HIGHWAY RESEARCH RECORD

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Subject Areas

11 Transportation Administration
15 Transportation Economics
84 Urban Transportation Systems

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CONTENTS

FOREWORD

This RECORD contains 5 papers on transportation planning improvement priorities. Melinyshyn, Crowther, and O'Doherty discuss the use of a cost-effectiveness technique with stated assumptions and objectives to select and time transportation investments. The technique, now being used by the Ontario Ministry of Transportation and Communications, selects transportation improvements that optimize overall public benefits and at the same time achieves horizon-year plans.

Harris, Hille, Olson, and Stein also look at long-range transportation investment planning. They offer a forecasting model that shows the impact changes in transportation costs due to improved highways on the regional location of population and industry and on income and employment in the region.

Weiner, Kassoff, and Gendell present a model for multimodal national urban transportation policy. They describe the multimodal urban model developed in the Transportation Resource Allocation Study and its application to the 1972 National Transportation Study. The model employs aggregate modeling techniques that consider each urban area as a single analysis unit. With a given level of investment, the model evaluates the alternative mixes of freeways, arterials, conventional bus transit, and rapid transit. The model includes consideration of travel projections, socioeconomic variables, modal split, interactions of demand and supply for travel based on performance measures, travel times and costs, land consumed, air pollution effects, and fatalities.

Gendell, Hillegass, and Kassoff use the model described above and vary the priority emphasis to show the effects on the national highway program. Their analyses included base economic optimum and maintenance of current level-of-service alternatives, transportation implications of alternative national population distributions, import of changes in highway travel demand and modal split, effects on highway requirements of long-term economic changes, and consequences of increased emphasis on highway impacts.

Campbell and Humphrey describe the revitalized transportation planning process in Massachusetts and the procedures that were used to develop the unified transportation work programs. Unified work programs have been developed for each of the state's 12 regions. The work programs describe the comprehensive transportation planning work for the next 5-year period. The programs will be under the direction of regional policy groups composed of representatives from state, regional, and local agencies and from citizen groups and the general public. The objective is to develop projects that are mutually aggreeable to all groups in the region. The paper also describes the way in which the planning work, defined in the work programs, is being implemented.

TRANSPORTATION PLANNING IMPROVEMENT PRIORITIES: DEVELOPMENT OF A METHODOLOGY

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The selection and timing of large-scale transportation investments should be undertaken by using a cost-effective technique within a framework of clearly stated objectives and assumptions. Such a technique bridges current long-range planning and project implementation and ensures that implementation of transportation improvements optimizes overall benefits to the public and simultaneously achieves horizon-year plans. The priority planning methodology discussed in this paper identifies and assesses transportation improvement impacts on both transportation users and the community at large. Impacts, beneficial or disbeneficial, are evaluated and used to develop time streams of present worth of benefits as functions of the year of implementation. The functional benefit and cost time streams are combined with future budget estimates and subjected to linear programming analysis. The linear program selects and stages a mix of transportation improvements that maximizes the total present worth of benefits capable of being realized, given the assumed budgets. The methodology has important potential uses as both a management decision-making tool and a readily accessible transportation planning data source.

•IN APRIL 1972, the Ontario Ministry of Transportation and Communications, in collaboration with the consulting firm of Read, Voorhees and Associates, undertook the first phase in the development of a methodology for planning transportation improvement priorities. During the first phase, the ministry's existing decision-making practices and priority planning methods were studied. The culmination of this phase was a working paper in which 3 alternative methodologies were selected for further testing. The second phase began in June 1972 and involved the selection of a test area, the collection of data, and the testing of the 3 methodologies. Phase 2 also resulted in a working paper in which the results of the 3 tests were evaluated and a recommendation of one of the methodologies was made to the ministry. This paper contains a general description of the first 2 phases in the development of a planning priority methodology and the assumptions and conclusions that were drawn from the study.

DEFINITION OF THE PROBLEM

When the Ontario Ministry of Transportation and Communications was recently formed and its functions were expanded to encompass all modes of transportation and communications, the number, magnitude, and complexity of its programs greatly increased. More recently, social, economic, and environmental issues relating to transportation improvements have emerged and had significant impact. In addition, a scarcity of financial resources has necessitated that improvements be considered as investments competing for those resources and that the ministry's expenditures achieve maximum effectiveness.

The problem is further complicated by an apparent change in public attitude toward acceptance of only those transportation improvements that can be shown to be desirable for the general good of the public. This issue is particularly troublesome in that the traditional methods for setting improvement priorities do not appear to adequately reflect the desires and needs of the public as a whole. Undoubtedly, much public dissatisfaction stems from the fact that priorities are often based on highway user demands and not on economic, social, and environmental impacts caused by the improvement.

Any organization that makes substantial public investments during a protracted time period should therefore have a rational method for establishing the magnitudes and order of the investments. The necessity for having and employing an efficient priority-setting technique is dictated by the fact that the costs and benefits associated with particular investments may be heavily dependent on their timing. When the aggregate sum of all investments involves very large capital outlays, the effects of timing are greatly magnified.

PRESENT PROCEDURES

In its present form, the ministry's annual allocation of funds is the culmination of a selection and decision-making process of candidate improvements identified through a comprehensive long-range planning process. The decision-making procedure is continual, but fund allocation occurs on an annual basis. Those areas of the ministry's budget that lend themselves to priority analysis are maintenance, construction, and public operations. In fiscal year 1971-1972, those areas accounted for almost 94 percent ($558,300,000) of the ministry's total budget of $596,100,000. Within each area, the various programs involved the King's Highway System, subsidies for municipal street systems, development roads, and public transit systems.

At present, 2 major levels of decision-making exist. The first, involving allocation of the ministry's total budget, is a political decision made at the government level. The second, which is also political in nature, concerns the relative allocation of funds among competing programs. At this level, fund allocation is considerably influenced by historical trends because considerable momentum or inertia exists in most of the programs.

For the highway construction program, performance standards are set for various service levels and problem areas are then identified. In conjunction with the long-range system planning programs, a list of desirable and justifiable improvements is compiled and reviewed continually. Relative improvement priorities are derived by considering traffic volumes and types, physical conditions, costs and system values, public attitudes, and political commitments.

While this type of priority analysis is performed, attention is focused on needs for the first 5 years. An effort is made to match the anticipated improvement costs with projected budgets; but, in the short run (1 year), a large portion of the budget is already committed to continuing projects, leaving little room for discretionary changes.

Consideration of social, economic, and environmental factors and public participation is being introduced at the system planning level. However, no systematic procedures exist for incorporating this information into the setting of priorities. In addition, cost-benefit and rate-of-return analyses are used only to a limited extent in priority determination and program selection.

The present priority planning methods (1, 2) could be improved by the following actions:

1. Account for social, economic, and environmental impacts; and
2. Identify benefits and costs of improvements and consider their effects over time.

OBJECTIVES OF PRIORITY PLANNING METHODOLOGY

An operable methodology has been developed for the systematic assessment of transportation improvement priorities. Specifically, this methodology bridges the gap between current long-range planning efforts (i.e., area studies, needs studies) and project implementation in that improvements will be staged or implemented in such a way that overall benefits to the general public are optimized and horizon-year plans are simultaneously achieved.

In the development of the methodology, both short- and long-range objectives were set. The principal short-range objectives were that the methodology be immediately applicable for testing; identify and order improvement priorities; be applicable, if not now, at least in the future to multimodal and multijurisdictional improvements; reflect economic benefits and disbenefits; identify and quantify as many of the social and environmental factors as possible; consider spot upgrading and minor and major improvements; be sensitive to policy, budgetary constraints, and regional development objectives; be sensitive to commuter, recreational, and commercial transportation needs; and be consistent with long-range objectives.

The long-range objectives were that the methodology quantify as many factors as possible for inclusion in the priority planning technique at some later date, present nonquantifiable factors in relative numerical form, totally assess environmental and social impacts, and be applicable to multimodal and multijurisdictional improvements.

IMPROVEMENTS, VARIABLES, AND FACTORS

The Ontario Ministry of Transportation and Communications is concerned with all forms of transportation and wished to pursue initially the development of a methodology to derive priorities for highway and transit improvements. These improvements involve considerable capital expenditure and include construction of new highways, improvements to highway rights-of-way (realignments), upgrading highways (additional lanes), major reconstruction of highways, resurfacing highways, installation of major traffic control systems, replacement of structures, addition or replacement of transit equipment, and construction of new transit fixed facilities.

The first step in developing the methodology was to create an economic definition of an improvement. The variables (3) were divided into the following 5 categories: regional development, user, social, environmental, and right-of-way (early acquisition).

Within each category, items of benefit or disbenefit were grouped into "hard" and "soft" factors. Hard factors are those items that can be quantified with relative simplicity (often in monetary terms). Soft factors are those that are more difficult to quantify directly in monetary terms and include items in the social, environmental, and regional development categories.

IDENTIFICATION OF BENEFITS

The variables were further divided according to benefits.

Regional development benefits due to the improvement include

1. Net change in wages,
2. Net change in corporate profits,
3. Net change in housing costs to metropolitan area residents, and
4. Change in probability of achievement of other regional and provincial goals and objectives.

User benefits due to the improvement include

1. Change in user's travel time,
2. Change in user's vehicle operating costs,
3. Change in accident cost,
4. Change in automobile and truck vehicle maintenance costs,
5. Change in user comfort,
6. Change in user comfort cost,
7. Change in out-of-pocket cost of transit user other than vehicle operating cost,
8. Change in car ownership cost,
9. Change in transit comfort and convenience,
10. Change in road or transit maintenance costs, and
11. Change in transit operating costs.

Social benefits due to the improvement include

1. Net change in community cohesion,

2. Change in sufficiency of shopping, cultural, and other community services,
3. Change in employment stability,
4. Change in community growth rate,
5. Social cost of relocation caused by acquisition of right-of-way,
6. Social cost of loss of special landmarks,
7. Social cost of changes to the individuals unemployed,
8. Social cost of public reaction to the announcement of improvement, and
9. Change in mobility for captive transit riders.

Environmental benefits due to the improvement include

1. Net change in number of people affected by noise,
2. Net change in number of people affected by air pollution,
3. Net change in water pollution,
4. Loss of natural land area,
5. Change in vibration, and
6. Net change in view.

Right-of-way benefits include change in costs due to timing of right-of-way acquisition.

VARIABLE QUANTIFICATION TECHNIQUE

Initially, social and environmental factors were to be identified and quantified on a replacement cost basis. Considering the improvements proposed for the Kitchener-Waterloo test area clearly indicated individual estimates of social and environmental costs were not appropriate for scheduling priorities of a large number of projects where only preliminary information was available. At the same time, a common framework for dealing with all the social and environmental benefits was desirable.

The basic framework used to measure each impact was adapted from a study sponsored by the U.S. Department of Transportation (4) in which it was suggested that the measurement of impact should be based on the amount of impact, the effect of the impact, and the value of the impact. For use in this study, the above nomenclature was changed in order to be compatible with the nature of the improvements and impacts under discussion. (The valuable assistance of Professor J. H. Shortreed, University of Waterloo, and Professor L. Topperman, University of Toronto, is gratefully acknowledged.) Each social and environmental impact was, therefore, considered within the following framework.

$$\text{Benefit or disbenefit (value equivalent)} = \text{quantity} \times \text{sensitivity} \times \text{cost}$$

where quantity is a measure of the amount of change that takes place because of the introduction of an improvement (e.g., 25 acres of recreational land taken, 2,000 people in a community relocated, unemployment rate reduced by 1.5 percent); sensitivity indicates the relative sensitivity of the community to the quantity of improvement impact, is designed to take on values ranging from 0 to 1, and can be direct input from public participation programs; and cost is taken as the cost of preventing the impact, the replacement cost, or a value judgment that would be subject to sensitivity analysis and revision by decision-makers.

The following example involving community disruption shows how the value equivalent is computed.

1. Determine the expected number of households in the improvement corridor or neighborhood separated from their community by a barrier effect of an improvement (i.e., limited-access facility). In this example, $Q = 200$ households.
2. From census data, use a statistical analysis to estimate the cohesion or sensitivity to disruption based on income, length of residence, age, and family dependency ratio. With a public participation program, direct sensitivity may be obtained from the people affected. In this example, $S = 0.7$.

3. Establish the cost of providing the necessary vehicular and pedestrian grade separations to reconnect the community or, alternatively, the net cost of relocating the households. In this example, C = $3,000 per household.

Therefore,

$$\text{Value equivalent} = 200 \times 0.7 \times \$3{,}000 = \$420{,}000$$

This value equivalent is recognized as a negative benefit (disbenefit) and applied to the improvement.

TIME VALUE OF CAPITAL

Implicit in the consideration of investment timing is the concept of a time value of capital. A dollar invested now at an interest rate of 5 percent would be worth $1.05 a year hence. Conversely, a sum of money to be spent or received in the future may be "discounted" to be the equivalent of a smaller sum at the present time. This smaller sum is called the present value. Both the present and future values are linked by time and rate of interest such that

$$F = P\,(1 + r)^n$$

where

F = future sum,
P = present sum,
r = rate of interest per time period, and
n = number of time periods.

A common base for the comparison of time streams of costs and benefits (expressed in monetary terms) can be obtained by expressing future sums (costs and benefits) in terms of present values. A measure known as present worth of benefits (PWB) can thereby be obtained.

TIME HORIZON

The benefits to be gained from large-scale public investments are strongly influenced by the timing of those investments, i.e., when implementation of transportation improvements should be undertaken. The problem is to adopt a system of timing for which the maximum return is gained from the total investment. That is especially important because the magnitude of public investments, such as highway expenditures, is very large and design lead times may run to several years. Thus, a rational method of measuring costs and benefits and their relation to time is needed as the basis of an economically efficient timing program for improvement implementation.

Because improvement benefits accrue over many time periods, the sum of the benefit streams will be influenced by the choice of a time horizon. How far forward in time are the effects of the improvement to be considered? Several factors influenced the decision to adopt a 20-year horizon. First, the present value of a future sum of money, discounted, for example, at a 7 percent rate of interest, decreases by 75 percent during a 20-year period. Second, the effects beyond 20 years into the future (or even less than 20 years under some circumstances) are speculative and uncertain.

