, a bus is a "shelf" item that can be ordered from a number of manufacturers, principally General Motors and Flxible.

Similar to the treatment of rail, costs of providing and operating a bus system are divided into the three major categories of capital costs, operating costs, and user costs.

Capital expenditures for bus systems are primarily limited to the purchase of equipment and the construction of garage and maintenance facilities. Occasionally, the construction of busways is undertaken to provide a special service called "bus rapid transit."

The price of a standard bus depends on the size of the vehicle and the options desired. General Motors, the major manufacturer of transit buses (89.3 percent of all buses in the N.Y.C. metropolitan region are GM manufactured), has a wide range of standard models. The largest of these, a 53-seat coach with an 8-cylinder diesel engine and air conditioning, costs from $40,000 to $45,000, depending on other options. The smallest, a 33-seat coach with a 6-cylinder diesel engine and air conditioning, costs approximately $30,000. Air conditioning is an option but is almost standard on buses manufactured since 1970. Air conditioning costs from $4,000 to $4,400 per bus. An antipollution system developed in 1971 may be added for less than $500 on a new bus, although it costs many times more to add the device to an older vehicle. The device substantially reduces overall pollutants emitted and virtually eliminates visible pollutants. (Prices quoted are for 1972.)

The service life of a bus ranges from 15 to 25 years depending on the quality of maintenance and intensity of use. It should be noted that careful servicing and maintenance of buses greatly increase useful service life. Bus engines (diesel) must be overhauled every 200,000 to 300,000 miles.

Operating costs for bus systems are generally divided into five major categories: maintenance, conducting transportation, fuel, administration, and miscellaneous. These costs are readily isolated from ATA annual statements (26). Unit costs may be assigned according to Table 1, which was specifically prepared for bus systems.

Maintenance expenses for buses include normal vehicle servicing and engine repairs plus major engine overhauls at intervals of several hundred thousand miles. Diesel engines entail lower maintenance costs than gasoline engines and go longer intervals between overhauls. Garage and maintenance facilities must also be maintained, but this represents only a small fragment of the total maintenance cost.

Expenses under conducting transportation include bus drivers, dispatchers, and operating supervisors. Costs in this category are almost 100 percent for labor and make up approximately 50 percent of total operating costs.

Fuel and oil consumption varies with a number of factors, including speed of operation, acceleration rate, number of stop and go cycles, loaded weight of vehicle, and size and type of engine. Fuel costs for diesel engines are lower than those for gasoline engines in buses of similar size. This is primarily due to the lower cost of diesel fuel, not to great differences in consumption rates, which are higher in diesel engines.

Administrative costs include all normal costs for system supervisors and supporting staffs, accounting, personnel, training, public relations, and other administrative departments.

Miscellaneous costs cover items such as insurance, operating taxes (for private operators), and advertising. Both administrative and miscellaneous costs vary widely depending on the extent of auxiliary services offered by the various systems and the efficiency of administrative operations.

Tables 6 and 7 give unit costs for public and privately owned bus services. Data are for 1970 and were extracted from the 1970 ATA operating report (26).

Most of the unit costs in Tables 6 and 7 show greater variability than would be desirable for the development of reliable unit cost models. In general, there is a tendency for smaller operators to have lower unit costs. Though this trend is not distinct enough to base a relationship on, a definite diseconomy of scale is indicated. It appears that privately owned services run more economically than publicly owned systems, but this appearance is partly because the private operations given in Table 7 are in general smaller than the public services in Table 6. Because of this, no strong conclusion may be reached on this point. Services in southern areas have lower costs because of lower labor wage rates in these areas.

To use the data in Tables 6 and 7 for the formulation of unit cost models and operating cost predictions requires careful judgment. Where no definitive information on characteristics of proposed bus services is available, average unit costs might be used to obtain gross cost estimates. However, where the service characteristics are better defined, unit costs for a particular operator of similar size in a similar area would undoubtedly produce more reliable predictions. Of course, where additional bus services are planned for an existing system, unit costs for that system should be investigated and used. Example unit cost models based on the average unit costs in Tables 6 and 7 are as follows: for public operations

$$\begin{aligned} OC &= (0.197 + 0.030)VM + 5.700VH + 6{,}527.48PV + 0.038RP \\ &= 0.227VM + 5.700VH + 6{,}527.48PV + 0.038RP \end{aligned}$$

and for private operations

$$\begin{aligned} OC &= (0.159 + 0.028)VM + 4.659VH + 3{,}639.05PV + 0.046RP \\ &= 0.187VM + 4.659VH + 3{,}639.05PV + 0.046RP \end{aligned}$$

where

OC = annual operating costs,
VM = annual vehicle-miles,
VH = annual vehicle-hours,
PV = number of vehicles in peak-hour service, and
RP = annual revenue passengers.

These costs may be increased by 1.07^x to account for inflation. This, however, is not done for economy studies in which inflation is most often ignored, being constant among all alternatives.

As with rail rapid transit costs, the only user cost element included in economy studies is travel time. The unit travel time value used must be the same for all alternatives in comparative analysis.

USE OF OPERATING COST MODELS IN ECONOMIC ANALYSIS

For the purposes of discussion, it is assumed that the reader has a working knowledge of the basic methods and theory of engineering economy, particularly as it is applied to highways. The reader is referred to basic textbooks on the subject if background is needed (3, 27).

The concern here is not for the precise estimation of cost items for a given year, but for the use of these data in comparative analysis in the planning sense. Alternatives for transportation improvements should be compared from the economic standpoint as one input into the ultimate decision-making process. Although alternative highway plans have always been examined in this manner, the results of this research now make it possible to compare transit alternatives to each other in the same way and, more importantly, transit versus highway alternatives.

For the planner, three elements of cost take on importance and must be considered: capital costs, operating and maintenance costs, and direct user costs including travel time. To combine all three, they must be converted to similar bases. Either the annual cost method of analysis, in which all costs are converted to equivalent annual cost, or the present worth method, in which all costs are converted into a single sum representing a given number of years of service, may be used.

Because the bus data presented here are for 1970 and the rail data for 1971, bus costs should be multiplied by 1.07 when the two are compared to adjust them to the same base year. When transit costs are compared to automobile costs, the case is not so clear. Most highway cost analyses will be generated by using AASHO tables, which are for a base year of 1959. However, it would be improper to inflate these to a base year of 1971 (multiply by 1.07^{12}), inasmuch as improvements in automobile efficiency have greatly offset inflation. In fact, studies conducted by Claffey (2) and others show that automobile operating costs have decreased and are lower than those predicted by AASHO in many cases. Therefore, lacking any better basis for modifying AASHO data, they should be used directly without adjustment. Further, in using AASHO tables, an implicit travel time value of $0.86/person-hour is assumed, and this must then be used to evaluate transit alternates as well. Because this value is considered low by most transportation economists, the AASHO travel time component may be omitted and another value used for both highway and transit alternates.

FUTURE RESEARCH AND DATA NEEDS

Because of certain data deficiencies, this project was able to produce specific cost models for specific transit systems. A generalization of these would be most useful but can be obtained only if systematic relationships between unit cost coefficients and underlying transit system characteristics can be isolated. All attempts at such investigations produced little of interest. However, a great deal of the problem relates to the lack of uniformity in data from different systems and the lack of data describing characteristics of great interest, e.g., train speed and average station spacing for rail systems.

