EFFECTS OF VARYING POLICIES AND ASSUMPTIONS ON NATIONAL HIGHWAY REQUIREMENTS

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This paper presents the results of an analytical policy planning study in which computerized modeling techniques were developed to examine the effects of varying policies and assumptions on the national highway program. The techniques are aggregate models in that they deal with large geographic areas as the unit of analysis. They are capable of dealing with a wide variety of alternatives ranging from building no additional highways to extensively building highways. In addition, the models are capable of indicating the mix among highway facility types based on trade-offs between investments and benefits both direct and external. The paper presents the results of this study in terms of analyses of a base economic optimum and maintenance of the current level-of-service alternatives, the transportation implications of alternative national population distributions, the impact of changes in highway travel demand and modal split, the effects of varying economic assumptions on highway requirements, and the implications of increased emphasis on highway impacts.

•THE Interstate Highway System is nearing completion, and the direction and substance of a post-Interstate program must be determined. Interest is high in a wide range of questions concerning possible program structure and extent; transportation implications of national growth alternatives; intermodal trade-offs and financing; and external impacts of the highway program such as relocation, community disruption, impact on land development, housing availability, air and noise pollution, and the like. It is anticipated that the most far-reaching federal transportation legislation since the 1956 Interstate highway act will be developed within the next few years.

National decisions of this importance deserve at least as much in the way of analytical support as state or local decisions concerning a transportation system or a particular project. Yet, it has been apparent during the course of the past few years that analytical tools capable of evaluating the consequences of a range of transportation-related policies on a national scale do not exist. The Transportation Resource Allocation Study (TRANS) was initiated by the Federal Highway Administration with the objective of providing this analytical support.

The TRANS approach provides a set of analysis tools that can assess the consequences of a broad range of alternative transportation investment policies as well as provide an indication of appropriate program levels and mixes to achieve desired performance levels. Performance can be measured in terms of both user and external impacts.

THE ANALYSIS APPROACH

The TRANS analytical procedures were developed to operate at a scale suitable for policy planning at the national level and to provide an overview of the consequences of

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This paper originally contained extensive additional material that has been omitted here because of space limitations. The material is available on request to the authors at the Federal Highway Administration.

a broad range of alternatives. The models are capable of dealing rapidly with the large number of transportation-related issues that lend themselves to an analytical evaluation. They use in part a cost-benefit approach under widely varying assumptions of input parameters such as modal split, cost of constructing facilities, and relocation costs. The utility of the approach lies not so much in its ability to derive "optimum" investment strategies as in its ability to indicate the effects of alternative policy assumptions on highway requirements.

The models are of an aggregate nature in that they deal with large geographic areas as units of analysis. Urbanized areas are treated as individual units; the central city and suburban portions of large cities are analyzed individually. Small urban areas are treated in groups by state. The rural models deal with whole states or large portions of states. Figure 1 shows a generalized diagram of the models. The urban models are described in greater detail in another paper (1).

The process begins with a postulation of a transportation supply alternative for each area included in the analysis. The supply alternative is described in terms of a possible future extent of freeway and surface arterial system mileage and of a level of usage of other transportation modes. A travel demand forecasting function is then used to project future travel based on the transportation system and socioeconomic factors. The forecast travel for the area is then distributed by time, direction, and facility type.

The interaction of travel demand and system supply leads to the system performance submodels, which yield estimates of system congestion, speed, vehicle operating costs, accident costs, travel time costs, fatalities, and air pollution.

The direct costs of providing the capacity specified in the supply alternative include the costs of right-of-way, new construction, and reconstruction. Indirect costs include, for example, costs of relocations beyond those required for the purchase of property. All cost items are incorporated in an investment-return analysis that treats dollar benefits and dollar costs. The results of this analysis are fed into an evaluation process that explicitly considers such external effects of transportation improvements as number and type of relocations, air pollution, fatalities, and land consumption. Unless the alternative meets predetermined constraints regarding these critical factors, it can be rejected regardless of the results of the economic analysis.

The system of models has been programed in FORTRAN IV for operation on the IBM 360. It is designed for flexibility, quick turnaround, and inexpensive operation.