CONSTRAINTS AND LIMITATIONS

One set of uncertainties that must be considered concerns future rates of interest. Because interest rates are affected by economic fluctuations, an assumption of an average or long-run interest rate (based on historical experience) is required.

The second set of uncertainties concerns the future annual capital budgets. The present worth of benefits of an improvement depends on the timing of its implementation. If implementation is immediate, early capital costs and benefits are incurred. The deferment of an improvement will postpone both the capital expenditure and the start of benefits. Generally, for a single improvement, it is possible to use a comparison of the present worth of benefits with year-by-year costs to determine an optimum time period of implementation (7). The procedure yields a solution to the time-staging problem but ignores the budget constraints. An economically efficient procedure that solves the time-staging problem and also simultaneously satisfies budget constraints is mathematical programming, and that procedure was adopted.

OPTIMIZATION ASSUMPTIONS

In the development of a practical method of assigning priorities, several assumptions were adopted.

First, the time horizon for accruing benefit streams extends over a period of 20 years from the year of implementation.

Second, the list of candidate improvements for which priorities are desired contains legitimate improvements and not irrelevant alternatives.

Third, for each year in the planning period (20 years), estimates of the capital budget are available, and the capital budget is completely exhausted during each period.

Fourth, each improvement, once started, may be implemented during a number of time periods, i.e., a particular improvement may require 3 years to construct. In such a case, the capital cost will influence the budgets of 3 successive years. The mathematical formulation will allow the user to specify both the number of years over which a particular improvement will be constructed and the proportions of the cost to be allocated to each year.

The discounting factors to be applied to future sums of money are calculated based on the assumption that the interest rate is both constant and known. This rate of interest may be manipulated, as the need arises, to test sensitivity. An interest rate of 6 percent was used.

Finally, provision was made in the benefit and cost streams for future inflation.

OPTIMIZATION TECHNIQUES

Benefit-cost ratio, benefit maximization, and cost minimization are the 3 optimization techniques studied.

Benefit-Cost Ratio

The benefit-cost ratio technique is one commonly used in capital budgeting of projects. For the period in question, the candidate improvements are ranked in descending order by the ratio of present worth of benefits to the capital cost of the improvement. The improvements on the list are included in order until the period's budget is exhausted. Because the opportunity costs of delaying any given improvement are not considered, the method is nonoptimal. It has the advantage that calculations for only one time period need be done. The information content of the results is less than for the other alternatives, but the solution is the easiest to understand. This procedure can be slightly modified to consider future opportunities by delaying any improvement until such time as the first year following implementation shows a benefit return relative to costs at least equal to the interest rate.

Benefit Maximization

Early in the study a linear programming procedure was identified as the technically correct solution to the problem of assigning priorities to improvements (5, 6). It provides, basically, an optimum solution by ensuring that maximum benefit (maximum effectiveness) is derived from the expenditure.

In assessing the priorities of transportation improvements, the linear program deals with 3 basic inputs:

1. The cost of an improvement. Costs differ for each year of implementation in the planning period and may be represented in current dollars as shown in Figure 1.
2. The composite of the present worth of all benefits and disbenefits during a 20-

year period for an improvement introduced in each year in the budget period. Typical benefits and disbenefits are shown in Figure 2. Several shapes may emerge for individual improvements, and some typical examples are shown in Figure 3.

3. The anticipated budgets. In all cases, the dollar streams were inflated at an appropriate rate and then discounted to the present base year at a specific discount rate. A simplified explanation of the function of the linear programming technique is shown in Figure 4.

The shapes of the different benefit-disbenefit curves shown in Figure 3 indicate the most advantageous year, from a maximum net benefit point of view, in which to implement an improvement. The "input" (Fig. 4) places these improvements into their maximum benefit year and shows the total costs that accrue in each year during the time period. The anticipated budget line indicates, for example, that in the year 1975 there are more improvements than can be afforded. Conversely, in the year 1985, there are insufficient improvements to exhaust the anticipated budget.

The linear program rearranges the timing of the improvements and produces an "output" that is within the budget constraint for each year but has minimum benefit loss. The choice is made by trying all alternative programs until the optimum solution, within the budget constraint, is found.

The data for a typical improvement are shown in Figure 5. The graph on the right shows the relative size of the different benefits and disbenefits for 1981, the year in which the linear program placed the improvement. The graph on the left shows the present worth of all the benefits and disbenefits for this improvement for each possible implementation year in the planning period.

The maximum benefit year is 1979; however, the optimal year to introduce the improvement is 1981. The linear program has displaced this improvement by 2 years from its peak benefit year in order to meet the budget constraints and optimize the overall program.

Cost Minimization

The cost minimization program provides an optional solution for programming improvements, for it minimizes fiscal dollar expenditures for construction and right-of-way acquisition. All other impacts due to positive and negative benefits of the improvement are ignored for this analysis. This method uses the linear programming technique. The principal advantage of this method is that the least cost schedule provides a standard against which to measure the added cost for programming improvements in a priority sequence derived by any other technique.

TESTING PROCEDURE

Test Area

The test area selected for this study was the Kitchener area because a good mix of highway improvements was available and the information base was satisfactory. In 1971 the area population had reached 250,000. The cities of Kitchener, Waterloo, Galt, and Guelph form a regional center with a connecting pattern of radial transport routes and good links with Toronto and Hamilton. The road transport connections are well developed, and 11 of the proposed highway improvements consist of either upgrading or realigning existing provincial routes. Transit improvements were also considered for the test area. The highway and transit improvements are discussed separately in the following sections.

Highway Improvements

Forty-six highway improvements were proposed for the test area. These improvements, which were taken directly from the Kitchener Area Highway Planning Study, ranged from major highway additions costing approximately $18 million to smaller improvements such as geometrics, capacity, and resurfacing. Sections selected for improvements had uniform traffic and benefit characteristics and could be constructed independently.

Figure 1. Typical improvement cost stream.

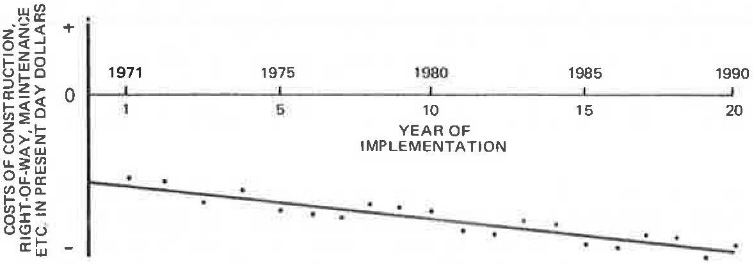


Figure 2. Typical improvement benefits and disbenefits.

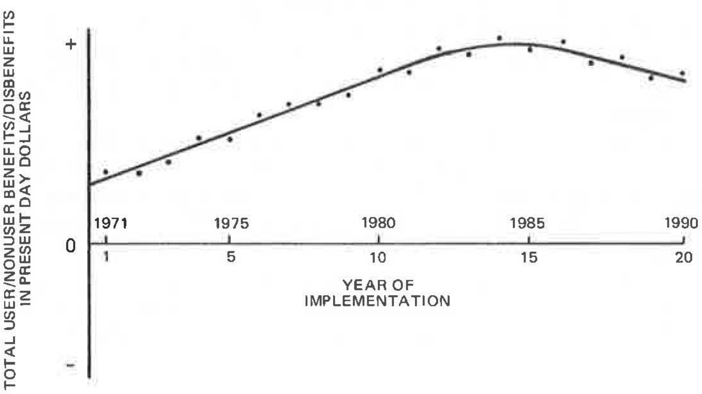
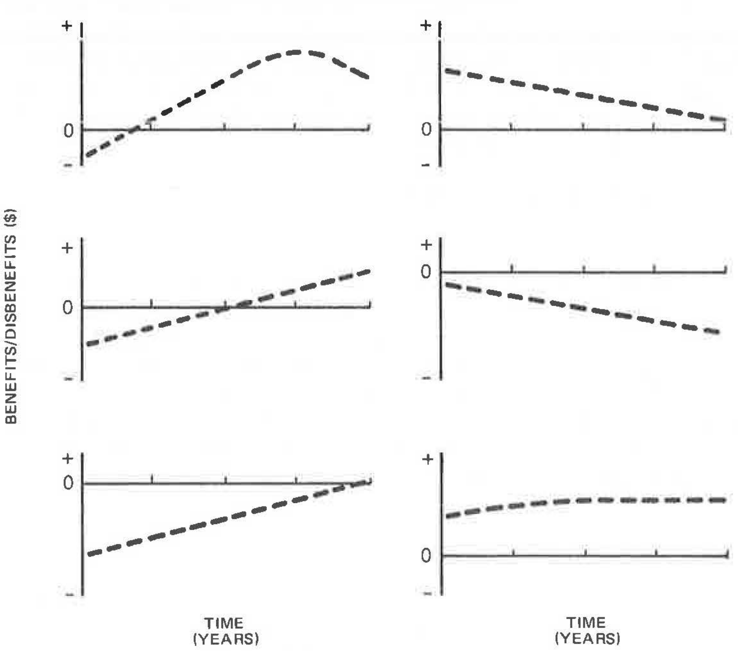


Figure 3. Typical benefit-disbenefit and time relations.



For each highway improvement, the applicable benefits and disbenefits were summarized. Annual maintenance, operating, accident, and time costs were all accumulated for 20 years. On the other hand, social, environmental, and regional development benefits were considered as one-time impacts.

Most of the social and environmental benefits were associated with the improvements on a new alignment. These benefits-disbenefits, in many cases, were found to be relatively small in comparison to the present worth of the average user benefits. In other cases, however, where the user benefits were low, the social and environmental benefits became a significant proportion of the total.

Transit Improvements

The 6 transit improvements included in the study were developed as a set of typical regional transit projects. The transit improvements varied from a rural dial-a-bus system with 2 buses on 2 routes offering hourly service to an intermediate-capacity elevated busway with 5-min headways. The benefits and disbenefits for all transit improvements were summarized. As with the highway improvements, even the large social benefits appeared small in relation to the user benefits.

Test

In the test of the methodologies, several formulations were used in which the benefit-disbenefit factors were varied. Table 1 gives a summary of the tested methodologies.

Benefit Maximization

Run LP 1 corresponded most closely to the stated objectives of the study, namely, to develop a priority methodology that considers hard and soft factors and highway and transit improvements consistently. One of the questions addressed in the test of the methodology concerned the effect on the priority schedule of excluding soft factors. Therefore, in run LP 2, soft factors were omitted. Although the results (Table 1) vary slightly, the difference in total benefit value was only 0.28 percent.

This result has significant implications. During implementation the ministry will have some areas where satisfactory estimates of soft factors are not yet available but where estimates of user benefits can be produced. The results of the comparison of runs LP 1 and 2 suggest the following procedure, in this case: Assign priorities for all improvements on the basis of the hard factors only, identify the improvements for which no soft factor estimates are available, and accept the priorities generated for those improvements. These results can be forced into a second run as given data, along with the improvements for which both hard and soft factors are available, to develop an integrated priority program. These can subsequently be revised as soft factor information becomes available.

Benefit Maximization Versus Cost Minimization

A second question investigated in the testing of the methodology concerned the fiscal cost to the ministry of considering the present worth of benefits in developing a priority program. To investigate this question, 2 paired runs were made: LP 3 and 5 and LP 4 and 6. Table 1 gives the present worth of benefits and fiscal costs. The percentage differences are as follows:

Runs	Present Worth of Benefits	Fiscal Costs
LP 3 and 5	6.65	37.75
LP 4 and 6	7.25	36.49

Results of the 2 comparisons were similar. Part of the difference arose from right-of-way acquisition costs, which grew during the schedule period but which had very low user benefits in the early schedule years. This suggests a policy of early right-of-way

Figure 4. Linear programming technique for maximizing benefits.

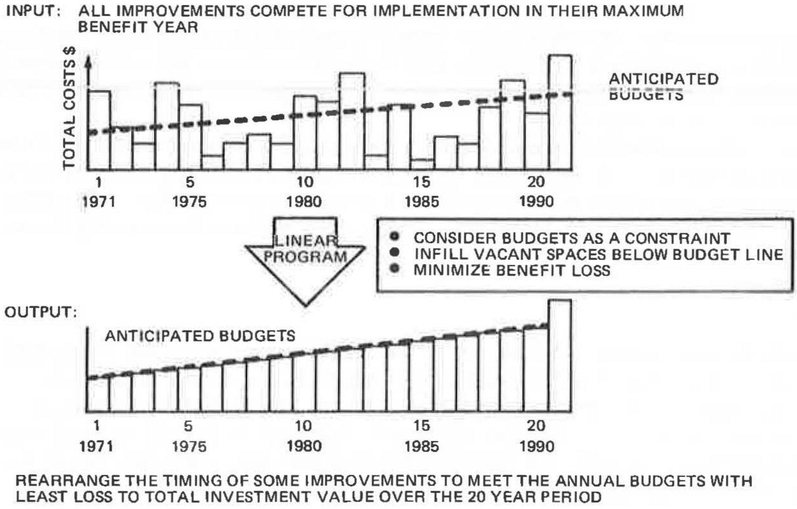


Figure 5. Typical improvement benefit data.

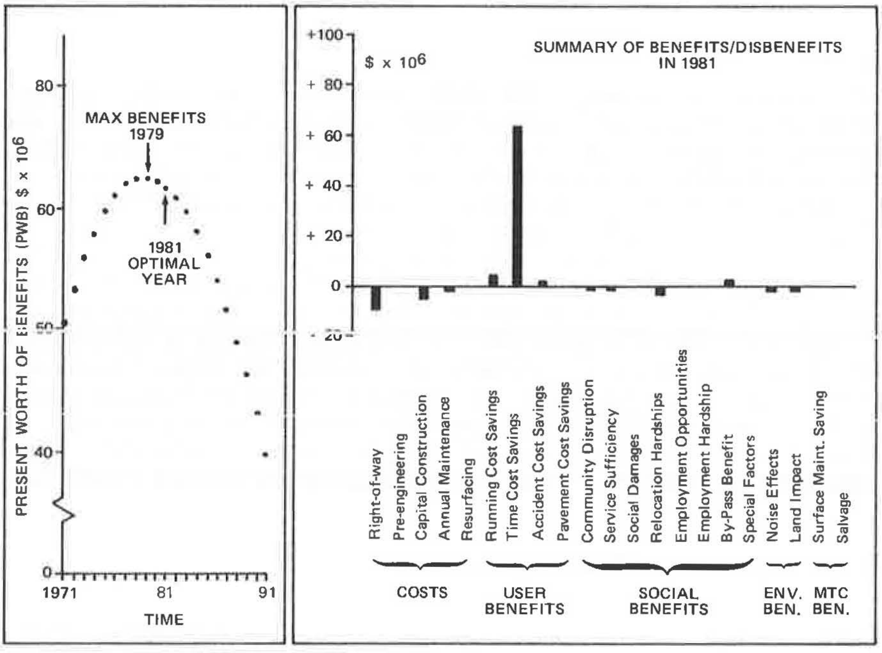


Table 1. Methodologies tested.