As a result of the investigations reported on, recommendations concerning uniform formatting of data for rail and bus systems are made. It is intended that attempts be made to obtain data from the sources participating in this study in this format, so that further investigation into general cost models may be made.

From the research point of view, the need for uniform reporting of data is great. It is recognized, however, that situations existing in each transit system may be quite unique and that budgeting formats are suited to the convenience of the operator. It is hoped that the operators who cooperated with this effort will find the results useful to them and that they will make an effort to supply the information needed to generalize the results obtained herein.

A brief outline of the desired format for budget data follows this discussion (Appendix). Note that, within each budget category, there is a breakdown of costs into nonlabor, direct labor (salaries and wages), and indirect labor (benefits: pension, vacation, workmen's compensation, medical plans). This is viewed as a critical point in that each component of cost may depend on variables not common to all components. Also, cost items to be included in each account are defined in some detail so as to avoid confusion. It is hoped that the detail of these definitions will result in the acquisition of a more uniform data base.

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APPENDIX

SUGGESTED DATA FORMAT FOR RAPID TRANSIT SYSTEMS

The following system characteristics should be obtained for use as independent variables in cost analysis. They should all be for a particular year of operation.

1. Annual car-miles;
2. Annual train-miles (1 train traveling 1 mile is 1 train-mile regardless of train length;
3. Annual car-hours;
4. Annual train-hours (1 train traveling for 1 hour is 1 train-hour, regardless of train length);
5. Miles of revenue track in system;
6. Total route-miles in system;
7. Total number of stations in system;
8. Total number of cars owned;
9. Maximum speed of operation in system;
10. Average station spacing;
11. Number of cars owned of the following ages: <5, 5 to 10, 10 to 15, 15 to 20, 20 to 25, 25 to 30, 30 to 35, 35 to 40, 40 to 45, 45 to 50, and >50 years; and
12. Annual revenue passengers.

The tabular arrangement shown in Figure 1 is recommended for reporting of annual costs categorized as shown.

Maintenance of way and structures includes all equipment, labor, and labor benefit costs associated with the maintenance of trackage, switches, power supply, signals, ventilation, and all station facilities.

Maintenance of equipment includes all parts, equipment, labor, and labor benefit costs involved in maintaining revenue rolling stock, maintenance equipment, and the upkeep and operating cost of maintenance facilities (shops, cleaning facilities, yard and garage facilities, etc.).

Power includes all costs, including labor and labor benefits, incurred in the purchase and/or generation of power.

Conducting transportation includes the cost of train crews (motormen and conductors), station attendants, guards, porters, traffic managers, switchmen, towermen, and the like.

Administrative expenses include the operating costs of system executives and their supporting staffs, bookkeeping and accounting costs, personnel services, public relations departments, consumer information services, lost and found, and purchase and stores departments.

Miscellaneous expenses include insurance against public liability, taxes, and other miscellaneous items not covered under other categories.

In addition, information concerning labor aspects as shown in Figure 2 should be obtained.

SUGGESTED DATA FORMAT FOR BUS TRANSIT SYSTEMS

The following system characterics should be obtained:

1. Total number of routes operated;
2. Total number of route-miles operated;
3. Annual bus-miles operated;
4. Annual bus-hours operated;
5. Total number of bus stops in system;
6. Average speed of buses in service;
7. Average bus stop spacing;
8. Number of buses owned of the following ages: <5, 5 to 10, 10 to 15, 15 to 20, 20 to 25, 25 to 30, 30 to 35, and >35 years and how many are gasoline-powered and diesel-powered;

Figure 1. Annual cost categorization for rapid transit systems.

Category of Expense	Type of Expense		
	Nonlabor	Direct Labor	Indirect Labor
Maintenance of Way and Structures Track and Switches Power and Signals Stations			
Maintenance of Equipment Rolling Stock Plant and Other Equipment			
Power Purchase or Generation			
Conducting Transportation			
Administrative Expenses			
Miscellaneous Expenses			

Figure 2. Labor data for rapid transit systems.

Labor Category	No. of Employees	Average Hourly Wage	Average Hourly Benefits
Motormen			
Conductors			
Station Attendants (includes ticket or token agents)			
Station Porters			
Switchmen/Signalmen			
Traffic Managers			
Operating Supervisors			
Track Maintainers			
Car Maintainers			
Maintenance Supervisors			
Yardmen			
Guards/Police			
Administrative Secretaries/Clerks			
Executives			
Other Administrative Personnel			

Figure 3. Breakdown of operating expenses for bus transit systems.

Category of Expense	Type of Expense		
	Nonlabor	Direct Labor	Indirect Labor
Maintenance			
Fuel			
Conducting Transportation			
Administrative Expenses			
Miscellaneous Expenses			

9. Annual revenue passengers; and
10. Mileage of express bus routes operated.

Operating expenses should be broken down as shown in Figure 3. Maintenance includes the cost of servicing, cleaning, overhauling, and repairing buses, garage expenses, direct labor involved in such maintenance, and the corresponding labor benefits.

Fuel includes the cost of purchasing deisel or gasoline to power buses and all labor costs involved in operating filling stations.

Conducting transportation includes the cost of all drivers, traffic and schedule supervisors, dispatchers, and the like.

Administrative expenses include the total cost of executive offices and support personnel, bookkeeping and accounting, and personnel and public relations services.

Miscellaneous expenses include public liability insurance, taxes, terminal expenses (if any), advertising, and other costs not included elsewhere.

A labor data summary, shown in Figure 4, should be obtained.

Figure 4. Labor data summary for bus transit systems.

Labor Category	No. of Employees	Average Hourly Wage	Average Hourly Benefits
Drivers			
Dispatchers/Traffic Managers			
Maintenance Personnel			
Maintenance Supervisors			
Administrative Secretaries/Clerks			
Executives			
Other Administrative and Office Employees			

TRANS-JAVA HIGHWAY—TRANSPORTATION ECONOMY—NEW ANALYSIS PROCEDURES

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Economic analysis of the proposed trans-Java highway, as described in this paper, involves several procedures that have rarely, if ever, been reported in the literature. It includes (a) calculating vehicle running costs on the basis of vehicle speed distribution rather than by using one specific average speed, (b) including the changes in vehicle speeds as a running cost item, (c) estimating highway construction costs and vehicle running costs for segments of the highway rather than for the entire length of the proposed project, (d) calculating rates of return for segments of the proposed highway, (e) calculating the rate of return for each year for each highway segment, (f) using seven classes of vehicles, including separate costs for gasoline- and diesel- fueled vehicles, (g) making the complete analysis for six levels of design (traffic service) as contrasted to use of one design, and (h) applying the analysis to the network of existing highways affected by the trans-Java highway. The analysis is applied to the 237-km west portion and the 284-km east portion. Traffic is much heavier in the west than in the east. The six levels of design for both two- and four-lane basic designs include alternatives of all intersections at grade, major intersections separated, and all intersections separated. Traffic was estimated for 1980 to 1999 yearly for each of the six levels of design and for all existing roads affected. Fifteen percent per year was considered to be the minimum attractive rate of return. Because of increasing traffic volumes, the rates of return increased from a low in 1980 to a high in 1999. The rate of return varied from less than 1 percent to 15 percent depending on the route section, the level of design, and the year.