The strengths of these models are their ability to compute quickly arterial highway requirements for large geographic regions and their ability to repeat those calculations rapidly and use different values for any of the variables contained in the models.

BASE AND MAINTENANCE OF LEVEL-OF-SERVICE ALTERNATIVES

Although the major strength of the TRANS approach lies in its ability to study the effects of changed conditions on investment, the models are also capable of producing an "optimum" level of investment under a given set of assumptions. The following results, which give arterial investment in billions of dollars from 1970 to 1990, represent an economic optimum without the use of constraints.

Area	Investment	
	Amount	Percent
Urbanized	142	66
Small urban	24	11
Rural	49	23
Total	215	100

The 1970-to-1990 national investment of $215 billion is for the arterial highway system only and includes new freeway and surface arterial capacity and reconstruction. Maintenance costs have been excluded as have all costs on collector and local streets.

Additional alternatives were analyzed including one that was designed to maintain today's level of service defined in terms of system speed. That alternative was found to require about 82 percent of the investment indicated for the base economic optimum.

IMPLICATION OF CHANGES IN OTHER AREAS ON HIGHWAY REQUIREMENTS

The determination of an appropriate level of investment to meet future highway needs depends in large measure on a number of key assumptions regarding the magnitude of travel demand, the costs of providing highway improvements, and the benefits and external impacts expected to result from highway investment. For example, if the distribution of population among areas in the United States were to change substantially from the current projections, the result would be a shift in the expected levels of travel demand and highway requirements. Similarly, if the costs of providing increased highway capacity were to change from the anticipated costs, the appropriate level of highway requirements would also change. To measure the effects of such changes, a series of "sensitivity" tests was conducted.

Performing sensitivity tests identifies those variables that significantly affect highway requirements and hence indicate where emphasis should be placed in forecasting. In addition, and perhaps more important, they provide insight into the potential effects of various policy changes. By comparing the effects of policy changes in several areas, the decision-maker can select a course of action that may be most effective in terms of achieving desired results. Several sensitivity tests have been selected for discussion. These tests are described in greater detail in another report (2), which also presents the results of a number of additional tests. The tests involve national growth alternatives, changes in highway travel, varying economic assumptions, and increased emphasis on highway impacts. Within each of these general areas, several tests were made.

NATIONAL GROWTH ALTERNATIVES

The first test involves national growth alternatives. In the United States today, there is an increasing concern about the manner in which the nation is growing and the lifestyles that we are molding for ourselves and for future generations. Although we recognized that national growth policy formulation must consider economic, social, and political implications, we focused on the highway investment implications that would likely result from the implementation of national growth alternatives.

Two basic sets of alternatives were examined. The first involved the relative share of the total national growth occurring in communities of various sizes and in rural areas; the second involved the distribution of growth between the central city and suburbs of large urbanized regions. The alternative selected for presentation assumes that, by 1990, 10 million persons previously forecast to live in cities having more than 1.25 million population will live instead in smaller urbanized areas. This amounts to a redistribution of about one-third of the growth expected in the large areas. The results of this analysis are shown in Figure 2.

New freeway mileage justified in the economic analysis is about 3 percent greater than that developed under the base projections. In other words, the increase in mileage in smaller urbanized areas that will receive the additional growth exceeds the decrease in miles in the large areas that will lose population. However, the lower cost of providing freeway capacity in smaller areas results in almost a 5 percent reduction in urban arterial investment.

The general conclusion that can be drawn from this analysis is that there would be a limited highway investment savings associated with shifting the population growth from large urbanized areas to smaller communities. There would, of course, be a change in the distribution of highway investment among areas of different size.

CHANGES IN HIGHWAY TRAVEL

The next analyses concerned changes in highway travel. Highway requirements are, of course, directly related to the amount of travel that takes place. If the amount of travel expected in the future were to change for some reason, highway needs would also change.