Methodology	Improvement	Factor	Run	Present Worth of Benefits (dollars)	Fiscal Costs (dollars)
Benefit maximization	Highway and transit	Hard and soft	LP 1	846,887,647	
		Hard	LP 2	844,489,866	
	Highway	Hard and soft	LP 3	634,030,991	349,643,444
		Hard	LP 4	636,574,484	349,643,496
Cost minimization	Highway	Hard and soft	LP 5	594,469,919	253,821,654
		Hard	LP 6	593,540,785	256,158,814
Benefit-cost ratio	Highway	Hard and soft	BC max 1	604,914,144	
		Hard	BC max 2	609,845,176	

acquisition where right-of-way purchases may be treated as investments, separate from construction, in the priority methodology.

A compromise between maximum benefits and minimum costs can be generated by listing the alternatives, where the ratio of cost saved to benefits foregone is large, and adjusting a maximum benefit priority schedule to take advantage of the cost savings.

Benefit-Cost Ratio Maximization Versus Benefit Maximization

The benefit-cost ratio maximization methodology was of interest because it is currently in use in other jurisdictions. It was also felt that it might be more flexible and easier to administer. It was tested to assign priorities by including and excluding soft factors and was compared with the appropriate LP methodology. Table 1 gives the results; the percentage differences are as follows:

Runs	Present Worth of Benefits
BC Max 1 and LP 3	4.59
BC Max 2 and LP 4	4.20

The reason for the substantial reduction in the economic value of the improvement schedule under the benefit-cost ratio maximization methodology is that it ignores trade-offs on opportunities arising from the relation of benefits over time. Thus, it recognizes an improvement as being relatively better or worse than other improvements in a specific year but does not consider the possibility that a good improvement may become better in the future or that a poor improvement may become worse.

Both methodologies will cost about the same to use. They both require the same data, and the benefit maximization methodology will not take significantly more computer time to operate. In short, the benefit-cost ratio maximization methodology appears to offer no advantages.

SUMMARY AND CONCLUSIONS

The testing procedures demonstrated an application of the selected methodologies. The linear programming procedures, which are already programmed, have greater capacity, in terms of the number of alternatives that they can handle, than the ministry required for this application. The programs themselves can be executed very quickly, and no problems were encountered in their use. The full set of output includes, in addition to the solution itself, a sensitivity analysis of the resulting priorities to input data variation and a full economic analysis and interpretation of the solution results.

The programs provide for the preservation not only of the input data but also of the solution. This means that, once the data base is loaded initially and the problem solved once, additional information may be added as it becomes available. The capacity of the programs to accept changes in input data and then calculate revised priorities inexpensively is an extremely important feature of the methodology. Thus, in operation, the cost of calculating the linear program solutions does not become a significant factor. The annual budgets and estimated improvement cost data can also be changed. The linear program procedures support the systematic reevaluation of priorities as more definitive information is received. Other capabilities are as follows:

1. The program can examine alternative choices and select and assign a priority to the best alternative. This capability can be used to decide between 2 alternative alignments or new links. This formulation may also be used to determine the economic point in time when surface maintenance and increasing annual cost should give way to a capital resurfacing. This adaptation can be used to select an improvement from a set of alternatives and to assign the appropriate priority.
2. It has the capacity to handle sequentially dependent improvements. An example of this kind of choice arises when the right-of-way acquisition and the remainder of the improvement are considered as 2 separate choices. These are related so that the right-of-way acquisition must be completed before the construction of the improvement

is undertaken. An additional constraint such that the right-of-way acquisition may not precede the remainder of the improvement by more than 5 years may also be added. For both parts of the improvement, the program can then simultaneously set priorities with respect to these conditions.

3. The program can also accept "commitments" and adjust to the given decisions. It can also accept restrictions in choice where, for example, a specific improvement cannot be commenced before a given year or later than another defined year.

4. The program does not have to be formulated in terms of 20 separate years. Thus, priorities can be assigned, year by year, for the first 5 years of the schedule, then for the next 5 years as a single interval (years 6 through 10 in the schedule), and finally for the remaining years of the schedule.

In summary, the linear program procedure was the theoretically correct solution to the problem of assigning priorities to improvements and fulfilled the objectives set out initially for the methodology. It is now operational on the computer and is exceptionally flexible and well-adapted for inclusion in a practical administrative and analytical support system. Preliminary testing indicates that the methodology will probably generate priority programs that, for given budgets, will yield a present worth of benefits 1 to 5 percent higher than other methods.

Although this increase in benefits is a small percentage benefit gain, the absolute amount is appreciable when compared to the total budget for the time period. This improvement in priority assignment efficiency and informative output should more than offset the costs of implementing and operating the methodology. The methodology also includes both positive and negative benefit effects and in so doing gives a better set of priorities.

The methodology is based on information that, for the most part, either is collected now or could be collected systematically in the future. Implementation of the methodology would use more fully and systematically the information that the ministry now develops for various purposes preceding construction. In addition, this methodology gives valuable support to ministry management and decision-making processes.

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LONG-RANGE TRANSPORTATION INVESTMENT PLANNING: A FORECASTING APPROACH FOR ASSESSING THE IMPACT OF ALTERNATIVE HIGHWAY SYSTEMS ON REGIONAL DEVELOPMENT

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The increasing difficulties associated with justifying new highway systems are becoming well known. Reliance on the benefit-cost approach may not be adequate for determining which future highway improvements should be undertaken because of problems involved in incorporating social values and locational changes into the calculations. This paper presents a planning tool that may supplement benefit-cost analysis to improve the ability of highway planners in assessing the impact of alternative highway systems. The approach employs a forecasting model that explicitly shows the impact of changes in transportation costs due to improved highways on the regional location of the population and industry and on regional income and employment. The model being used is an operating interregional dynamic model that forecasts industry activity and other variables at the regional level. The researchers conclude that new transportation systems affect interregional trade, regional output, and transportation needs. Forecasting future transportation requirements, therefore, requires systematic evaluation of differential regional sensitivity to changes in transportation networks.

•COMPREHENSIVE evaluation of the overall impact of new transportation systems on national, regional, and subregional economic and demographic changes implies the need for a complex economic and transportation planning model. Earlier applications of input-output analysis used in dealing with this problem were limited to the measurement of the impact of a specific highway or highway system (3, 4, 9). Recently a synthesis of the TRANS network planning model, the University of Maryland multiregional and -industry forecasting model, and a linear programming transportation model has resulted in a new and improved tool for assessing the impact of highway improvements. Early highway researchers revealed the nature of highway transportation benefits to the economy in terms of mobility improvements and cost reduction (11); yet, the accurate measurement of the ripple effects of those improvements on regional comparative advantage (the cost trade-off patterns that determine how much each area exports and imports) has eluded researchers. When changes in transportation investments are planned, the feedback effect of those investments on new growth can be significant if the growth is cumulative during long periods of time. The synthesis of models described in this paper facilitates the identification of the range of potential economic and demographic impacts by evaluating the expected changes resulting from postulated hypothetical networks.

The remainder of the paper is divided into 4 parts. The first briefly explains the forecasting model. That is followed by an explanation of how transportation costs are affected by highway improvements; the second section also explains how transportation cost reductions due to highway improvements can be incorporated into the forecasting model and used to explain locational changes. The third section discusses the alternative highway systems that are being evaluated by the researchers. Finally, some preliminary conclusions and possible further uses of the forecasting model are presented.

THE FORECASTING MODEL

The multi-regional and -industry forecasting model is designed to make long-run regional forecasts under reasonable assumptions and to evaluate impacts of alternative governmental decisions on those forecasts. Essentially, forecasts are made based on no exogenous changes in governmental spending and on a set of predetermined changes. Comparison between the 2 sets of projections shows the economic impacts of the governmental decisions.

One of the major advantages that this model has over the typical impact model is that regional demand is dependent on supply. For example, in most input-output models, it is necessary to predetermine levels of final demand for each region and then use interdependence coefficients to produce the changes in output. Although this approach may have merit at the national level, it seems inappropriate on a regional basis. Because the national economy is essentially a closed economy, final demand forecasts can be predetermined; but, for a region, the final demand levels influence the output levels, which determine income levels, which in turn determine major components of final demand sectors. Because the location of demand and supply need not be in the same region, it is necessary for a model to specify these interrelations and to allow changes in the location of output and resources to occur.

The multi-regional and -industry forecasting model starts by forecasting industry output. The output or change in output of each industry is explained by the marginal costs or prices that firms face in each location. The parameters are estimated by using least squares estimating procedures with regional data as observations. (The data requirements for the model are enormous. For the nearly 100 input-output sectors, 1965 and 1966 county data are used to estimate employment, payrolls, output, and final requirements by consumption expenditures, capital expenditures, government expenditures, and exports. In addition, population is estimated by race, age, and sex; labor force, unemployment, and personal income are also estimated.) In addition, agglomeration also helps to explain output location. After output has been determined, then payrolls, employment, population, and personal income are derived. Also, the final demand sectors are forecast—consumption and governmental expenditures are related to income, investment is related to output, and foreign exports are determined exogenously.

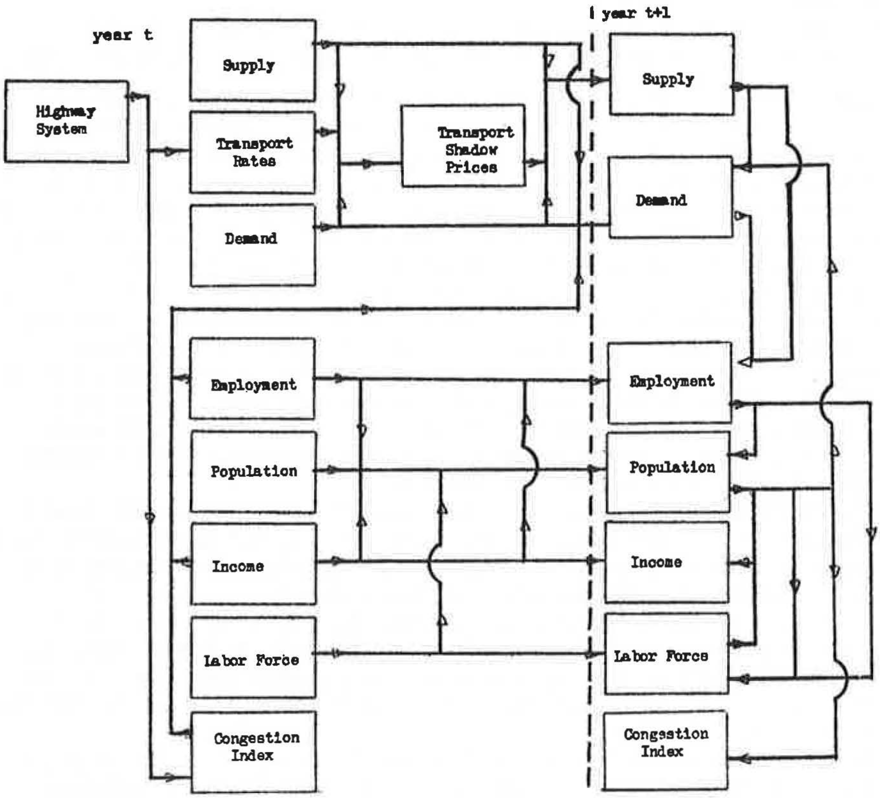
The model is recursive. The supply and demand data in the year t are used to forecast variables in the year t + 1. A simplified flow chart of the forecasting model is shown in Figure 1. On the left side of the chart, the data and computations are itemized for the year t. The connecting lines show how the data are used to make forecasts in year t + 1. After t + 1 forecasts are made, they are realigned as data (given in the left side of the chart) in order to forecast for year t + 2. In any given year, predetermined changes may be made in the data, such as changes in the governmental expenditures or in the highway system.

An important set of variables used to determine the location of output is the transportation variables. Those variables are the cost of transporting a marginal unit of a commodity either into or out of a region. They are derived by determining both rail and truck costs by weight class of shipping a unit of goods between each pair of regions (7). The least cost method of shipping goods in each weight class for each commodity is determined, and these costs are used in a linear programming transportation algorithm to produce the marginal costs, often referred to as shadow prices. The shadow prices are then used in the forecasting model to help explain industry location.

The quality of the highway system within each region may also affect the attractiveness of that region for the location of certain industries. In the equations that explain the location of output, highway quality is incorporated in a regional congestion index, and the index is used as an explanatory variable.

In addition to cost savings and highway quality, the construction of the highway itself may have an influence on the regional economies. Highway construction is part of the

Figure 1. Simplified flow chart of multi-regional and -industry forecasting model.



final demand for goods in a region, and the income of the construction workers contributes to the income of the region. Thus, industries that supply construction materials and consumer expenditures are affected by the location of the highway construction. Although construction has some impact on the expansion of the economy of a region during the construction phase, it must be remembered that when the construction stops decreases in the economy may occur.

The forecasting model, as it is used at the University of Maryland, uses counties as regions. However, because there are 3,112 counties, the model is very costly to operate; therefore, counties have been aggregated into 173 economic areas as determined by the Office of Business Economics (OBE). Not only is operation of the aggregated version of the model less expensive, but a regional delineation more appropriate than counties is provided for evaluating highway impacts. Most of the major highways in recent years have been built either to improve the travel time between major cities or to improve the travel time within a metropolitan area. Each of the OBE economic areas has a major city as its center; therefore, estimating travel time and vehicle costs between OBE economic areas is almost identical to estimating the time and cost between cities. The population centers are used as geographic points from which to compute the distance between regions.