•WHEN WORK BEGAN in February 1972 to determine the engineering and economic feasibility of the proposed east to west trans-Java highway, it was soon realized that the project presented some unusual features. Java's 76 million population, mountains and lowlands, existing and possible agricultural and industrial development, and contrasts in culture and state of development in the east and west portions all were challenging factors to consider. This paper, however, discusses only the analysis of transportation economy, which offered opportunities for procedures not used before to any great extent. Full details of the study are given in the final report (1).

Traffic was forecast for 1972 to 1999 for each route segment (a distance from one highway crossing to the next or one interchange to the next) on a yearly basis. This forecast was also made for existing routes that would be affected by the opening to traffic of any segment of the trans-Java highway. Motor vehicle running costs and road user costs were calculated for all existing highway routes affected by any segment of the trans-Java highway. Thus, the analysis of transportation economy was considered on a systems basis.

The transportation economy analysis included the following features that, although not new in concept, have seldom, if ever, been applied in U.S. or other studies:

1. Calculating vehicle running costs on the basis of vehicle speed distribution rather than one general average speed,
2. Including the cost of changes in vehicle speeds in the calculation of running costs,

3. Estimating highway construction costs and road user costs by segments so that the transportation economy could be calculated by segment for the full route distance,
4. Calculating by segment a rate of return for each year so that the optimum year to open the new route could be determined,
5. Using seven classes of vehicles for calculating running costs with gasoline- and diesel-fueled vehicles separated,
6. Making the complete analysis of alternative designs for six levels of traffic service as contrasted to one level of design, and
7. Applying the analysis to the network of existing highways affected by the construction of any part of the proposed new route, thus approaching the system concept of analysis.

GENERAL CHARACTER OF THE PROJECT

Figure 1 shows the general location of the trans-Java highway. There are three main sections: The west from Djakarta to Tjirebon is 237 km; the central from Tjirebon to Semarang is 230 km; the east from Semarang to Surabaja is 284 km; and a spur south to Bandung is 55 km. The study was made in detail for the west, east, and spur portions.

The network of paved and unpaved highways connecting the major cities have physically deteriorated surfaces, narrow or no shoulders, poor horizontal and vertical alignments, narrow bridges, congested roadside development, and congested city and town traffic. Traffic within urban areas, and to a lesser extent in rural areas, is a dense mixture of pedestrians, animal-drawn carts, bicycles, motorcycles, scooters, betjaks (a hooded tricycle for passengers), bemoes (three-wheeled minibuses), passenger cars, pickup trucks converted to people carriers, small and large buses, two-axle trucks, three-axle trucks, and tractor-semitrailer combinations. With this mixture, vehicular flow in urban areas moves at slow average speeds (10 to 20 km/h) with constant speed changes due to stops, slowdowns, and speedups.

The population of Java in 1971 was 62,371,000 rural and 13,732,000 urban. Overall population density per square kilometer in 1971 was 467 in west Java, 640 in central Java, and 533 in east Java. Djakarta's population density is 7,931.

PRELIMINARY AND FINAL ANALYSES

Because of existing narrow rights-of-way, heavy roadside development, and drainage problems, it was evident that redeveloping the existing rights-of-way for improved facilities was more unfavorable than favorable. For all portions of the trans-Java highway, alternative locations were considered with respect to servicing the urban areas, transportation needs, and preserving and developing land uses.

In the preliminary economic evaluation phase, various possible route locations were studied and an economic analysis was made of the west and east portions on a total distance basis. It was determined that the trans-Java route would be sound economically over the 20-year analysis period, 1980 to 1999, but the year economic feasibility would be reached was not determined.

The objective of the second phase, the project formulation study, was to determine the relative economy on a yearly basis of six levels of design and to make a comparison with the existing highways. This phase was restricted to the one route identified in the first phase. Thus the final engineering design and construction cost estimates apply to only the location recommended for ultimate construction.

The design alternatives were chosen to provide a range of traffic service measured by number of lanes and access-control factors. The specific design alternatives evaluated for both the two-lane bidirectional highway and four-lane divided facility are

1. All highway and railway crossings at grade,
2. Major grade-separated crossings, and
3. All grade-separated highway and railway crossings.

All design alternatives were based on ultimate construction with full access control. Therefore, each of the six design alternatives includes rights-of-way required for a four-lane freeway. The two-lane alternatives included earthwork and drainage for only two lanes.

EXISTING TRAFFIC INFORMATION

Most of the necessary traffic information was available to determine existing traffic flows, to make traffic forecasts, and to estimate traffic diversion for each of the six design alternatives considered.

Traffic Volume

A continuing program conducted by Bina Marga for all of Indonesia makes vehicle classification counts on motorcycles, three-wheeled motorized vehicles, cars, pickups, microbuses, 36-seat buses, two-axle trucks, three-axle trucks, tractor semitrailers, bicycles, and animal-drawn vehicles.

Counting stations are located some distance from urban areas. Of 71 stations, 63 or 90 percent of the segments studied had the count station located farther than one-fourth of the segment length to the nearest terminus. Therefore, traffic volumes were considered to represent a low count because a large number of short-haul trips near urban termini were not counted. The consultant estimated that a 25 percent addition to the counted traffic volumes would reflect short-haul trips.

Traffic Characteristics

The following traffic characteristics were established:

1. A 60-40 directional distribution,
2. A mix of levels of service C and E, and
3. More than 1 hour of peak flow in the morning and afternoon.

From a review of local data and from reference sources (2, 4), it was established that 30 percent of the average daily traffic would flow in the peak 4 hours of the day.

Passenger Car Units

Equivalent passenger car unit (PCU) factors for flat terrain were determined locally, whereas those for rolling and mountainous terrain were based on data in the Highway Capacity Manual (2). Because factors in the Manual pertain to vehicle operation in the United States, engineering judgment dictated that the values be revised upward in some cases to allow for the greater average vehicle age and generally poor physical condition of vehicles operating in Java. It was determined that PCUs of the smaller vehicles do not vary significantly with terrain. For buses and trucks we decided to double the flat-terrain PCU values for rolling terrain, and double the rolling-terrain values for mountainous terrain.

SURVEYS AND ANALYSES

Existing traffic information was supplemented by surveys and special analyses of available data. Of particular significance were studies conducted to determine travel speeds and changes in speed.

Traffic Behavior

The analysis included effects of highway design and traffic control on vehicle running costs. Running cost data include the cost per kilometer for speeds on plus and minus vertical grades, horizontal curves, speed changes, and idle engine. Therefore, highway data such as design speed, distance, pavement condition, grades, and curvature, in conjunction with vehicle speed, make possible the estimation of total motor vehicle running cost on each existing and alternative route considered.

Traffic Speed and Speed Changes—Because of urban congestion and large numbers of speed changes, it was evident the trans-Java highway would produce a reduction in vehicle running costs. Benefits to traffic would be largely from lowering the number of speed changes and increasing both distance and speed driven at uniform speeds as compared to that driven by existing traffic. The poor quality of existing pavements, narrow roadway widths, and poor vertical and horizontal alignments also contribute to the high running cost of current traffic.

General travel speeds and changes in speeds were established by driving a test vehicle over existing routes under different conditions of traffic. Magnetic tape recordings were made by oral dictation of stopwatch time, odometer readings, readings of roadside kilometer posts, speedometer speeds for each 5-km speed change, and supplementary information on causes for speed changes, including stops, and elapsed time stopped. Table 1 gives the speed changes as adjusted from the observed field data for urban highways in flat terrain. In all field recordings of vehicle speeds, the test car was driven to approximate the behavior of the majority of traffic vehicles.