Questions concerning the relative roles of public transportation and private vehicles in serving personal transportation needs and the roles of highway transportation and other modes in moving goods must be carefully considered in attempts to arrive at an equitable allocation of transportation resources. The difficulties that normally arise in attempting to reach such optimal investment decisions seem to revolve about the concept of equity. Those issues obviously cannot be decided on the basis of an analytical model alone. Rather, they must be resolved on the basis of a more subjective give-and-take process where hard measures such as costs, revenues, speeds, and capacity are carefully weighed against less quantifiable, but perhaps more important measures, such as patterns of growth and service to the transportation disadvantaged.

Based on a full recognition of the limitations that characterize purely analytical approaches, the TRANS models were directed toward providing insights into the qualitative effects of alternative assumptions concerning the use of urban and intercity public transportation.

The postwar decline in transit ridership in the United States has brought absolute patronage down to the lowest level in more than 60 years (Fig. 3). Rising income and automobile ownership, availability of highway facilities, predominance of growth in low-density suburban areas, and increasing costs and declining service of transit systems have contributed significantly to the decline in patronage. In a growing number of urban areas, however, we have reached the point where the social costs of a further drop in transit service have been judged unacceptable by the community. Based on a recognition of this renewed interest in transit at both local and federal levels, a "base" transit projection was developed under the assumption that the annual number of trips in urbanized areas will increase from roughly 8 billion in 1968 to 10.1 billion by 1990.

An "upper" transit travel projection was also made and was based on the assumption that transit will serve the same percentage of trips in 1990 as it did in 1968. This would amount to a 50 percent increase in 1968 patronage levels, resulting in about 12 billion annual passengers in 1990. 1990 transit patronage is about 18 percent greater for the upper assumption than for the base assumption. In shifting travel, we recognized that the increased transit usage would occur primarily during peak periods when highway congestion is most severe.

The TRANS models used the base and upper transit use assumptions for all urbanized areas. Some of the results are shown in Figure 4. The analysis indicates that arterial travel and requirements are not affected to an appreciable extent by changes in transit patronage. The 18 percent increase in transit trips resulted in only a 1 percent reduction in travel. New freeway miles was reduced by 7 percent and total arterial investment by 4 percent. These data are for all urbanized areas. There were greater reductions in the larger cities. However, increasing transit patronage does not appear to significantly alleviate the need for highway improvements.

The modal analyses in rural areas included tests involving passenger travel and goods movement. The results of those tests are shown in Figure 5. Data from the 1969 Census of Transportation indicated that the automobile mode represents about 77 percent of passenger travel for trips of 100 miles in length or for overnight. Thus, use of nonautomobile modes for longer rural trips is significant, and the effects on highway travel of possible change in their use merits investigation. The analysis took the form of increasing the use on nonautomobile modes for intercity person trips by 50 percent in the base forecast level. As shown, this had the effect of reducing rural arterial investment by 7 percent.

The impacts of the rural goods movement analysis were more significant. It has been stated that, for hauls of more than 200 miles in length, shipping goods by rail is normally cheaper than shipping by truck. Without arguing the merits of this statement, we analyzed the impact of removing truck travel representing goods movements of more than 200 miles on economically determined rural highway requirements. That resulted in about a 50 percent reduction in rural truck vehicle-miles, mostly from the reduction of combination trucking to a minimal level.

Figure 1. TRANS model system.

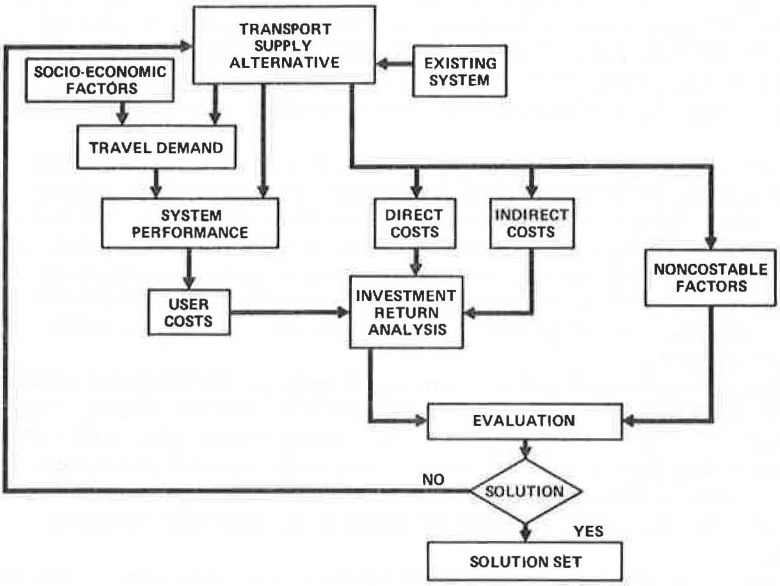


Figure 2. Effects of alternative population distribution on new freeway miles and arterial investment levels.