ESTIMATING TRANSPORTATION COSTS FOR THE MODEL

The expected benefits from proposed highway improvements are usually estimated by determining what the reductions in vehicle operating costs, travel time, and accidents will be during the life of the project.

Past methods for evaluating highway benefits are not usable for the purpose of determining the regional reductions they produce in transport costs. Benefit studies that consider operating speeds fall into 3 distinct categories:

1. Those that treat the benefits of speed advances as being measurable from the tolls paid by toll-road users;
2. Engineering studies that do not translate into vehicle cost reductions; and
3. Efforts that change vehicle operating costs when average regional speeds change.

The above types of studies are discussed in order. The Highway Cost Allocation Study exemplifies the class of study that treats improvements as being reflected in the willingness of individuals to pay tolls. That analysis does not provide an adequate basis for estimating savings to shippers related to improvements of segments of the highway system because there is no way of knowing whether the tolls adequately approximate the benefits. Methodology more sensitive to specific highway betterments is needed to effectively assess the impact of highway improvements on vehicle operating costs.

Engineering studies treat the impacts of specific improvements in highways in great detail but do not make broad analyses that are useful for measuring general highway advances by segment. For example, elimination of curves, improvement of road surfaces, and reduction of grades are examined in these studies in terms of reductions in fuel costs, tire wear, engine oil consumption, and maintenance costs. But there are no generalizations made about reductions in vehicle operating costs that are associated with changing a roadway from 1-lane to 2-lane or unlimited access to limited access under various topographical and traffic conditions (15).

Several studies conducted at the Texas Transportation Institute made giant strides toward solving this problem. The data used were from ICC records and varied regionally and depended on the quality of the roads in the area. Benefits were measured in terms of time saved and could be attributed to improvements on particular road segments. There is, however, one major drawback in this approach. Average speeds were estimated on a regional basis and not on a highway-by-highway basis. Regional speeds were increased only if highway improvements had a significant impact on regional speeds; then the average speed was increased, but not the speed for the link that was improved (1, 5, 6, 14).

ICC data were used in estimating the cost reductions due to improved highways for the forecasting model because they reflect average speed conditions for 9 geographic regions of the United States. The data show how vehicle operating cost is affected by variations in speed for each of the regions. That is to say, the data present a functional relation between cost and speed in each of the 9 regions. Thus, the ICC data provide the clearest and most straightforward basis for linking motor carrier costs to speed. These formula rates reflect realistic estimates of the relation between speed and cost because they reflect road conditions and congestion as well as quality of roadway over varying topography.

It is unclear whether a change in costs will necessarily result in a change in rates (and thus factor prices). However, it can reasonably be assumed that reductions in highway transportation costs will be passed on to the users in the form of lower rates because of the high level of competition between private and for-hire motor carriage. [Oi and Hurter (10) give a complete discussion of private motor competition with for-hire motor transport as well as with rail transportation. Empirical evidence gathered in this study indicates firms of all sizes conduct private transportation. Competition is especially intense on the short haul. For-hire motor transportation forces competition from rail on the long haul. Thus, it is believed that the above assumption is realistic.]

The multi-regional and -industry forecasting model approximates motor carrier rates by using out-of-pocket costs plus an adequate markup to ensure revenue needs will be met. These charges are assumed to apply to all trucking, including intrastate movements and private carriage. A method of adjusting these average cost figures for those hauls that would benefit from improved highways was desired.

The out-of-pocket costs used in the model are the ICC figures for 1965. The cost of transporting a unit bundle from the jth to the kth region is based on average operating conditions in the jth region, plus terminal costs at both ends. The ICC data are average and do not relate operating costs to road type. However, they do include information on the average speed for each region, and tables are available that show the relation between operating costs per vehicle-mile and assumed speeds that range from 15 to 45 mph. These data, along with the national highway network model (TRANSNET) of the U. S. Department of Transportation, are used as the basis of an adjustment to the out-of-pocket cost figures for changes in speed due to highway improvements.

TRANSNET is a system whereby all the principal highways in the United States have been coded into links. Data available for each link include the number of miles, the speed, and the terrain characteristics of the area. The model assigns a given trip between 2 points in the most efficient (fastest) manner and computes the time of the trip in terms of minutes. Each of these highway links has been classified and coded by OBE economic areas, making it possible to compute the number of miles and the average speed for each major type of highway in each area and between areas. The highway classifications are limited-access toll roads, limited-access free roads, other divided highways, principal throughways, and local connectors. Regional speed figures were available for each of these classifications.

The transportation rates as used in the multi-regional and -industry forecasting model are a combination of truck and rail costs. Shipments are divided into weight classes, and the cost of shipping a unit of goods between 2 regions is computed for both rail and truck transport in each of the weight classes. In determining the cost of shipping a unit between each pair of regions, the lower of the 2 costs is chosen to represent the transportation costs in that weight class, and then the selected transportation costs by weight class are averaged by using information on the total weight of goods shipped in each weight class.

Both the rail and truck transportation costs are computed by using ICC formulas, which consist of line-haul costs and terminal costs. Thus, if a highway system were to improve the speed in that region, then the line-haul cost of trucks would decrease and truck transport might be substituted for rail transport in the forecasting model, depending on the magnitude of the decrease.

Based on the ICC relation between speed and line-haul cost, the truck vehicle-cost per mile is substituted for the speed data in TRANSNET. The network model is then run in order to compute the minimum vehicle-cost path between each of the economic regions, as was explained above.

HYPOTHETICAL HIGHWAY SYSTEMS TO BE EVALUATED BY FORECASTING MODEL

The 3 systems described here are the extended primary system, highways for economic development, and the urban highway system. All highway links for the proposed highway systems are constructed to Interstate standards. The federal highway expenditure level is assumed to be $4 billion annually from 1977 to 1986. The model is used to assess the regional impact of investing in each of these systems.

Extended Primary System

Objective—The extended primary system is designed to meet the needs of small cities that are not served by the Interstate System. Most of those cities have less than 50,000 population, and many are located in low population density regions. The likely benefit of such a system would be the decentralization of industry, shifting economic activity from large to small cities. Because the principal purpose of this alternative highway system is to improve transportation to small and remote cities, less than half of the construction expenditures would be for urban highways. Those states that received little funding for this system, because of their population densities or existing Interstate highway links, were appropriated some funds for improved highways, e.g., beltways, in their large urban areas to make the distribution of federal funds equitable.

Allocation of Federal Funds—For each $7 of federal funds expended, the states expend $3. The federal funds are divided into 3 equal portions as a first approximation. One portion is allocated to states according to the 1970 population. The second portion is allocated according to the square root of the land area of the state. The third portion is allocated according to the miles of federal-aid highways located in the state. Because the extended highway system is intended to provide better highways nationwide to the smaller cities, there is deviation from this formula if some states have more priority links than others. However, every state receives at least 50 percent of what it would receive under the formula allocation.

Nodal Points in the System—Nodal counties were found by ranking counties in each state by the size of their 1970 urban population. The nodal point in each county is the center of the largest city in the county. Those cities already served by Interstate System were eliminated from consideration. The largest remaining cities were allocated the highest priority and so on down to the smallest cities.

Highways for Economic Development

Objective—The economic development highway system reduces transportation cost to the economically depressed areas of the nation. It results in a shift of industry from the highly developed areas to the underdeveloped areas.

Allocation of Federal Funds—Because this system is designed to help poor areas, matching state funds are not required. Not all of the states are served with this system. Economic areas as defined by OBE were ranked according to their per capita income. Nodal points within each economic area were selected, and a highway system was planned to serve those nodes. The allocation to any state or economic area was not predetermined but depended on income needs.

Nodal Points in the System—The OBE economic areas are delineated to form what may be called "little economies." Although the areas are not self-sufficient, the economic activity of any one area with other areas is minimized. Each economic area has one or more central cities, and the central cities are designated as nodal points in the new highway system.

Placement of Road Segments—Road segments in the new system tie into the Interstate Highway System. A network of segments was planned, and each nodal point is served by at least one new road segment. The new road segment meets or crosses either another new road segment in the nodal county or an existing road of primary quality.

Priority of Segments—The new segments in the system are given a priority rating according to the per capita income of the economic area that it serves (beginning with the lowest per capita income and working upward). Road segments are built according to the priority ratings until the total amount of money is exhausted.

Urban Highway System

Objective—The urban highway system is designed to eliminate urban congestion where it is the greatest. It favors large metropolitan areas and, thus, influences industry to centralize and concentrate in large cities.

Allocation of Funds—Because not all states and cities are served by this system, no matching state funds are required. Allocation of funds is determined by the U. S. Department of Transportation's arterial highway congestion index. Urbanized areas are ranked according to the congestion index, and funds are allocated to the most congested urbanized area until its congestion index falls to the value of the congestion index in the second most congested city. The funds are allocated to the first and second urbanized areas until their congestion indexes are reduced to the value of the third most congested area. Then funds are allocated to the first, second, and third city until their congestion indexes are reduced to the congestion index of the fourth most congested area. This procedure is continued until the total amount of funds is exhausted.

PRELIMINARY RESULTS AND CONCLUSIONS

The conclusions drawn are tentative in that the results and analysis were not complete at the time of this writing.

Comparisons of population and economic variables among the alternatives should be meaningful even if the 1970-1990 forecasts are in error because of incorrect economic growth assumptions because the only assumptions that change among alternative computer runs are those pertaining to alternative highway systems. In other words, everything is held constant except the highway system; thus, a comparison of the results should give a realistic measurement of the relative impacts of the alternative systems.

When the completed Interstate System is compared with the 1970 Interstate System (base year), the areas that gain the most population are Phoenix, Arizona; Burlington, Vermont; and Billings, Montana. Buffalo, New York; Bismark, North Dakota; and Raleigh, North Carolina show the greatest losses. Burlington is also a large gainer when measured by per capita income. Other areas that have large gains in per capita income are Cheyenne, Wyoming, and Clarksburg, West Virginia. The areas that would lose the most per capita income because of the completed Interstate System are Brownsville, Texas; Omaha, Nebraska; and Eureka, California.

Many of the areas that benefit by the completed Interstate System in 1990 are made relatively worse off by the extended primary system. The extended primary system improves the competitive position of additional areas and, thus, relatively lowers the 1990 population and income in areas that already have highway systems. The extended primary system benefits the smaller economic areas relative to the larger areas. In terms of per capita income, the poorest areas are made better off with the extended primary system, and the highest income areas are made worse off. The east-south central and the mountain census regions are the largest gainers from the extended primary system. The Pacific region has less population with this system.

The low-income economic areas are definitely helped by the economic development system. Fifty-eight out of the poorest 60 areas show some income improvement under this system. Many areas that show improvement under the economic development system also show improvement under the extended primary system. The links of the highway system in certain areas could be identical under both systems. The small areas, measured by population, also gain with the economic development system. The east-south central and the west-south central census regions gain the most population under the economic development system, and the Pacific region loses relatively the most.

The urban system does not benefit many areas because only 29 areas received construction expenditures under this alternative. The percentage of change in population and economic variables is not so high under this alternative as it is under the previous alternatives because the urban system affects areas with large economic bases and existing populations. The urban system definitely helps the large areas and the highest income areas. The mid-Atlantic region is the largest gainer in terms of population; the New England and the east-north central regions also show slight gains. All other census regions show relative losses.

Table 1 gives a summary of the economic projections for 1990 under the 5 alternative highway systems for the Washington, D. C., OBE area. Four alternative systems are compared on an index basis with the 1970 system, which is taken as the base of 100. Completing the Interstate System has little relative impact on Washington, D. C. The area loses slightly under the extended primary and economic development systems, which would not benefit it at all, and gains significantly under the urban system. In comparative terms, Washington, D. C., would be the second largest gainer under the urban system alternative.

Table 1. Indexes of 4 future highway systems relative to 1970 Interstate System.

Item	Completed Interstate	Extended Primary	Economic Development	Urban System
Jobs				
National resources	106	96	99	119
Construction	99	99	96	103
Manufacturing	104	97	98	114
Public utilities	102	96	97	111
Wholesale trade	102	98	95	106
Retail trade	101	98	99	105
Finance and real estate	100	100	100	100
Services	100	100	100	100
State and local government	107	99	99	103
Federal government	100	100	100	100
Military	100	100	100	100
Total	104	99	99	103
Population	101	99	99	104
Personal income	101	99	99	104
Per capita income	100	100	100	100

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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	Investment 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.

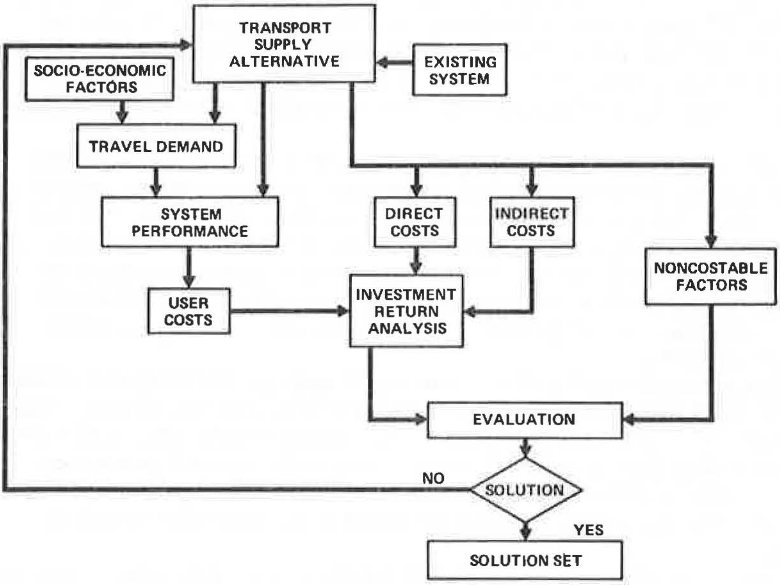


Figure 2. Effects of alternative population distribution on new freeway miles and arterial investment levels.