Speed change data indicate the total number of speed changes for increased and reduced speeds from an initial speed. For urban flat, rural flat, and rural rolling terrain, the number of speed changes was found to be similar for all vehicle types within the terrain type. For rural mountain terrain, cars and pickups have different numbers and types of speed changes from trucks and buses.

It was further found that slowdowns generally followed a pattern in the ratio of overall speed changes distributed to the 5-, 10-, 15-, and 20-km/h speed reductions, which were as follows:

Amount of Speed Reduction (km/h)	Percentage of Total Number of Speed Reductions
5	54
10	29
15	12
20	5

Distribution of Stops—The initial speeds from which stops were made are closely related to the number of speeds within a speed distribution (Table 2). For the operating speeds being analyzed, 40 percent of the lowest speeds in the distribution were considered as those from which stops were made.

Total numbers of stops were established for various existing and proposed conditions at individual speeds. The distribution of total number of stops to specific stop speeds was made as given in Table 3.

Idle Engine Time—For various terrain types and vehicle types, the average number of seconds vehicles remained stopped (idle-engine time) was established.

Speed Distributions—From tables of traffic speeds (2, 3), a series of traffic speed distributions was set up. These distributions were developed in 5-km/h intervals for existing highways, new two-lane highways, and new four-lane highways (Table 2). With these tables we could calculate vehicle running costs by speed distributions rather than by using one average speed.

The distributions were initially based on spot speeds from which an average running speed was obtained. The running speed was further analyzed to include stop time to establish an average operating speed. For each operating speed, the distribution was used to establish the theoretical distance a vehicle would cover at a set speed. This is based on the fact that, for example, if a vehicle averages 70 km/h over a length of road, it goes at various speeds over various distances. Running costs were thus obtained for level and gradient sections of road.

Vertical Grades and Horizontal Curvature—Based on field data, composite existing conditions were obtained for various terrains to reflect grades encountered, maximum speeds for two-vehicle groupings, and a length per kilometer for each grade. Similar data were also established for horizontal curvature.

Vehicle Weight Study

Roadside weighings of vehicles were used to assign existing vehicle types to the seven classes of vehicles for which running cost tables were developed and to establish

Figure 1. Proposed and existing highways.

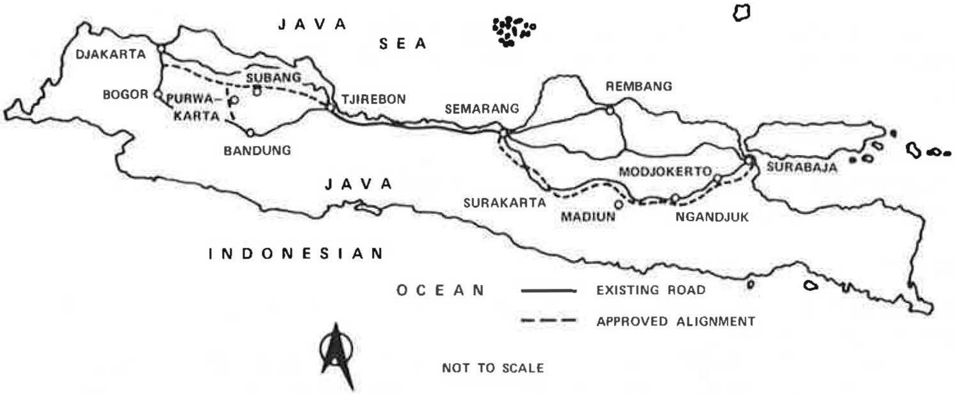

Table 1. Number of speed changes per 1,000 vehicle-kilometers on existing highway.

Initial Speed (km/h)	Speed Reduced to or Increased From Initial Speed															
	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75
0	—	95	60	35	30	15	10	4								
5	125	—	135	72	27	13										
10	105	30	—	166	90	31	14									
15	68	64	100	—	225	108	45	23								
20	38	27	110	210	—	288	130	72	22							
25	18	22	55	158	295	—	378	162	81	29						
30	10		40	80	190	360	—	450	189	90	21					
35	4		10	50	100	200	400	—	459	216	74	12				
40				30	70	95	190	385	—	432	171	54	10			
45					10	30	80	160	340	—	346	157	45	6		
50						5	20	55	130	275	—	220	90	23	5	
55								10	30	100	210	—	162	49	11	
60										13	73	148	—	76	27	5
65											6	46	76	—	36	12
70												5	15	30	—	18
75														5	15	—

Table 2. Percentage distribution of weighted average speeds on existing highway.

Frequency Group Speed (km/h)	Weighted Average Speed of the Distribution Below												
	15	20	25	30	35	40	45	50	55	60	65	70	75
0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0				
5	11.8	7.6	4.5	3.0	2.1	1.6	1.0	0.4	0.2				
10	24.1	11.9	7.1	5.3	4.2	2.4	1.5	1.0	0.3	0.0			
15	35.5	17.3	10.9	7.4	5.4	3.5	2.1	1.3	0.7	0.2			
20	18.6	24.2	15.2	10.5	7.9	5.0	3.4	2.0	1.1	0.4	0.0		
25	6.9	22.8	20.8	13.6	9.8	6.7	4.2	2.8	1.7	0.9	0.2	0.0	
30	2.5	9.8	19.0	15.8	11.8	8.9	5.5	3.3	2.0	1.5	0.7	0.1	0.0
35	0.6	4.1	13.8	16.9	13.8	11.4	8.9	5.2	3.2	2.4	1.3	0.3	0.1
40	0.0	1.8	5.8	14.0	13.7	14.0	11.8	9.1	5.6	4.4	2.3	1.0	0.2
45		0.5	2.2	7.4	12.4	14.7	14.6	13.3	10.1	6.4	4.1	2.1	0.3
50		0.0	0.7	3.9	8.9	12.6	14.8	15.9	13.6	9.3	6.7	4.0	1.3
55			0.0	1.6	5.6	9.6	13.2	15.0	15.9	12.8	9.7	6.8	3.6
60				0.6	2.8	5.8	10.1	13.2	15.1	16.4	14.2	11.0	7.4
65				0.0	1.2	2.4	5.4	9.7	14.9	16.0	17.3	15.6	13.0
70					0.4	1.0	2.1	4.9	8.8	13.8	16.5	17.8	17.3
75					0.0	0.4	1.0	1.8	4.6	8.5	12.7	15.3	17.7
80						0.0	0.4	0.9	1.7	4.7	7.6	11.8	13.4
85							0.0	0.3	0.5	1.7	4.1	7.6	10.3
90								0.0	0.0	0.4	1.6	3.3	7.8
95										0.2	0.8	1.8	2.7
100										0.0	0.2	1.0	2.0
105											0.0	0.5	1.3
110												0.0	0.9
115													0.7

Table 3. Percentage distribution of total stops (speed range increasing).

No. of Initial Speeds to Stop	To Lowest Initial Speed	Next	Next	Next	Next	Next	Next	Next
4	40	31	19	10				
5	38	29	18	10	5			
6	36	28	18	10	5	3		
7	35	28	18	9	5	3	2	
8	34	28	18	9	5	3	2	1

the adjusting factor (Table 4) to apply to the running cost tables to approximate the characteristics of local vehicles. Vehicle weights were also used in structural design of pavement.