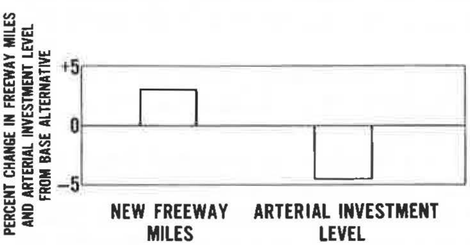
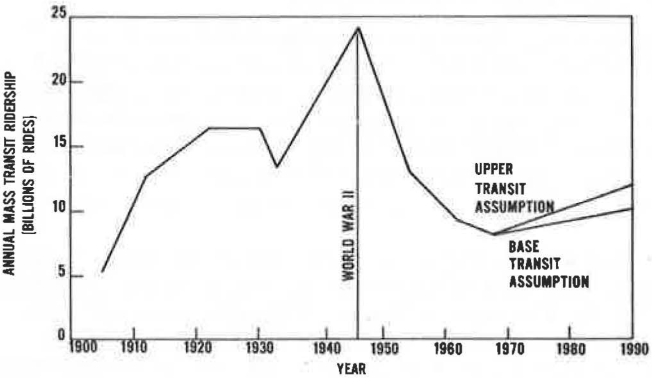


Figure 3. Urban transit patronage.



Because truck operating costs are substantially greater than automobile operating costs and because the value of travel time used in this analysis is $6 per commercial vehicle-hour compared to $3 per private vehicle-hour, it was anticipated that rural benefits would be reduced substantially. That would be offset to some extent by savings in construction costs that would be realized because of the lighter loads carried by the highways. However, the reduced travel itself would have the effect of reducing highway needs.

The above factors were considered in the application of the TRANS model. It was estimated that the economically justified arterial investment in rural areas would be reduced by 35 percent if all rural goods movements of more than 200 miles were not on the highways. It should be recognized, however, that the implementation of such a program would be extremely difficult because of the necessity to move the goods between the ultimate origin or destination and rail terminals in areas where no direct rail service exists. Nonetheless, the importance of truck travel in justifying rural highway improvements is apparent.

The highway requirements described in this paper are based on 1990 travel forecasts developed by the Federal Highway Administration in cooperation with the states. The forecast is shown in Figure 6 as the base forecast. Also shown is the historical growth in travel since 1920; travel doubles in about 16 years. The high forecast shown assumes the continuation of this experience. Travel in 1990 under the high forecast is about 2.5 trillion vehicle-miles annually, which is 37 percent greater than the base forecast of 1.86 trillion.

Although the base forecast is generally believed to be the more reasonable forecast, understanding the implications of the high forecast in terms of highway requirements is important should anything approaching that forecast actually come about. An analysis was performed by increasing the 1990 travel to the high forecast level and estimating highway requirements. This resulted in a 52 percent increase in the economically justified national arterial investment. The importance of closely monitoring travel growth is thus apparent. Should the historical growth in travel actually continue, the level of funding for highway construction would have to be increased substantially to avoid a severe drop in service to highway users.

In an effort to examine potential investment savings that would result from reducing the peaking phenomenon, the TRANS model was applied to those urbanized areas whose 1990 population is expected to exceed 1 million persons.

This analysis of the staggering of work travel took the form of accumulating all work travel in the 3 morning and the 3 evening peak hours and redistributing it uniformly within the 3-hour periods. That resulted in an 11 percent reduction in the economically justified new freeway mileage and a 3 percent reduction in total arterial investment needed (Fig. 7). These reductions are based on economic criteria and are, therefore, different from the reduction in travel peaking itself.