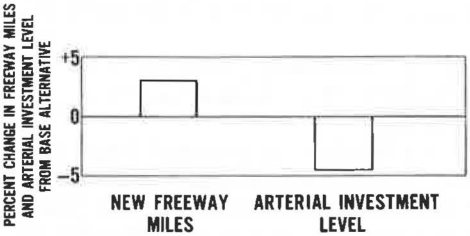
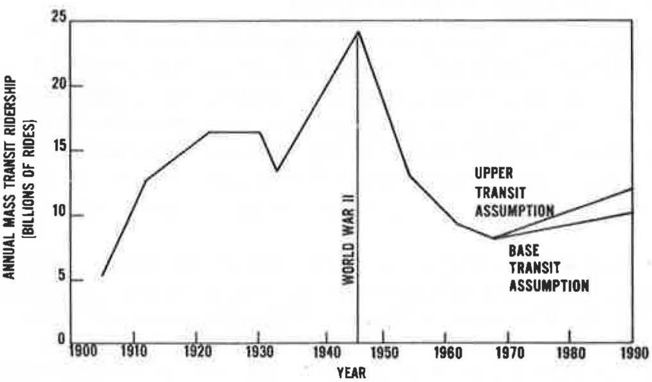


Figure 3. Urban transit patronage.



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.

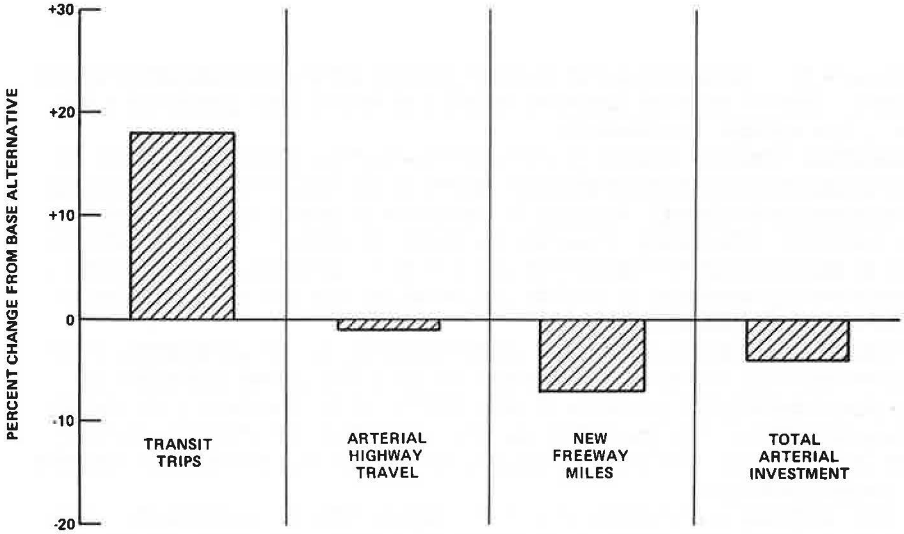


Figure 5. Passenger travel and goods movement in rural areas.

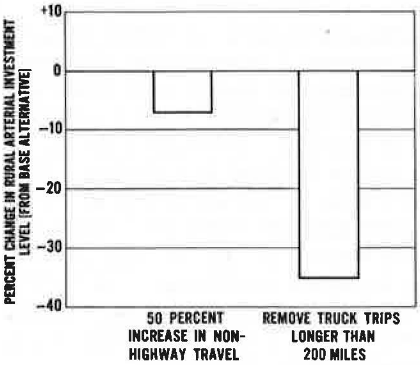
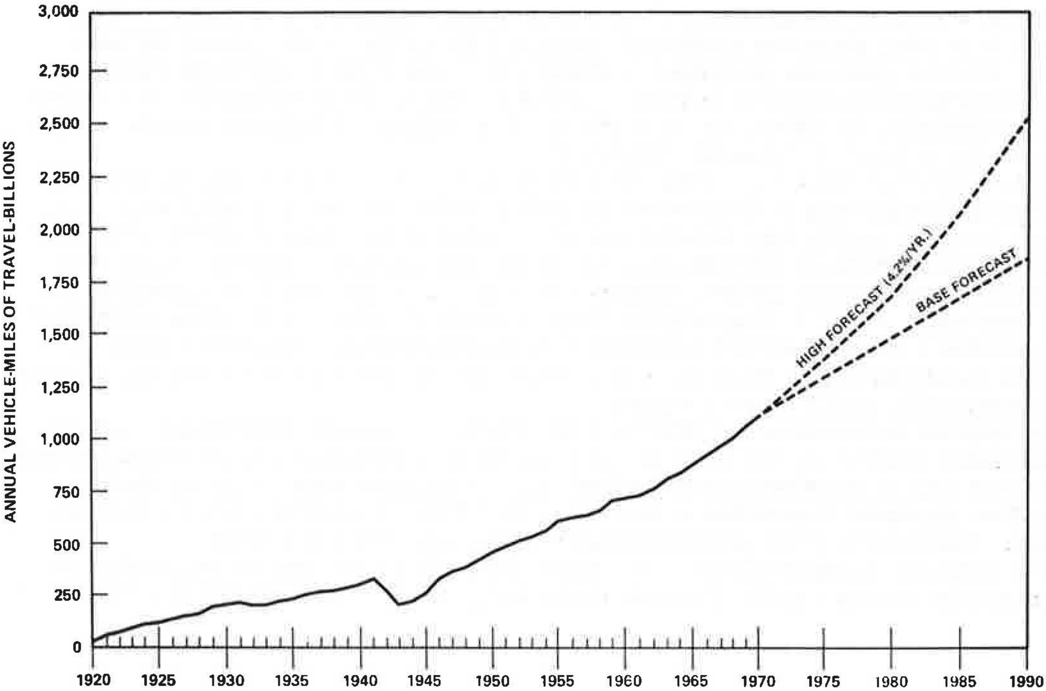


Figure 6. Trend and forecast of national travel.



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.

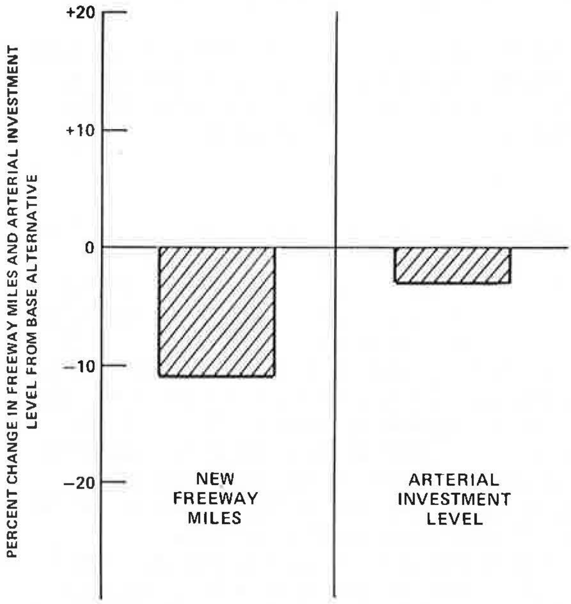


Figure 8. Sensitivity to value of travel time, construction cost, and interest rate.

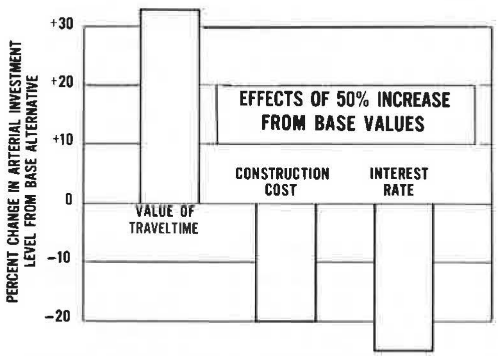
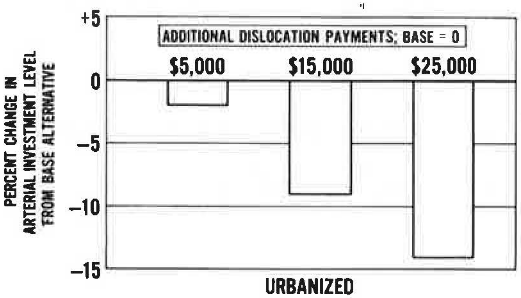


Figure 9. Effect of additional relocation payments on level of arterial investment in urbanized areas.



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.

ACKNOWLEDGMENT

Although the work reported in this paper is the result of a team effort, the authors want to recognize the particular efforts of Edward Fleischman, Robert D. Radics, and Samuel L. Zimmerman of the Federal Highway Administration who served as project leaders on various phases of the work. Credit is also due the consulting firms of Creighton, Hamburg, Inc.; Peat, Marwick, Mitchell and Company; and Alan M. Voorhees and Associates, who assisted in the development of several of the analytic submodels and the computer program.

The authors also want to thank William L. Mertz, James J. McDonnell, Kevin E. Heanue, and numerous others in the Urban Planning Division of the Federal Highway Administration for their support, ideas, and constructive criticism during the course of the study.

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MULTIMODAL NATIONAL URBAN TRANSPORTATION POLICY PLANNING MODEL

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Harold Kassoff*, Maryland Department of Transportation; and
David S. Gendell, Federal Highway Administration

This multimodal version of the model system of the Transportation Resource Allocation Study employs aggregate modeling techniques that treat each urban area as a single analysis unit. A level of investment is specified, and within that level are mixes of 4 types of transportation facilities: freeways, arterials, conventional bus, and rapid transit. For each alternative, travel projections are made on the basis of both socioeconomic variables and the nature and extent of the transportation system. Travel is split between automobile and transit modes. System performance measures are estimated on the basis of the interaction of system supply and travel demand. Travel times and costs are calculated for each mode. In addition, the model calculates external effects such as land consumed, air pollution, and fatalities. The model tested the effects of 12 alternatives consisting of 4 mixes of transportation facilities for the 63 urbanized areas that will have populations of more than 500,000 in 1990.

•THE MULTIMODAL national urban transportation policy planning model is the current operational version of the continuing Transportation Resource Allocation Study (TRANS) modeling effort (1, 2). The TRANS approach has been one of designing a set of models that are responsive to the needs of urban policy planners and decision-makers; capable of dealing effectively with a large number of transportation issues quickly and efficiently; capable of assessing the consequences of alternative courses of action and of determining preferred courses of action to achieve desired goals; and capable of explicitly relating to the social, economic, and environmental impacts of each alternative under consideration.

Prior to the TRANS activity, much of the effort involved in developing urban transportation planning techniques was directed to formulating transportation plans for individual areas. Although the need for a local planning process is self-evident, its application to national policy planning was difficult. Therefore, the model described in this paper was developed.

Earlier versions (1) of the TRANS model represent developmental stages and were basically highway oriented, treating highway investment trade-offs under varying transit-usage assumptions. The later version provided the capability to analyze central cities and suburbs separately and incorporated the results of 3 specific research projects into the model system (2). These projects produced a system-sensitive model for predicting area-wide urban travel (3), an analytical model for estimating the distribution of highway travel to freeways and surface arterials (7), and a set of relations describing in detail the variation in travel demand during the course of a day (4).

The current stage of development, the multimodal model, represents a major extension of the scope of earlier versions by including transit and highways in the same

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*Mr. Kassoff was with the Federal Highway Administration at the time this research was conducted.

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 U.S. Department of Transportation.

investment analysis. This version draws on the result of a research project that produced an aggregate, area-wide modal-choice model capable of predicting relative transit usage for work and nonwork trips, in peak and off-peak periods, on the basis of travel time and travel cost differences between private automobile and transit modes (5). This integrated multimodal framework has been the result of a combined effort of the Federal Highway Administration and the Office of the Assistant Secretary for Policy and International Affairs. It provided analytical support for the 1972 National Transportation Study performed by the U.S. Department of Transportation (6).

BASIC APPROACH

The TRANS model system comprises a set of analytical procedures for evaluating alternative levels and mixes of transportation investments in urbanized areas. The model operates on an aggregate level, treating each urban region as a basic unit of analysis. It is capable, however, of treating in a single application every urbanized area in the nation.

The underlying structure of the model system, as it is applied individually to each urban region, is shown in Figure 1. The process involves specifying a range of investment levels to be tested and, within each level, mixes of 4 types of transportation supply: freeways, surface arterials, conventional bus, and rapid transit (both bus and rail). The increments in supply are added to existing levels of each supply type (in each urbanized area) to provide a total 1990 transportation system alternative. Travel projections are made on the basis of both socioeconomic variables and the nature and extent of the transportation system supply alternative. The travel is distributed by time of day and mode; system performance measures (such as speed) are estimated on the basis of the interaction between supply and travel demand. User costs (such as travel time costs) and external costs (such as pollution and specified social costs for displacements and disruptions) are calculated for each mode.

For each alternative, changes in the costs are compared with changes in investment levels, and an economic analysis is performed. If the alternative passes various constraints placed on the economic analysis and also passes constraints due to "noncostable" factors (such as number of fatalities), then the alternative may be accepted. All specified investment levels and supply mixes are investigated, and the "best" alternative is selected and summarized.

The following sections describe in some detail the major elements of the TRANS urban model system.

Incrementing Structure for Testing Alternative Supply Levels

The multimodal version of the TRANS urban model considers a specified range of investment levels for each urbanized area. Within each investment level, the model considers a specified range of mixes in the supply of freeways, surface arterials, conventional bus transit, and rapid transit. The investments represent total expenditures for each mode and submode for the entire forecast period. Thus, appropriate unit costs are applied to the investment in each category, and total new supply provided between base and target years is calculated. This new capacity is then added to base-year (existing) supply in each category to yield total supply available in the target year.

The application of the incrementing structure within the model system is given in Tables 1 and 2. The first alternative (which is not really an alternative as such) operates on base-year conditions and performs an evaluation of system performance (speeds, operating costs, accidents, mode split) under current supply levels. The second alternative examines the do-nothing alternative under which future travel projections are derived on the assumption that no additional facilities are added to those existing in the base year. The third alternative involves the addition of a specified minimum supply of surface arterials to be provided for the growth area between the 1968 and 1990 urban boundaries. The fourth alternative adds a specified minimum supply of conventional buses in order to overcome the model's inability to appraise the very low levels of conventional bus service that would arise from the normal application of the incrementing structure under low investment levels. This alternative is

Figure 1. TRANS urban multimodal model system.