Origin-Destination Survey

The origin-destination survey was conducted to supplement existing data. The information obtained is given in Table 5.

Volume-Capacity (v-c) Analysis

A volume-capacity analysis was prepared to evaluate the existing road's ability to carry current traffic volumes.

The most critical factor found affecting the v-c ratio was considered the usable surface width, a refinement of actual surface width. A subjective evaluation was made of the actual surface width used by fast-moving vehicles. This was done because existing roads carry motorized vehicles—trucks, buses, automobiles, motorcycles, and scooters—and nonmotorized vehicles—bicycles, betjaks, horses, horse-drawn carriages, bullock carts, and people.

TRAFFIC PROJECTIONS

Traffic volumes were projected to 1999 on a yearly basis for each segment of the proposed highway and for the existing routes with and without the new highway.

Route Segments

Fifty-three total segments on the trans-Java highway were established, and 136 total segments for existing main roads were established. Each feeder road was considered an entire segment for the before situation, whereas for the after situation they may have been fragmented, depending on the origin-destination of traffic. When existing main roads also acted as feeder roads because of interchange locations, they were analyzed as main roads.

Traffic Volumes

Basic traffic volume was that on the existing road system. The base volumes for the three road categories (trans-Java, existing main, and feeder) were set up for the year 1972.

Existing roads were analyzed for both before and after situations. The before situation is the total traffic, which also includes the 25 percent surcharge explained previously. The after traffic volumes are those that would remain on the existing road after the diverted volumes transferred to the trans-Java route.

Feeder road traffic is that on roads providing access to interchange areas. Feeder roads were analyzed similarly to main routes. However, feeder road traffic, after a new highway is opened, will show a volume increase as opposed to existing road traffic, which will show a decrease.

Projections of Traffic Volumes

Projected traffic growth rates were established by the project economists and were used to project traffic volumes to the year 1999 on a yearly basis.

Diversion Analysis

The diversion analysis established traffic volumes assigned to the trans-Java highway. The assigned diverted trips were of two sources, through trips and long-haul trips. Through trips cover the longer distances as between Djakarta and Bandung or Djakarta and Tjirebon. Long-haul trips cover intermediate distances as between segment termini. In addition there is the 25 percent surcharge, or trips not physically counted.

Through trips were all considered diverted to the proposed route. Long-haul trips were assigned to the proposed or existing routes based on results of a traffic diversion analysis. Short-haul trips were all assigned to the existing roads.

Two basic sources of data were used to establish diversion volumes:

1. Origin-destination survey, which provided through trip patterns, especially to Djakarta; and
2. Traffic diversion curve, which is based on a travel time relationship and establishes proportions of traffic attracted to a new highway from an existing road network.

MOTOR VEHICLE RUNNING COSTS

The running cost tables developed by Winfrey (3) were used as the main framework for preparing similar tables for Java. From Winfrey's original work tables, the tables were updated to 1972 Java prices and converted to the Indonesian monetary system of rupiahs, at the rate of 415 rupiahs = $1. Conversion was also made to kilometers from miles. Because of the lack of base information on the performance and running costs of vehicles in Indonesia, the Indonesian tables were used as indicated in Table 4. Three adjustments were used: (a) assignment of the Java vehicle types identified in the traffic classification counts to the vehicle types for which the running costs had been computed, (b) choice of a factor on the basis of vehicle weight and engine description to be applied to the updated and converted Winfrey tables to adjust the running costs to Java situations, and (c) development of a further factor to adjust for the roadway or pavement condition.

Winfrey (3) gives running cost tables for five classes of vehicles: 4-kip (1800-kg) passenger car, 5-kip (2260-kg) commercial delivery truck, 12-kip (5400-kg) gas-fueled single-unit truck, 40-kip (18 000-kg) gas-fueled and 50-kip (22 600-kg) diesel-fueled tractor-semitrailer. The 50-kip diesel tables were not converted to Indonesian prices. The running cost items included in the tables are fuel, engine oil, tires, vehicle maintenance and repairs, and vehicle depreciation. The unit cost per 1,000 vehicle-miles covers a range of uniform speeds suitable to each vehicle class operated on high types of pavements on a range of minus grades, plus grades, horizontal curves, and sharp 90-deg corners. In addition, running costs are established for a range of cycles of speed changes (a change from an initial speed to a lower speed and back to the initial speed). The speed changes range from a high speed suitable to each class of vehicle to a stop and return to the initial speed.

A table of idle-engine running cost is given for each of the five vehicle classes. Conversion, or adjusting factors, are given to convert running costs on high types of pavements in good condition to those on gravel and stone surfaces and for lower types of bituminous pavements.

In addition to the conversion of the four sets of tables to Java application, additional tables were developed for a 36-passenger diesel bus, a 12-kip diesel single-unit truck, and a 40-kip diesel tractor-semitrailer combination.

Excise taxes, import duties, and sales taxes were estimated on new vehicles, fuel, oil, tires, and vehicle replacement parts. Final vehicle running costs were compiled in two sets, one with taxes and one without taxes.

Intersection-Interchange Turning Movements and Delays

Vehicles using the new highway would make additional turns to get on and off at intersections and interchanges. Turns are included in the analysis as 90-deg turns.

Delays at intersections and interchanges were considered in the analysis because there would be expected conflicts between vehicles from the proposed route with vehicles on the feeder roads. All such costs are considered above and beyond other costs contained in the analysis.

Procedures for determining costs for turning movements and delays were computerized, but analysis of several interchanges disclosed that the added costs were negligible. Therefore, they were not included in total running cost calculations.

TRAFFIC ACCIDENT COSTS

Limited information was available on the rate of traffic accidents on Java highways and their costs. Therefore, total traffic accident cost data were compiled on the basis of judgment by using information from the literature and other sources, modified to Java conditions. It is noted that accident costs could also be measured in terms of insurance premiums with similar results.

VALUE OF TRAVEL TIME

Values of travel time were assigned to the different classes of vehicles on the basis of number of persons per vehicle, their probable employment, and wage rate. Commercial vehicles were assigned a travel time value on the basis of the driver and crew and their wage rates.

HIGHWAY COSTS

The highway capital and maintenance costs were estimated for each segment of the trans-Java highway. Maintenance costs were estimated for segments of existing highways.

Highway Capital Costs

Highway capital costs were obtained for the six levels of improvement from construction cost estimates. Cost estimates were prepared for 31 basic construction items that were combined into the following six investment components: right-of-way, earthwork, minor drainage structures, major bridges, pavement, and miscellaneous.

Subsequent to capital costs being grouped in six categories, the order in which the various construction costs would be analyzed was based on the five current construction types:

1. Two-lane highway, all crossings at grade,
2. Interchange only,
3. Major road and railroad crossings only,
4. Minor road and railroad crossings only, and
5. Four-lane highway, all crossings at grade.

A second-phase analysis for later construction was prepared subsequent to the review of initial results as follows:

1. Interchange only,
2. Minor road and railroad crossings only, and
3. Add two more lanes to existing two-lane highway.

Roadway Maintenance Costs

Roadway maintenance costs were established for existing roads, feeder roads, and proposed highways. Costs for proposed roads include costs for maintenance of interchanges.