VARYING ECONOMIC ASSUMPTIONS

The next tests involved varying economic assumptions and included analyses of the effects of varying the value of travel time, the cost of construction, and the interest rates from the base values used. Construction costs might vary because of differential inflation in such costs versus user benefits due, for example, to increases necessitated by higher design standards. The value of travel time and the interest rate used in discounting are policy assumptions. Thus, the effects reported here are intended to reflect the selection of different policies. The results of these analyses are shown in Figure 8.

The value of travel time is one of the most important variables in determining economically derived highway requirements. In urbanized areas, time benefits constituted about 75 percent of the total benefits for the base analysis. Although somewhat less significant in rural areas, where congestion effects are less prevalent, travel-time benefits remain important. Base values for travel time of $3 per private vehicle-hour and $6 per commercial vehicle-hour have been established for use in this paper.

The level of investment associated with a 50 percent increase from the base value to $4.50 per private vehicle-hour and $9 per commercial vehicle-hour is shown by

Figure 4. Difference between base and upper transit use assumptions in travel and requirements.

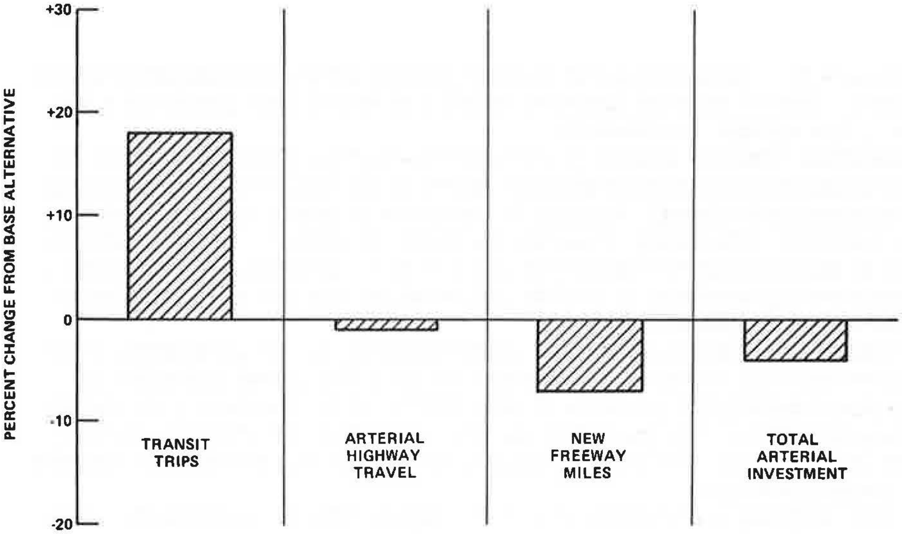


Figure 5. Passenger travel and goods movement in rural areas.

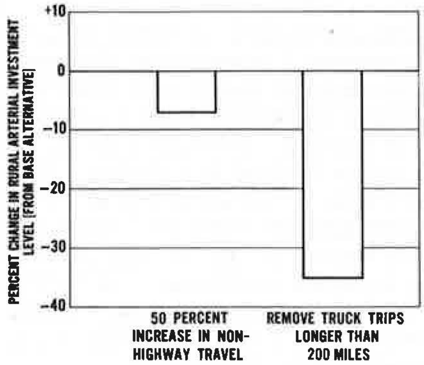
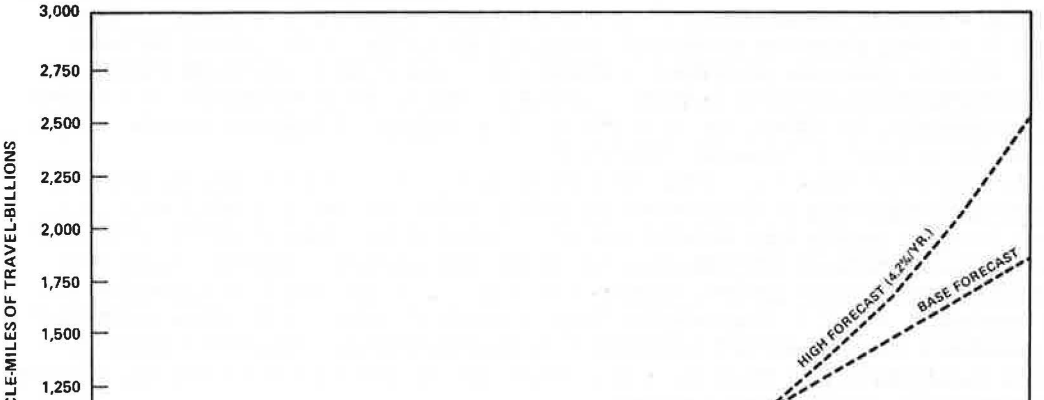