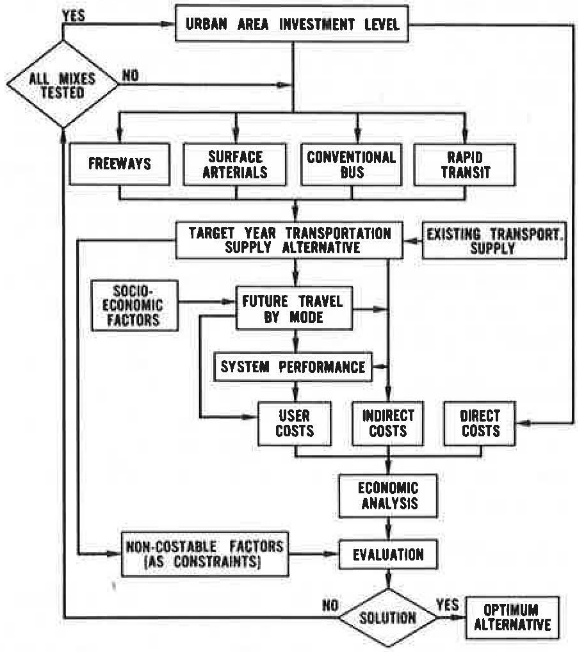


Table 1. Operation of incrementing structure at varying investment levels.

Investment Level		
Number	Investment	Operation
K_1	0	Evaluation of base-year system performance
K_2	0	Evaluation of target-year do-nothing alternative
K_3	I_s[a]	Addition of specified minimum surface arterial supply, which is not subject to economic evaluation
K_4	I_{CB}[a]	Addition of specified minimum conventional bus supply, which is not subject to economic evaluation
K_5	I_5	Normal incrementing structure
↓	↓	↓
K_{max}	I_{max}	Normal incrementing structure[b]

[a]Investment increments in the supply categories that follow in I_6 through I_{max} are in addition to the minimum investment levels specified for K_3 and K_4.
[b]See Table 2.

Table 2. Operation of normal incrementing structure from K_5 through K_{max}.

Investment Level		Investment by Category				
Number	Investment	Investment Mix Number	Freeway	Surface Arterial	Conventional Bus	Rapid Transit
K_5	I_5	1	$P_{11}I_5$	$P_{12}I_5$	$P_{13}I_5$	$P_{14}I_5$
↓	↓	↓	↓	↓	↓	↓
		m	$P_{m1}I_5$	$P_{m2}I_5$	$P_{m3}I_5$	$P_{m4}I_5$
K_{max}	I_{max}	1	$P_{11}I_{max}$	$P_{12}I_{max}$	$P_{13}I_{max}$	$P_{14}I_{max}$
		↓	↓	↓	↓	↓
		m	$P_{m1}I_{max}$	$P_{m2}I_{max}$	$P_{m3}I_{max}$	$P_{m4}I_{max}$

Note: P_{ij} = percentage of investment allocated in mix i to category j, $\sum_{j=1}^{4} P_{ij} = 100.0$. Both the upper and lower bounds of the modal percentages must be integer multiples of the modal percentage increment.

the base to which subsequent alternatives are compared until one is reached that is better according to the economic analysis (see later section on application of model), at which point the latter alternative becomes the new basis for comparison.

Beginning with the fifth alternative, the model's normal incrementing structure is applied (Table 2). Initially, within each investment level, the percentage of allocation to each of the modal categories is set at a predesignated lower limit. Increments are added to that mode until its specified upper limit is reached, whereupon the next mode is incremented and the first mode is reset to its lower limit. The procedure continues until all combinations within the specified ranges have been tested, at which point the overall investment level is increased, and the process of testing the various mixes is repeated. As indicated earlier, unit costs by mode are applied to each investment level and mix to determine the total target-year supply by mode. In the cases of freeways, surface arterials, rail rapid, and the non-rolling-stock portion of bus rapid, this simply involves dividing the modal investment by the appropriate unit costs.

In summary, the incrementing structure permits a systematic evaluation of specified mixes among 4 categories of urban transportation supply through a specified range of capital investment levels. Noncapital costs, such as those for highway maintenance and transit operations, are derived based on the level of supply stipulated and are incorporated in the economic analysis. However, they are not included as part of the investments specified in the incrementing structure.

TRAVEL SUBSYSTEM

There are 3 alternative methods for developing the travel projections in this version of the TRANS urban model. These include the direct use of urbanized area travel projections submitted by the states (Fig. 2), a modification to the states' projections based on a simplified adjustment factor to reflect variations in system supply, and a modification to the states' projections based on a set of sequential models that predict person trips, trip length, and vehicle occupancy. The same modal-choice model is applied regardless of which procedure is used. The selection of which of the 3 travel projections to use is left to the discretion of the analyst.

MACROLEVEL MODAL-CHOICE MODEL

The development of a macrolevel (area-wide) modal-choice model represented the key to providing the TRANS urban system with a true multimodal capability (5). The macrolevel model was formulated by using data from microlevel simulations in a hypothetical urbanized region of 2.5 million persons and a generalized microlevel modal-split model (applied to zone-to-zone trip interchanges) developed from actual applications to 3 real cities.

The macrolevel modal-choice models consist of families of curves that relate area-wide percentage of internal person trips via transit to area-wide travel time and travel cost differences between transit and private automobiles. The models are stratified by trip purpose (home-based work and other) and by time period (peak and off peak) (5).

The aggregate modal-choice models are applied to time period (peak and off peak) and purpose (home-based work and other) of internal person trips that emanate from any one of the 3 travel structures. As mentioned earlier, transit trips are then analyzed in the transit subsystem, and automobile trips are converted to vehicle-miles of travel and incorporated with truck and external VMT to yield total VMT for analysis in the highway subsystem.

TRANSIT SUBSYSTEM

After the modal-split analysis has been completed for each investment level and mix of investments, an analysis of transit use is performed in the transit subsystem. This consists of computing transit person-miles of travel, performing a submodal split, and calculating load factors by submode.

Transit Person-Miles

Transit person-miles of travel are computed by multiplying transit trips by average trip length.

Submodal Split

To determine the allocation of transit travel to conventional bus and to rapid transit systems, when the two are considered simultaneously, the model uses a submodal split, which was developed from the series of simulations performed to obtain the macrolevel modal-choice model. The sub-modal-split curves are shown in Figure 3 for rail and bus rapid transit systems. According to the data from which the curves were developed, a given share of seat-miles of supply on bus rapid transit attracts a greater share of the transit market than that attracted by the same share of seat-miles on a rail rapid system. That is perhaps a reflection of the ability of bus rapid systems to perform a collection-distribution function as well as provide rapid line-haul service. The sub-modal-split curves were developed only for peak periods. For lack of any data, it is assumed that they apply to off-peak periods as well, although the model is capable of accepting any other assumed or derived relations.

Calculation of Transit Load Factors

Based on the allocation of passenger-miles to each of the 2 transit submodes, the ratio of passenger-miles to available seat-miles is calculated and compared to a specified maximum load factor. This is done for peak and off-peak time periods for both submodes. If any of the computed load factors exceed the maximum allowed, a message is printed to that effect, and the model proceeds to the next highest investment alternative without further consideration of the alternative being examined.

HIGHWAY SUBSYSTEM

The highway performance portion of the multimodal model is substantially unchanged from the earlier version of the TRANS model system (1, 2, 4, 7).

TRANSPORTATION COSTS

In the evaluation of the consequences of each transportation investment alternative, the TRANS urban model incorporates criteria that include factors that can be treated in monetary terms, such as user costs and construction costs, and also factors that are difficult to treat in monetary terms, such as costs of pollution, fatalities, and displacements and disruptions. These factors are usually incorporated in the analyses through sensitivity tests, for costs associated with them are either subjective or difficult to identify. By treating them as policy variables, however, the model is capable of indicating the effect on an overall optimum solution of assigning any of a range of possible dollar values.

User Costs

The user costs in the model consist of costs of travel time, vehicle operation, accidents, parking, and gasoline tax for private vehicles on highways and costs of travel time and fare for public transportation. Gasoline tax and transit fare are included only in calculations of total value indicator.

Direct Capital Costs of Transportation Supply

The direct capital costs of providing transportation capacity for any particular investment alternative are, in fact, determined by the investment level under which the alternative is being considered. Within each investment level, and for each mix (or allocation) of this investment among freeways, surface arterials, conventional bus transit, and rapid transit, unit costs are applied to determine the amount of supply purchased. The cost parameters are as follows:

Highways	Public Transportation
New construction	Rolling stock
Freeways	Conventional bus
Surface arterials	Rapid system vehicles
Reconstruction	Guideways for rapid systems
Freeways	Stations and terminals for rapid systems
Surface arterials	Yards and shops

Noncapital Costs of Transportation Supply

Costs associated with the operation of the transportation system are included in the analysis. However, they are not a part of the investment level of each supply alternative as capital costs are. Thus, the investment level covers only capital costs; operating expenses are derived costs based on the level of supply. The noncapital costs of transportation supply include maintenance costs for the highway system and operating and maintenance costs for both conventional and rapid transit systems.

EVALUATION PROCESS

The approach to evaluation in the multimodal version of the TRANS urban model is to identify an optimum investment level and a mix of investments among modes subject to meeting certain predetermined constraints. The optimum investment strategy is determined on the basis of economic efficiency considerations, and comparisons among alternatives are made in terms of dollar costs and savings. The use of contraints enables the explicit incorporation of evaluation criteria that are not suitably expressed in dollar terms. Thus, if an alternative succeeds in terms of the economic-based criteria but fails under any of the constraints that are imposed, it is rejected as a possibility for optimality.

APPLICATION OF THE MODEL

For the 1972 National Transportation Study, the multimodal TRANS model system was used to evaluate the effects of alternative allocations of urban transportation funding. In those analyses, the economic evaluation portion of the model and the system-sensitive travel forecasting option were not used. Twelve alternative programs were analyzed to provide a broad spectrum for comparison. Those programs were expressed by both a total dollar level and a percentage split of funds among the 4 major types of transportation facilities: freeway, surface arterials, rail and bus, rapid transit, and conventional bus transit. The analysis was conducted only for the 63 urbanized areas that will have a 1990 population of 500,000 or greater. Those are the areas in which there will be major trade-offs between highway and transit.

Three program levels were analyzed for the 22-year period from 1968 to 1990: $45 billion, $135 billion, and $225 billion. For each program level, there were 4 allocation alternatives for the 4 major types of transportation facilities (Table 3):

1. Needs alternative—funds allocated according to needs estimates returned by states and urbanized areas;
2. High highway alternative—half of public transportation allocation reallocated to highways;
3. High transit alternative—half of highway allocation reallocated to public transportation; and
4. Rapid transit alternative—100 percent increase in bus and rail rapid transit allocation.

The different program levels and funding allocations resulted in substantially different amounts of facilities. Figures 4 and 5 show the change in freeways and rapid transit facilities between 1968 and 1990 for the 12 alternatives. The increase in freeway miles is greatest under the high highway alternative, ranging from 38 to 164 percent. The increase in freeways is lowest under the high transit alternative, ranging

Figure 2. Process for estimating internal person trips based on travel estimates by states.

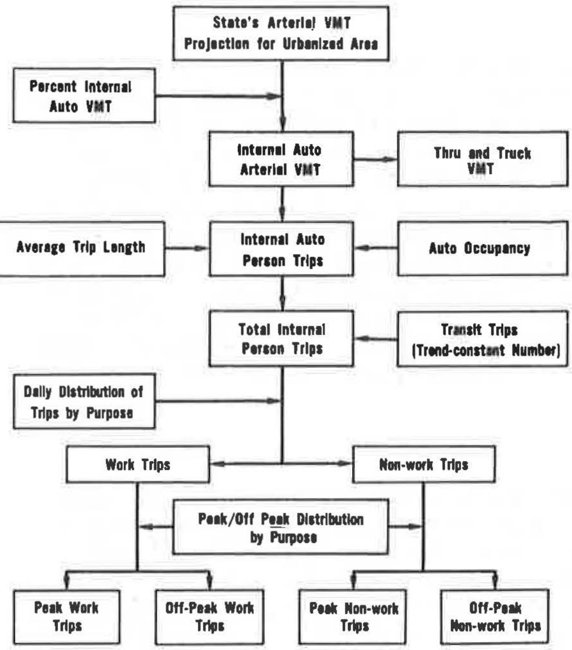


Figure 3. Peak passenger-miles of travel and seat-miles of rapid transit systems.

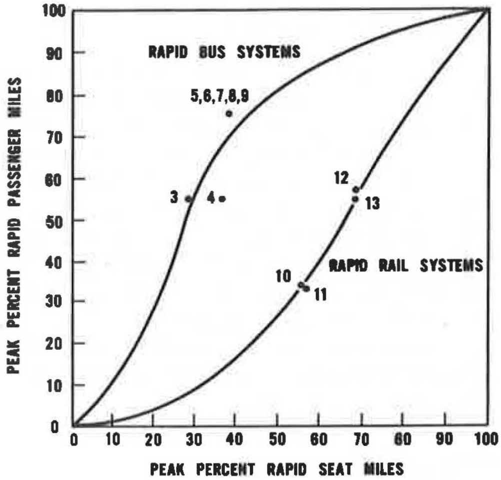


Table 3. Percentage of funds allocated for transportation alternatives.

Alternative	Freeways	Arterials	Rapid Transit	Conventional Bus
Needs	39	32	26	3
High highway	47	38	13	2
High transit	19	16	56	9
Rapid transit	24	22	51	3

Note: Percentages are averages for all 63 urbanized areas.

Figure 4. 1968-90 freeway miles.

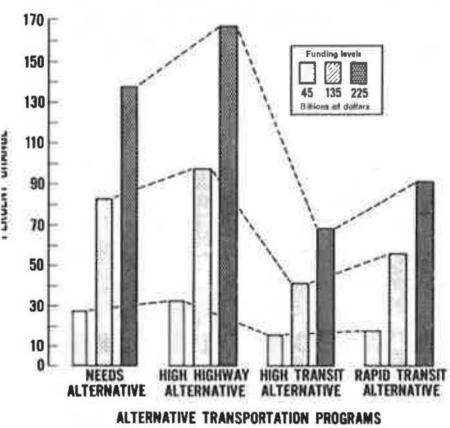
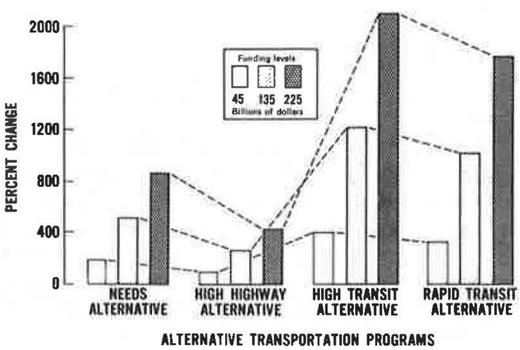


Figure 5. 1968-90 rapid transit miles.



from 14 to 69 percent. For rapid transit facilities, the largest increase occurs for high transit alternative, ranging from 412 to 2,056 percent.