For feeder roads, it was assumed that maintenance costs in 1972 for the before situation were one-half the existing road expenditure, whereas the after situation was analyzed on the basis of full existing road expenditures.

CONCEPTS AND PROCEDURES FOR THE ANALYSIS OF TRANSPORTATION ECONOMY

The economic analysis of the transportation economy of the proposed trans-Java highway compares the investment cost in the trans-Java highway to the road user costs plus highway maintenance costs without and with the new highway. A first analysis determined the degree of economic feasibility, or project evaluation of the proposed highway.

A second analysis determined the relative economy of varying designs and calendar timing of construction and may be called "project formulation."

The overall feasibility analysis was reported in the preliminary report in November 1972 and identifies the route to which the final report applies. In this final report, however, the economic feasibility of the chosen route and of its segments is redetermined. The project design formulation is directed to a comparison of the transportation economy of the six levels of design and their staging.

Highway Design Levels and Supplementary Stages

The analysis of the transportation economy of the trans-Java highway is based on six basic design levels and three supplementary stages for upgrading in design levels as follows:

1. Two lanes with at-grade highway and rail crossings,
2. Two lanes with partial access control (only major crossings and intersections are grade separated),
3. Two lanes with full access control and full grade separations,
4. Four lanes divided with at-grade highway and rail crossings,
5. Four lanes divided with partial access control (only major crossings and intersections are grade separated),
6. Four lanes divided with full access control and full grade separations,
7. Adding access control (grade separations and interchanges) in later years to alternative 1,
8. Adding access control (grade separations and interchanges) in later years to alternative 4, and
9. Adding two lanes to alternatives 1, 2, and 3 subsequent to their original construction.

The analysis of the first six alternatives was on the basis that each would be constructed initially without regard to future upgrading.

Highway Sections and Segments

Criteria used in selecting segments (one or more combined) for analysis of transportation economy were traffic volume (ADT); traffic volume exchange between routes; traffic attraction and accessibility to the trans-Java highway; topography, land use, and population distribution; continuity of design standards and adaption of traffic safety to changes in design (avoidance of frequent changes from at-grade crossings to grade separations and interchanges, and changes from two to four lanes and vice versa); and requirements for a construction contract.

COMPUTER ANALYSIS

All calculations of the transportation economy were done on an IBM 1130 computer. A combination of memory storage and direct input was used. The entire analysis procedure was designed to produce estimated yearly transportation costs for each segment of the proposed trans-Java highway and each existing route segment for the seven classes of vehicles.

Stored Data

Data stored in the computer consisted of the following items: PCU factors, volume-speed relationships showing the relationship between volumes of vehicles and theoretical speeds of various design criteria, vehicle running costs for seven vehicle classes, speed distributions, and vehicle by fuel type, which was used to convert input of six vehicle types to operating costs for seven types as follows:

Vehicle	Gasoline (percent)	Diesel (percent)
Cars	100	
Pickups	100	
Trucks, single unit	40	60
Trucks, trailer and semi-trailer		100
Buses	50	50

Direct Input

Direct input for each roadway segment consisted of initial (1971) traffic volumes by six vehicle types, length in kilometers, type of area (rural or urban), type of terrain (flat, rolling, or mountainous), design speed, operating speed (applicable to existing roads), traffic growth rates for each vehicle type, and construction and maintenance costs.

TRAFFIC PROJECTIONS AND ANALYSES

Vehicle traffic counts of six basic vehicle types were projected yearly to establish annual total PCU volumes, which were divided into peak-hour and remaining volumes. Speeds were established annually for corresponding PCUs for cars and pickups as a group and for trucks and buses as a group. Because of the capacity limitation placed on the proposed two-lane facility, speeds for reverted volumes were also noted. The six vehicle types were then converted to seven study types.

The traffic volume analysis was based on the acceptance of a designated level of congestion inasmuch as traffic volumes, both existing and projected, are quite high. The basic premise was that 4 hours of congestion was considered to be the tolerable or acceptable situation. It was further considered that 6 hours of congestion would be the maximum in the analysis.

For existing routes, the maximum acceptable congestion was 18,000 PCU per day with a minimum speed of 15 km/h with traffic volumes projected to the year 1999. The premise for projecting volumes higher than the maximum congestion level is that as traffic continues to grow road users find parallel routes to their destination, which is anticipated as normal growth and development.

The analysis of the proposed two-lane trans-Java highway was set up for combinations of volume and speed (Table 6). Traffic above 30,000 ADT was considered as reverting to the existing roads.

The criteria used in the analysis of the proposed four-lane trans-Java highway are given in Table 6.

VEHICLE OPERATING COST

Total operating costs for the proposed and existing routes were obtained by summing the following various items:

Item	Proposed Highway	Existing Roads
Running cost	x	x
Pavement factor	—	x
Load factor	x	x
Travel time	x	x
Accident costs	x	x
Investment costs	x	x
Time depreciation	x	x
Management	x	x

Pavement and load factors where applicable were applied to running costs to obtain actual running costs. The management factor applied to all vehicles except automobiles.

Running Costs

For the seven vehicle classes, running costs were established for five component items: grades (flat to ± 8 percent), horizontal curves (0 to 30 deg), speed changes, stops, and idle-engine.

Costs for these five items for each vehicle type were calculated and summed for total vehicle running costs. The costs were established for peak-hour volumes and remaining volumes.

Grades—Grades are the primary running cost item, with the remaining four items added to produce total vehicle running costs. Grades were analyzed on a speed distribution basis. Overall operating speed used was either that based on PCUs or the maximum speed at which the vehicle could traverse the grade as obtained from vehicle running cost tables. The lower of the two speeds was used in the analysis.

Composite data were prepared for the existing road system for the various areas and terrains. Data for the proposed highway were taken from the plan and profile sheets.

Horizontal Curves—Horizontal curvature was analyzed on the basis of a constant speed. This speed could be either the operating speed based on PCUs or the maximum speed at which the vehicle could traverse the curve as obtained from running cost tables. The lower of the two speeds was used in the analysis.

Composite data were prepared to reflect existing horizontal curvature conditions. Data for the proposed highway were taken from the plan and profile sheets.

Speed Changes—The excess cost of speed changes as compared to the cost at uniform speed was computed. Based on field data and judgment, total numbers of slowdowns were estimated for the six design standards and for various speeds. These total numbers of slowdowns were apportioned first by the ratio of time spent at any speed within the speed distribution and, secondly, by a set proportion to speed differentials of 5, 10, 15, and 20 km/h.

Stops and Idle Engine—Total numbers of stops were estimated for the six design standards at various operating speeds. A review of field data led to the analysis distribution of all stops. Idle-engine costs were computed in accordance with the amount of time vehicles were considered stopped.

Pavement Factor

For existing roads, because of surfaces in generally poor condition and surface types other than high type, a pavement factor correction was applied to the running cost.

Adjusting Factor Applied to Specific Vehicles

An adjusting load factor was applied to each of the vehicle types as given in Table 7. This factored cost was considered to be the total running cost of each vehicle.

CAPITAL COST

Most of the physical components of the highway have useful average service lives of 20 years or more. Therefore, the analysis provides for a terminal value credit for the years of available service remaining at the end of the year 1999. The following table shows the average service lives used. They are based on general usage (3).