Figure 6. Trend and forecast of national travel.



the first bar in Figure 8. As expected, the level of investment is very sensitive to the value of travel time. The 50 percent increase in value of travel time produced a 33 percent increase in the arterial investment.

The second bar illustrates the effects of varying construction costs on highway requirements. The process of estimating highway needs on the basis of an economic approach involves evaluating trade-offs between investments in system improvements and the resulting benefits. Obviously, then, the so-called economic optimum solution is quite sensitive to the costs of providing highway service. This analysis shows that the 50 percent increase in construction cost would result in a 20 percent reduction in the total arterial investment level.

The effect of reducing the investment when construction costs are increased, combined with the increased costs themselves, leads to about a 50 percent reduction in justified mileage and a significant increase in user costs. It is, therefore, clear that, unless major changes in the cost of providing highway facilities are offset by corresponding changes in user costs, the level of investment and, hence, the level of service provided can be radically altered.

The last test in this group involves the effect of interest rate on investment. The most appropriate investment level from an economic viewpoint depends in large part on the time value of money or interest rate. A base interest rate of 10 percent has been used elsewhere in this paper as required by the Office of Management and Budget for conducting federal economic analyses in the United States. Sensitivities were tested by using interest rates of 5 percent and 15 percent. Increasing the interest rate from 10 percent to 15 percent, as shown in the last bar of Figure 8, reduces the justified arterial investment by 25 percent from the base level.

The analyses shown in Figure 8 have demonstrated the effects of certain key economic measures on the level of investment. Two of the 3 measures, value of travel time and interest rates, represent key policy variables that significantly affect the level of investment in new arterial capacity. Although the interest rate adopted for the base analysis reflects a federal policy decision, a single value of travel time has not been adopted by public agencies concerned with transportation investment. If there is to be some degree of consistency among public agencies in allocating resources for transportation, it appears that the question of the value of travel-time savings should be addressed as a major policy issue.

INCREASED EMPHASIS ON HIGHWAY IMPACTS

Today, the goals and priorities of the nation are being critically examined. More emphasis is being placed on social well-being and the quality of the natural environment. Because goals and priorities do change, it is important to try to estimate the effects of possible changes on highway programs. The analysis included land consumption, air pollution, fatalities, and relocations. The analysis of highway-related relocations has been chosen to illustrate this work.

One of the chief criticisms of the highway program has been the displacement of families and businesses by freeway construction. Although a large part of American society is highly mobile with respect to their residential locations, there are many who do not desire to move or who cannot move except under severe hardship. When displaced by a public works project, these people may not be completely compensated for their hardship. The U.S. Congress has been increasingly sensitive to these issues and has provided a range of initiatives in this area in recent years. The trend seems to indicate a commitment to the concept that people should be compensated for any adverse effects caused by public works programs.

An analysis was made of the effects of this equity approach to relocations. The approach taken was to vary the costs associated with relocating families and businesses and to note the impact on economically derived highway requirements. Various levels of relocation payments were added to the fair market value of acquiring homes and businesses. The results of the urbanized area analysis are shown in Figure 9.

The program investment level is relatively insensitive to relocation payments. At the maximum provided by the Federal-Aid Highway Act of 1968 of $5,000 per relocation,

Figure 7. Effect of staggered work hours on new highway requirements in urbanized areas having 1990 population of more than 1 million.