Speed and Travel Time

Figures 6 and 7 show the change in area-wide peak travel speeds for automobiles and in peak travel times for transit during the 22 years. As the level of funding increases, the speeds and travel times improve as a result of additional facilities being provided at the higher funding levels. For automobiles, peak travel speeds improve by 2 and 7 percent under needs and high highway alternatives respectively at the $225-billion funding level. There is a 7 and a 4 percent decrease in peak automobile speeds at the $135-billion funding level for needs and high highway alternatives respectively. The most severe drop in automobile peak speeds occurs under high transit and rapid transit alternatives for the lowest funding levels. For transit, decreases in peak travel times result for only 3 alternatives; 0.2 percent for the high transit alternative at $135 billion, 15 percent for the high transit alternative at $225 billion, and 10 percent for the rapid transit alternative at $225 billion. All other alternatives result in an increase in transit travel times.

Modal Split

The modal split increases over 1968 conditions for all alternatives, for both daily and peak travel (Figs. 8 and 9). The increases are most dramatic for the high transit alternative under which daily modal split increases from 28 to 71 percent and peak modal split increases from 38 to 112 percent. Large increases occur for the rapid transit alternative also, in particular at the $135-billion and $225-billion funding levels. Figure 10 shows that daily transit trips increase from a low of 79 percent under the high highway alternative at $225 billion to 174 percent under the high transit alternative at $225 billion. Total person trips during this same 22-year period increase 62 percent.

Relocations

The number of residential relocations (Fig. 11) is related directly to the level of funding. As the new facilities increase, so does the number of relocations. The increases are greatest under the high highway alternative.

Fatalities

Under all 12 alternatives, annual fatalities increase (Fig. 12). The largest increase occurs under the high transit alternatives for all program levels and results from 2 factors. First, with large amounts of money reallocated from highways to transit, fewer freeways can be constructed. As a result, a higher proportion of highway travel takes place on arterial streets, which have a higher fatality rate than freeways. The increase in fatalities is lower, however, for the higher funded programs because of the increased construction of freeways and rapid transit, which have lower fatality rates than arterials and conventional bus.

Air Pollution

Figures 13, 14, and 15 show the change in the daily tons of carbon monoxide (CO), nitrogen oxides (NO_x), and hydrocarbons (HC). Current air pollution emission rates and controls were used throughout the analysis to maintain comparability of the results from 1968 to 1990. The area-wide differences in air pollution among alternatives and funding levels are small. The CO and HC levels decrease slightly with increased funding levels. This decrease is the result of higher speeds that occur when more money is invested. The NO_x levels increase with increased automobile travel and increased proportions of automobile travel on arterial streets. The levels are highest for the high highway alternatives for all funding levels because of the large amount of automobile travel. The high transit and rapid transit alternatives result in higher CO and HC levels because of lower speeds and increased starting, stopping, and accel-

Figure 6. 1968-90 peak automobile speeds.

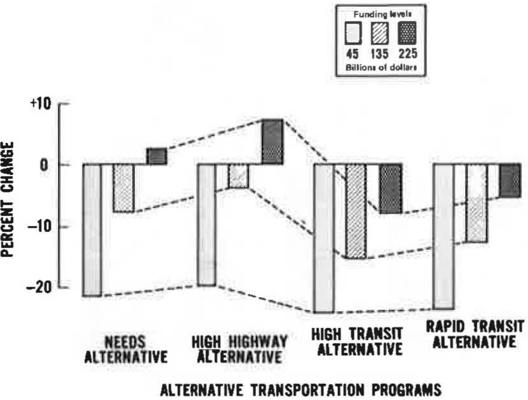


Figure 7. 1968-90 peak transit travel.

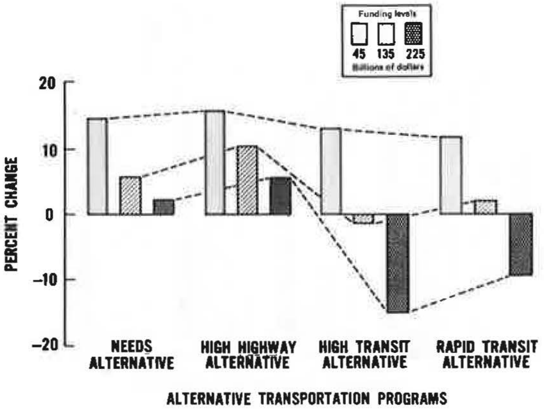


Figure 8. 1968-90 daily modal split.

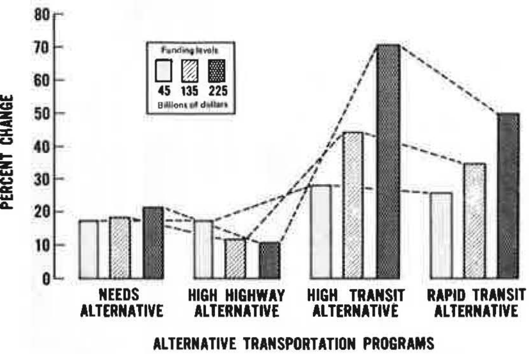


Figure 9. 1968-90 peak modal split.

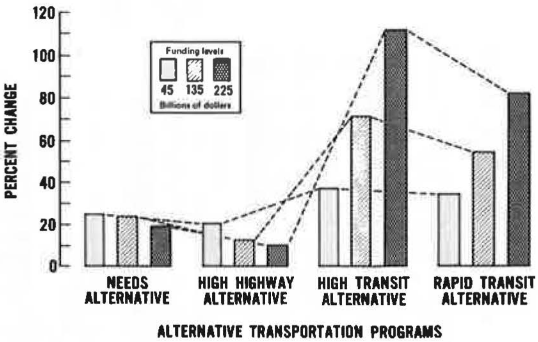


Figure 10. 1968-90 daily transit trips.

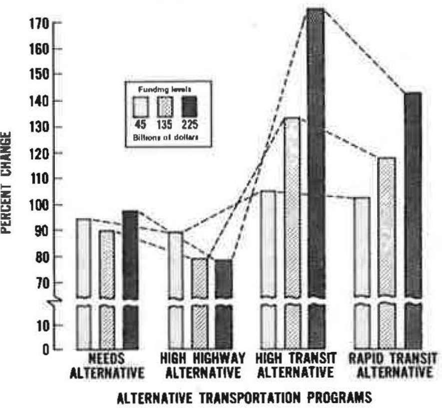


Figure 11. 1968-90 residential relocations.

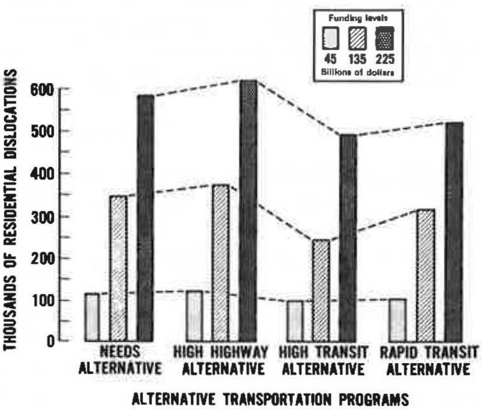


Figure 12. 1968-90 annual fatalities.

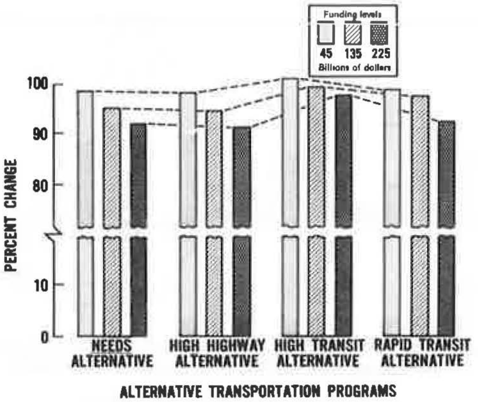


Figure 13. 1968-90 daily tons of carbon monoxide.

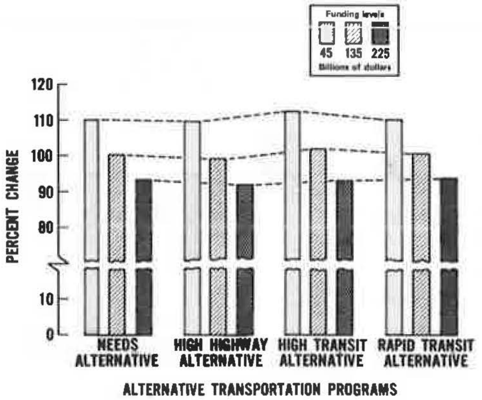


Figure 14. 1968-90 daily tons of nitrogen oxides.

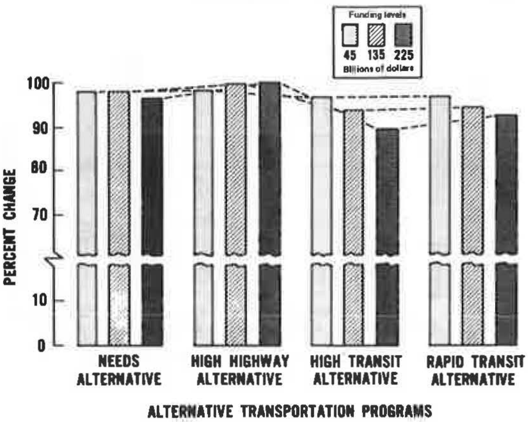
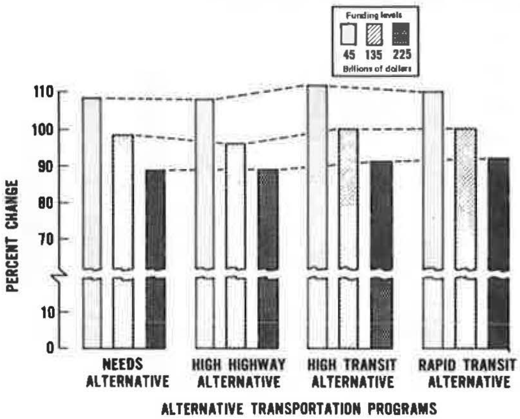


Figure 15. 1968-90 daily tons of hydrocarbons.



erating on the highway system as a result of less money being spent on highway facilities. Transportation is, of course, only one contributor to air pollution. A more sophisticated analysis is required, therefore, to determine the effect of alternative transportation funding levels and program composition on overall air pollution levels.

SUMMARY AND APPLICATIONS

The purpose of the multimodal version of the TRANS urban model system is to afford an insight into the consequences of alternative levels and distributions of future transportation resource allocations. The model is capable of treating the 2 principal modes of urban transportation, transit and highways; transit is characterized in terms of conventional bus and rapid transit, and highways are characterized in terms of freeways and surface arterials. Analyses can be made either to derive optimum future levels and mixes among the 4 submodes for each urban area or to evaluate the impacts of specific investment strategies. The efficiency of the model system at its current state of development lies not in its application to any unique, individual urban situation but rather in its ability to treat many urban regions simultaneously in assessing national program alternatives.

The macrolevel analyses typified by the TRANS approach can in no way substitute for the more detailed planning tools that support specific plans and project level recommendations. The TRANS approach arose from the recognition that the level of analytical effort must be commensurate with the magnitude, level of aggregation, and complexity of the problem to be tackled. The TRANS system is a technique that can respond to the need for a wide range of planning information for transportation resource allocation.

ACKNOWLEDGMENTS

Although the work reported on in this paper is the result of a team effort, the authors want to recognize the particular efforts of Robert Davis, Office of Systems Analysis and Information, Office of the Secretary of Transportation, and Samual L. Zimmerman, Federal Highway Administration, who served as project leaders on various phases of the work.

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PROCEDURES USED IN DEVELOPMENT OF UNIFIED TRANSPORTATION WORK PROGRAMS FOR THE MASSACHUSETTS PLANNING PROCESS

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The Massachusetts Department of Public Works has undertaken an ambitious program to revitalize its transportation planning process. The major focus has been on the 12 regional planning agencies that incorporate every community in the commonwealth. For each of the regions, unified transportation work programs have been developed that describe the comprehensive transportation planning work to be undertaken for a 5-year period. The work programs will be implemented under the direction of policy groups established in each region. Each policy group is composed of representatives from state, regional, and local agencies and from citizen groups and the general public. A major objective of the revitalized planning process is to develop projects for implementation that are mutually agreeable. Therefore, the success of the program will be measured by its ability to produce agreed-upon projects for implementation. A key mechanism for accomplishing this objective is the development and subsequent implementation of the unified transportation work programs. This paper describes the major features of the revitalized planning process, the procedures used to develop the unified transportation work programs, and the manner in which the planning specified in the work programs is being implemented.

A UNIFIED transportation work program is a single document containing a detailed description of the transportation planning work for all modes of transportation to be accomplished in a specific area covering a period of 1 or more years. Important functions it serves in the planning process include

1. Enhances the ability of various planning agencies at all levels of government to integrate all transportation modes into a unified planning program;
2. Ensures the coordination of transportation planning with other functional planning programs, such as housing, open space, water and sewage, and land use;
3. Provides the information needed at all levels of government to program the allocation of planning resources during a relatively long period of time;
4. Provides the information needed by various federal agencies to determine whether the specific items of work are in conformance with the overall planning program and eligible for consideration for program funding;
5. Encourages and promotes full participation by all interested and concerned groups who wish to make inputs to the work program; and
6. Describes the roles and responsibilities for carrying out the various work tasks and specifies the resources needed for each task.

The development of unified transportation work programs is encouraged by the U.S. Department of Transportation as a necessary element in the transportation planning process. The commonwealth of Massachusetts, through its Office of Transportation and Construction (OTC) and Department of Public Works (DPW), initiated the development of unified transportation work programs in November 1972. The OTC Secretary and DPW Commissioner viewed the development of such documents as essential to the reorganization and revitalization of the transportation planning process throughout the commonwealth. Subsequent sections of this report describe the procedures used to accomplish that objective.