Item	Average Service Life (years)
Right-of-way	100
Earthwork	75
Minor drainage structures	40
Pavement section	30
Major bridges	60
Miscellaneous	20

Terminal value is handled in the computer program as follows:

1. The investment cost of each of the six highway components is spread over its full service life by use of the capital recovery factor corresponding to the discount rate being used. This produces an equivalent uniform annual cost over the full service life.
2. At the end of the year 1999 the present worth of the remaining number of yearly equivalent uniform annual costs is calculated, which is the terminal value or value of remaining unused yearly service.

Table 4. Vehicle and passenger data.

Category of Vehicle Type Counted	Vehicle Class	Applicable Running Cost: Vehicle Class	Applicable Running Cost: Adjusting Factor
Motorcycle	Motorcycles, scooters	Excluded	
Bemo	Bemo (3 wheels)	Excluded	
Passenger car	Mobile penumpang	4-kip P. C.	0.80
	Opelet	4-kip P. C.	0.80
	Sedan	4-kip P. C.	0.80
	Suburban	4-kip P. C.	1.25
	Land Rover	4-kip P. C.	1.00
	Jeep	4-kip P. C.	1.00
	Overall weighted	4-kip P. C.	0.90
Pickup	Pickup	5-kip C. D.	1.00
Microbus	Microbus	5-kip C. D.	1.00
Delivery van	2-axle, 4-tire truck	5-kip C. D.	1.00
Bus	2-axle, 6-tire bus	36-seat bus	1.00
2-axle truck	2-axle, 6-tire truck	12-kip SUT	0.75
3-axle truck	3-axle, 10-tire truck	12-kip SUT	1.00
Trailer	Trailer	40-kip 2-S2	0.75
Semi-trailer	Semi-trailer	40-kip 2-S2	0.75

Table 5. Vehicle classification types and running cost adjusting factors.

Vehicle	Average Number of People (including driver)	Average Vehicle Age (years)
Passenger car	6.8	8.9
Van (pickup)	3.6	9.3
Truck	3.7	12.9
Bus	35.0	8.6
Trailer, full and semi	3.7	11.0

Table 6. Level of service for proposed highways.

Proposed Highway	Intersections Separated	Volume: Minimum	Volume: Maximum	Speed (km/h): Minimum[a]	Speed (km/h): Maximum: Cars and Pickups	Speed (km/h): Maximum: Trucks and Buses
Two-lane	None	25,000	30,000	30	60	60
	Only major	25,000	30,000	40	70	70
	All	25,000	30,000	50	80	70
Four-lane	None	90,000	120,000	40	70	70
	Only major	90,000	120,000	50	80	70
	All	90,000	120,000	60	90	80

[a]All vehicles.

Table 7. Incremental rates of return for trans-Java highway.

Base Alternative[a]	Design Level	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
T	U	28.0	30.7	35.8	37.4	40.9	43.0	44.1	44.8	46.7	49.7	50.9	52.6	57.6	60.0	61.7	61.0	59.3	61.5	62.8	63.4
	V	30.3	33.0	38.0	39.8	43.2	46.3	47.3	48.0	49.7	52.5	53.6	55.2	59.8	62.1	63.6	63.0	61.4	63.4	64.6	65.2
	W	30.1	32.7	37.5	39.5	43.0	46.2	47.2	47.8	49.4	52.1	53.1	54.6	59.0	61.2	62.6	62.0	60.5	62.5	63.6	64.1
	X	21.4	23.5	27.6	29.4	32.4	35.1	37.5	39.5	42.5	46.2	48.7	51.2	51.2	59.0	61.4	62.5	63.0	65.9	68.3	70.3
	Y	22.3	24.5	28.5	30.4	33.3	36.0	38.4	40.5	43.5	47.2	49.7	52.2	56.9	59.9	62.4	63.5	64.1	67.0	69.5	71.5
	Z	21.3	23.4	27.2	29.0	31.8	34.5	36.8	38.8	41.6	45.2	47.6	50.1	54.6	57.5	60.0	61.1	61.7	64.6	67.0	69.0
U	V	76.6	79.8	82.8	87.3	90.8	107.1	107.1	107.1	107.1	107.1	107.1	107.1	107.1	107.1	107.1	107.1	107.1	107.1	107.1	107.1
	W	47.3	49.6	52.1	57.0	60.6	71.5	71.5	71.5	71.5	71.5	71.5	71.5	71.5	71.5	71.5	71.5	71.5	71.5	71.5	71.5
	X	4.5	5.2	6.0	9.1	10.4	15.8	22.3	28.2	33.8	29.1	44.4	48.6	52.8	56.9	61.0	65.0	69.0	73.1	77.1	81.1
	Y	9.9	10.8	11.8	14.5	16.0	20.8	26.7	32.1	37.4	42.5	47.5	51.6	55.6	59.6	63.5	67.5	71.5	75.4	79.4	83.3
	Z	9.8	10.6	11.6	13.9	15.2	19.4	24.4	29.2	33.8	38.4	42.9	46.6	50.2	53.9	57.5	61.2	64.8	68.5	72.2	75.9
V	W	25.9	27.6	29.5	35.4	39.3	44.9	44.9	44.9	44.9	44.9	44.9	44.9	44.9	44.9	44.9	44.9	44.9	44.9	44.9	44.9
	X	—[b]	—[b]	—[b]	—[b]	—[b]	—[b]	6.7	15.9	23.7	30.7	37.3	42.4	47.3	52.1	56.8	61.4	66.0	70.4	74.9	79.2
	Y	—[b]	—[b]	—[b]	2.3	3.5	5.3	14.6	22.2	29.0	35.4	41.4	46.2	50.9	55.5	60.0	64.4	68.8	73.1	77.5	81.7
	Z	—[b]	1.5	2.3	4.9	6.0	7.4	14.5	20.8	26.6	32.1	37.4	41.7	45.9	50.1	54.1	58.2	62.2	66.2	70.2	74.1
W	X	—[b]	—[b]	—[b]	—[b]	—[b]	—[b]	—[b]	8.9	19.4	28.2	36.0	42.0	47.7	53.1	58.4	63.5	68.5	73.4	78.2	83.0
	Y	—[b]	—[b]	—[b]	—[b]	—[b]	—[b]	7.4	17.7	26.3	33.9	40.9	46.4	51.7	56.8	61.8	66.7	71.4	87.0	80.0	85.4
	Z	—[b]	—[b]	—[b]	—[b]	—[b]	—[b]	9.3	17.2	24.1	30.5	36.6	41.4	46.0	50.5	55.0	59.4	63.7	68.0	72.3	76.5
X	Y	55.6	58.3	61.1	63.9	66.8	69.8	72.9	76.1	79.4	82.8	86.2	89.1	92.1	95.2	98.3	101.4	104.7	108.0	111.3	114.6
	Z	21.0	22.4	23.8	25.3	26.9	28.6	30.3	32.1	34.0	35.9	38.0	39.7	41.5	43.4	45.4	47.4	49.5	51.6	53.8	56.1
Y	Z	9.1	9.9	10.6	11.4	12.3	13.2	14.2	15.3	16.3	17.5	18.8	19.9	21.0	22.2	23.5	25.0	26.3	27.8	29.5	31.1

[a]T = do nothing (existing highways); U = 2 lanes, no intersections separated; V = 2 lanes, only major intersections separated; W = 2 lanes, all intersections separated; X = 4 lanes, no intersections separated; Y = 4 lanes, only major intersections separated; and Z = 4 lanes, all intersections separated.