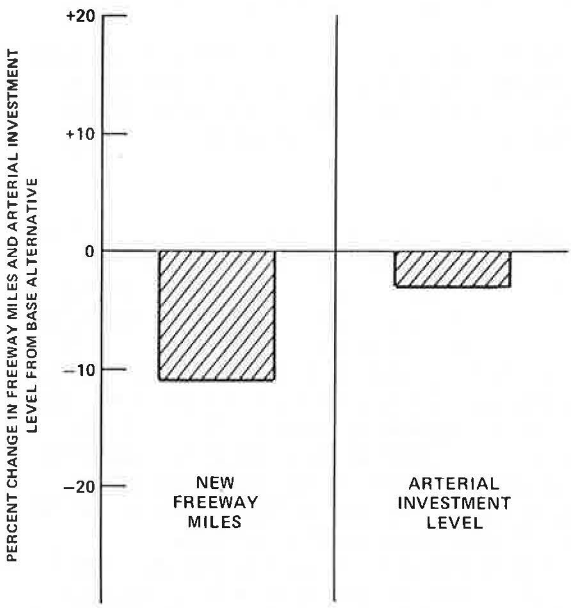


Figure 8. Sensitivity to value of travel time, construction cost, and interest rate.

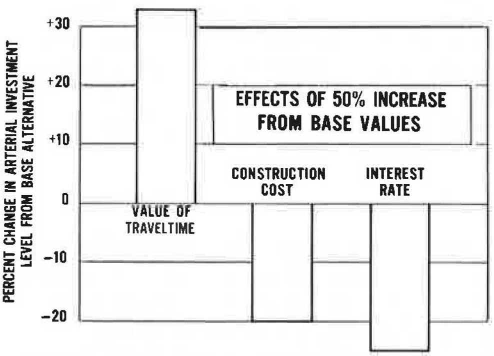
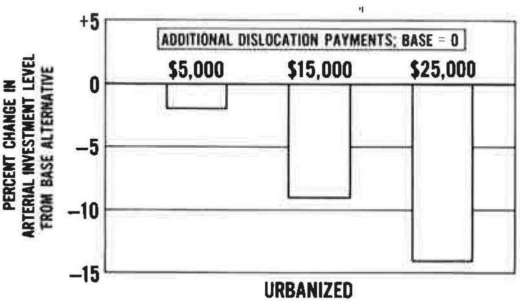


Figure 9. Effect of additional relocation payments on level of arterial investment in urbanized areas.



the arterial highway investment is only reduced by 2 percent from the economic optimum indicated without dislocation payments. At the high value of $25,000 over the fair market value for every relocated family or business, the investment is reduced by less than 15 percent.

This analysis illustrates how consideration of transportation-related impacts, which are generally difficult to define in terms of dollar values, can be incorporated within a benefit-cost framework. Sensitivity analysis permits an indication of their relative importance to be obtained without the necessity of defining specific costs.

CONCLUSION

This paper has presented the results of using an analytical policy planning model to examine the consequences of alternative assumptions regarding national population distributions, travel demand, economic factors, and highway impacts. The variation in so-called optimum investment levels under varying input assumptions was identified.

It would be presumptuous, however, to assume that government programs and policies should be based solely on the results of an analytical modeling technique. Those who have worked with analytical procedures oriented toward a social and economic phenomenon such as transportation understand the limitations of these analyses. Thus, the TRANS effort should not be interpreted as being aimed at prescriptive solutions to the problems of transportation resource allocation. What has been achieved is the development and application of a systematic approach that probes the interaction of the various parameters underlying an objective determination of highway needs.

Although the analyst should not conclude that he has derived an absolute optimum in resource allocation given the uncertainties and subjective judgments that characterize his inputs, he may fairly conclude that the TRANS models have provided some analytic insight into which parameters are important and what their relative effects on highway needs are. Although none of the analyses leads a decision-maker directly to a decision, they do offer assistance by adding relevant information that, when integrated with other knowledge, can be useful in reaching sound decisions.

The development of the TRANS procedures is an ongoing effort. The models have been extended to deal directly with multimodal alternatives. In addition, they are continually being refined to increase their capabilities to analyze emerging issues such as the conservation of energy resources. Finally, the urban procedures are being modified so as to be appropriate for application by an urban transportation planning study as a policy planning tool.

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