[b]Less than 1 percent.

3. The terminal value at year 1999 is the equivalent of an income to be received at the end of the year 1999. When discounted back to time zero, or 1980 (the first year of the analysis period), this reduces the effective amount of the investment cost to be charged off during the analysis period.

CALCULATION OF RATE OF RETURN

The computer was programmed to calculate both the benefit-cost ratio and the rate of return. The present worth procedure was used in which the computer solves for that discount rate that reduces the present worth of road user costs of a pair of alternatives to the present worth of the difference in the capital highway costs of the pair of alternatives. A minimum attractive rate of return of 15 percent per year is used.

For the rate of return for a single year the procedure was to calculate the equivalent uniform annual capital cost for the highway investment for 20 years. The individual-year road user cost reductions for the alternative under study (the challenger) as compared to the base alternative (the defender) were calculated for the specific-year traffic volume. The yearly rate of return is that discount rate that equates the equivalent uniform annual highway capital costs with the yearly net road user benefits.

CHARACTER OF GENERAL RESULTS

The analysis of transportation economy was designed to produce for each section (one or more segments) of the trans-Java highway the following determinations:

1. The economic feasibility of the proposed highway as compared to the existing highway without improvement,
2. The design economy of six traffic service levels,
3. Identification of the first year that each trans-Java section will produce the minimum acceptable rate of return of 15 percent, and
4. The year the design levels of less than four-lane divided with full access control could be upgraded to a higher service level with a 15 percent rate of return on the cost of upgrading.

When the six levels of design for the trans-Java highway are compared, pair by pair, the economic feasibility of the added capital investment to produce a higher level of service is determined. The year-by-year rate of return permits identification of the first year that the increase in capital investment required for the higher level of service will produce a rate of return of 15 percent or more.

Whereas an overall analysis for the 20-year period may show a rate of return in excess of the minimum attractive rate of 15 percent, the early years of the overall 20-year period may produce less than the desired 15 percent. To ensure the maximization of return on the investment requires that the analysis identify the first year the recommended design level will attain the 15 percent rate of return. In effect, then, if any section has an overall rate of return of 15 percent or greater and if the first few years have rates of return of less than 15 percent, the delay of that project until the initial year has a 15 percent or greater rate of return would ensure a greater rate of return in the following 20-year period than found in the initial overall analysis.

In selection of the design stage, all route sections were reviewed for their 20-year rate of return, and those with 15 percent or greater were considered without regard to monetary limitations. These selections were then reviewed a second time to establish the year that the minimum attractive rate of return would be greater than 15 percent.

Table 7 shows, for each year from 1980 to 1999, incremental rates of return on a trans-Java highway section by design levels compared to incrementally lower design levels. With the do-nothing (existing highways) alternative as a base of analysis, the six proposed design levels can be compared incrementally. Using the base alternative of the next higher design standard (the two-lane, no intersections separated situation), the incremental comparisons are made to the five incrementally higher design levels. This procedure is repetitive through the last analysis which consists of the base alternative of four-lane with only major intersections separated.

Figure 2. Incremental rates of return for proposed and existing highways (west Java section; do-nothing alternative as base).

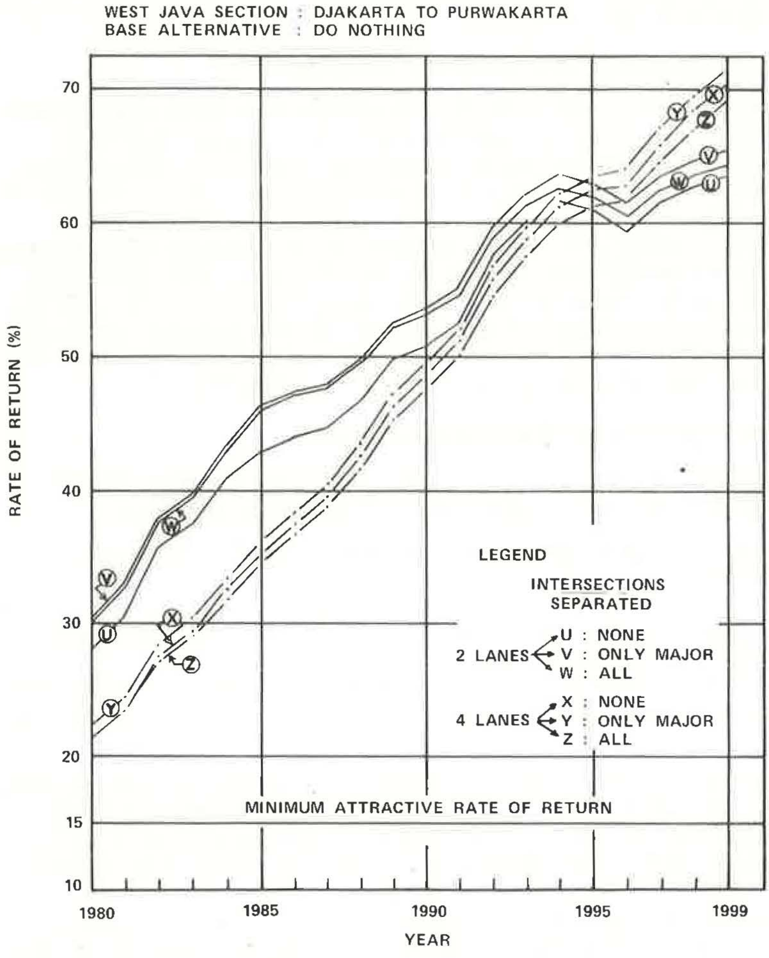

Table 8. Recommended construction for trans-Java highway sections.

	First-Phase Analysis			Second-Phase Analysis		
Termini	Design Level[a]	Year to Be Opened to Traffic	First Year Rate of Return	Design Level	Year to Be Opened to Traffic	First Year Rate of Return
Djakarta to Purwakarta	W	1980	30.09	Z	1987	16.53
Djombang to Surabaja	W	1980	18.62	Z	1993	21.01
Purwakarta to Bandung	W	1982	15.51	Z	1989	15.07
Purwakarta to Tjirebon	V	1983	15.69	W	1998	17.62
Semarang to Surakarta	V	1983	15.17	Y	1997	15.69
Madiun to Djombang	V	1985	15.79	—[b]		
Surakarta to Madiun	V	1987	15.71	—[b]		

[a] V = 2 lanes, only major intersections separated; W = 2 lanes, all intersections separated; Y = 4 lanes, only major intersections separated; and Z = 4 lanes, all intersections separated.

[b] No upgrading meets the minimum rate of return.

Figure 2 shows results of the analysis of the six design levels compared with the do-nothing situation as base. From the figure it is possible to establish the initial year in which the rate of return is 15 percent or greater. If the initial analysis shows a design level other than the proposed two-lane, no intersections separated as the best design level, subsequent analysis must be conducted for the incremental difference in costs to establish the viability of that design level at a rate of return of 15 percent.

Phased Construction Analysis

A first phase analysis was conducted to indicate initial construction. The results were such that in later years several initial recommendations could be upgraded to higher levels of design, and therefore a second phase analysis was undertaken. The only difference between the two analyses was increased construction costs used for the second phase analysis. Table 8 gives results of both first and second phase analyses.

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