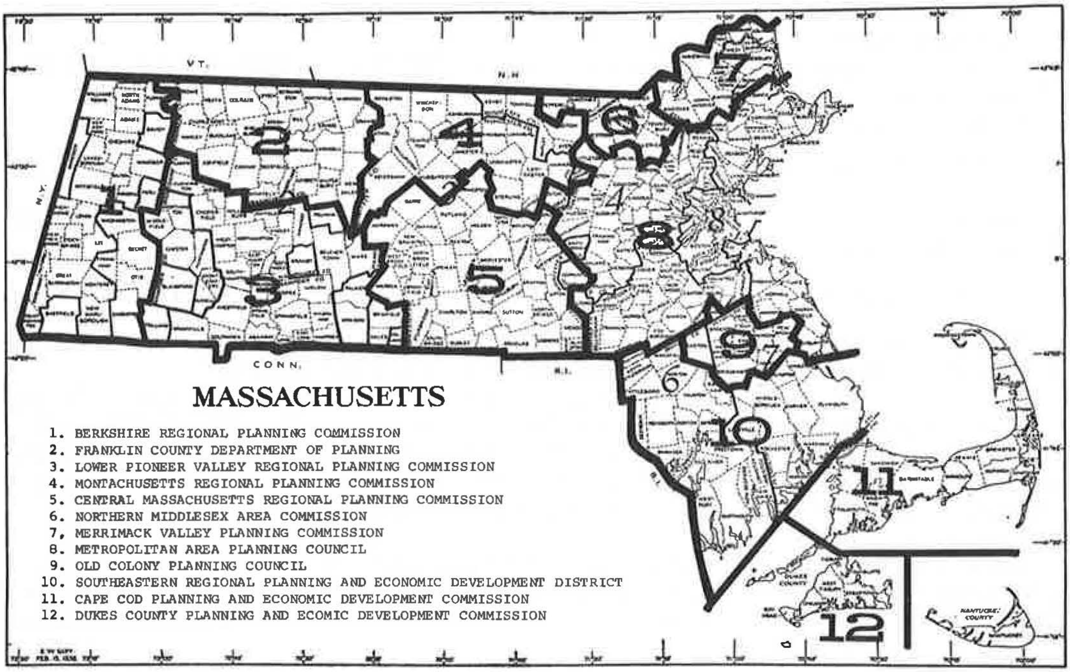
BACKGROUND

The major focus of the reorganizing and revitalizing of the planning process was on the 12 regional planning agencies (RPA), which are shown in Figure 1. Professional staff of each RPA would thus have an opportunity to integrate transportation planning with all other functional planning elements within the overall framework of comprehensive planning on a regional scale. It was felt that planning should be done on a regional scale to give proper consideration to the regional impacts of transportation decisions. However, this in no way would interfere with decisions that must be made at the local level.

Because the intention of reorganizing the planning process was to make it open and participatory, it was necessary to use an open and participatory process to achieve that objective. Therefore, the OTC Secretary and the DPW Commissioner invited local, state, and federal officials; citizen groups; transit companies; and other interested individuals and groups to attend a public meeting in each region to discuss the planning process. Approximately 500 letters of invitation were sent in each region, and in most cases more than 100 people attended. The purpose of each meeting was to obtain a consensus concerning the role of the RPA in the planning process and to describe the objectives of the new process. In each case the consensus was that the RPA is the proper mechanism for transportation planning.

After a consensus was reached on the role of the RPA, steps were taken immediately by RPA and state personnel and their consultants to develop a memorandum of understanding and a unified transportation work program within each region. The purpose of the memorandum of understanding was to establish the organizational framework within which the new transportation planning process would be implemented. The mem-

Figure 1. Regional planning agencies.



orandum of understanding states that the objective of the OTC Secretary and the DPW Commissioner is to create a transportation planning process that

1. Is ultimately responsible to those at the state and local levels who have authority to implement transportation plans;
2. Is oriented toward resolving issues and controversies and provides a forum for building consensus and airing disputes;
3. Includes a technical arm to support decision-making while emphasizing the key role of elected officials in making decisions;
4. Integrates transportation modes more effectively so that the process is a balanced planning effort and moves toward a comprehensive transportation planning process embracing all modes;
5. Recognizes both the short- and long-range impacts of the proposals on the overall transportation plan for the region;
6. Has wide and effective participation at the local level, both public and private, both municipal and regional, without diluting the ultimate capacity to take decisive action;
7. Is perceived by participants and reviewers as a dynamic process that is shaped in large part by the participants themselves with variations among regions and from time to time;
8. Is effectively integrated into the structure of proposed regional transit agencies and other transportation entities; and
9. Provides for the formulation of a unified work program for transportation within the context of comprehensive planning at the local, regional, and state levels of government.

The memorandum of understanding established a policy board to ensure that the planning process is an open and broadly participatory one, to serve as a forum for discussion and as the operational arm of the transportation planning process, and to establish the basic policies governing the conduct of the continuing transportation planning process. As a general policy, membership on the policy board is inclusive, rather than exclusive; its membership is drawn from the following sources:

1. Regional planning agencies and cities and towns within each region;
2. Department of Public Works;
3. Office of the Secretary of Transportation and Construction;
4. Other appropriate state agencies;
5. Private institutions, associations, and organizations representing low-income groups and minority interests in the area; and
6. Other groups mutually agreed on.

Although the memorandum of understanding provides the overall organizational framework for conducting transportation planning work, the unified transportation work program describes the work to be accomplished and assigns the responsibilities for doing the work.

BASIC PHILOSOPHY USED TO DEVELOP WORK PROGRAMS

The philosophy used to develop a unified transportation work program for each RPA is best illustrated by discussing the basic features contained in each.

The work program covers a 5-year period and gives a detailed description of work to be accomplished during the 1972 calendar year and a more general description of work to be accomplished from 1973 to 1976. This long-range look at the planning program will assist the RPA, the communities within each RPA, and the state planning agencies to program planning funds with a greater degree of certainty as to planning priorities.

As indicated earlier, the focus of the planning process is on the 12 regional planning agencies. Therefore, planning will be conducted for urbanized areas as well as for urban and rural areas. In this way, the planning program will include every community in the commonwealth.

The work program describes both short-range and long-range planning objectives and tasks. Short-range planning is defined as proposed action that resolves transportation problems that are of immediate concern and importance and that is within the framework of the long-range comprehensive plan. The long-range plan covers a period of 20 to 25 years. In planning work that has been undertaken in the past, the important link between planning and program implementation was frequently missing. Therefore, heavy emphasis is placed on integrating long-range and short-range planning so that recommended projects are a direct product of the planning process. Establishment of program priorities is, therefore, another important part of the planning process and will be done jointly by local, regional, and state agencies in accordance with the provisions in the memorandum of understanding. It is apparent to all groups involved that the real measure of the effectiveness of the process is the ability to reach agreement on the need for specific transportation projects and the early implementation of those projects.

The work program is concerned with the movement of people and goods by all modes of transportation, including highways, urban public transportation, intercity transportation, and waterways. Therefore, its format is such that it can be used as a single source document by the RPA and the state in applying for federal planning funds. Because it also describes the manner in which transportation planning will be coordinated with other aspects of comprehensive planning (such as housing, open space, water and sewer facilities, environmental considerations, and social and economic factors), the document also is intended to be used in applying for funds from other than the U.S. Department of Transportation.

Each work program contains approximately 15 specific tasks related to the planning process. The tasks were established to meet all state and federal goals and requirements, but they were also structured so that as much flexibility as practical is allowed in conducting the planning process. This provides a dynamic mechanism for fast and efficient decision-making on specific projects and programs. Each task includes a description of the agencies responsible for the work, the budget required, the various sources of funds, the expected start and completion dates, the types of end products expected, and the target dates for producing them.

The mechanism established for conducting the revitalized planning process provides a number of unique opportunities for making the planning process an integral part of the decision-making process, thereby providing the means by which plans will be transformed into action programs to achieve the goal of developing a balanced transportation system throughout the commonwealth. The revitalized planning process will

1. Provide for broad political and citizen participation, which parallels the technical elements of the work program;
2. Provide for the simultaneous consideration of both immediate planning decisions and long-term planning decisions and enough flexibility in each case to allow for necessary adjustments;
3. Provide sufficient opportunities to evaluate the full consequences of various transportation alternatives;
4. Provide the opportunity to develop innovative solutions to transportation problems by integrating multimodal transportation solutions with nontransportation solutions and by giving full consideration to low capital-intensive alternatives;
5. Provide a mechanism for continual feedback from the sketch plan stage through final design; and
6. Integrate various staff disciplines to allow for the application of solutions that account for all social, environmental, economic, political, and physical impacts.

PROCEDURES USED TO DEVELOP WORK PROGRAMS

The first step in developing the unified transportation work program was the development of a set of guidelines to be used by each RPA in generating a first draft work program. These guidelines were developed on the basis of instructions received from the OTC Secretary and DPW Commissioner and of various federal guidelines, including the following:

1. From the Federal Highway Administration, (a) PPM 50-9, Urban Transportation Planning, November 24, 1969, (b) IM 50-4-68, Operations Plans for Continuing Urban Transportation Planning, May 3, 1968, (c) IM 50-3-71, Urban Transportation Planning-Federal-Aid Highway Project Approvals in Urban Areas Over 50,000 Population, April 13, 1971, (d) Uniform Interpretation of Factors Necessary for Annual Certification in Urban Areas Over 50,000 Population, October 6, 1971, (e) Memorandum to Regional Federal Highway Administrators from G. E. Marple, Urban Transportation Planning—Unified Urban Work Program, March 17, 1972;
2. From the Urban Mass Transportation Administration, various informal discussions with UMTA personnel; and
3. From the U.S. Department of Housing and Urban Development, overall program design requirements from the 701 Handbook.

Guidelines for developing an operations plan and a technical work program and definitions of planning process documents were developed and used as the basis for generating the first draft of a work program by the staff of the Southeastern Region Planning and Economic Development District (SRPEDD), which was the first region in which this program began. After a comprehensive review of the first draft, we then incorporated all comments in the preparation of a second draft. The second draft was then reviewed by local, regional, state, and federal agencies, and their comments were obtained. We then prepared a third and final draft, which included all of the features described earlier in this report. The SRPEDD staff then made final minor changes to the work program, which reflected final budget estimates. The work program was then transmitted to the policy group established for SRPEDD under the provisions of the memorandum of understanding. At the present time, the planning process is being implemented in SRPEDD in accordance with the work program.

Similar procedures were used in each of the other planning regions. However, the third draft of the SRPEDD work program was used as the basis for developing the first draft of work programs in all the other regions. More generalized work programs have also been prepared by the 3 nonurban regions.

In the development of work programs for each region, particular attention was given to the procedures to be used in updating various transportation studies that had been completed in previous years. The major objective in this case was to make total use of all completed work in as comprehensive a fashion as possible. In addition, full consideration was given to the need for integrating the state's planning process with the U.S. Department of Transportation's National Transportation Study. The objective in this case is to provide the information requested for that study as a by-product of the planning process.

IMPLEMENTATION OF THE PROCESS

The major responsibility for implementing the revitalized planning process rests in the Department of Public Works. Steps have been taken within the department to reorganize its functions in a manner that will allow for a quick response to the planning process. There are now 3 major bureaus that are actively involved in the highway portion of the process: Transportation Planning and Development (BTPD), Project Development (BPD), and Traffic Operations (BTO).

In general, the BTPD will work with the RPA to develop and evaluate various alternative long-range transportation system plans in accordance with policy guidelines established by the DPW Commissioner and the OTC Secretary. The plans prepared by the BTPD will be developed jointly with state, regional, and local agencies in accordance with the memorandum of understanding.

At the point where plans are completed (under the guidance of the BTPD) for the development of transportation alternatives in a given area and the need is indicated for a specific facility, the BPD becomes responsible for developing functional design drawings, including preliminary engineering and related locational and specific environmental studies to prepare for final design.

The BPD will work closely with the BTPD and the RPA in the development of major projects. The BPD will develop specific location plans for alternative routes, coordinate the preparation of environmental statements for projects, and coordinate specifics for the urban systems program. The BPD will play a key role in linking the planning process and project implementation.

The BTO will be responsible for the development and coordination of traffic control, safety, and TOPICS projects. These projects will include signing, pavement markings, traffic control signal installations, highway lighting, speed zoning, and capacity analysis. The BTO will work closely with the DPW districts and the RPA in the planning and development of such projects. The BTO will also review traffic engineering and capacity aspects of all projects.

The DPW has provided HPR funds to each RPA for the purpose of hiring in-house staff to implement the work described in the unified transportation work programs. Although the amount of funds available for this purpose is somewhat limited at this time, it is possible that, as the program continues in a successful manner, additional HPR funds can be made available. However, great potential exists in each RPA at the present time for obtaining additional planning funds from other sources because of the presence of a full-time in-house professional transportation planning staff. The major source of such additional funds will most likely be the Urban Mass Transportation Administration.

CONCLUSIONS AND RECOMMENDATIONS

The development of unified transportation work programs was a complex and time-consuming process. It involved the participation of numerous individuals in numerous agencies. Each participant had his own objectives, criteria, and biases; thus, a considerable degree of compromise had to be achieved. In addition, we were breaking new ground in undertaking such an effort—not only in Massachusetts but in the entire nation. Therefore, a great deal of trial, error, feedback, and negotiation was necessary. However, in the end, success was achieved because everyone involved was single-minded in achieving the ultimate objective of establishing a mechanism that would be sound and long lasting. Now the challenge remains to continue with this unifying objective and to implement the process that has been established.

Much work remains to be done as we move into the implementation stage. The following major challenges are to be met:

1. A continuing funding program must be established to provide the resources necessary at the regional level to do the work;
2. A clear distinction must be made in defining roles and responsibilities at the local, regional, and state levels of government;
3. The state must be prepared to respond to the needs of the RPA and, in effect, provide a centralized professional capability to assist the RPA with miscellaneous computer processing, model development, data collection, technical analyses, and general technical assistance;
4. The process must produce project recommendations for implementation, and projects must be actually implemented, or the process will be a failure;
5. A statewide schedule of capital improvements for all modes of transportation must be developed for a 5-year period and adjusted and updated annually;
6. Written technical guidelines must be developed by the state to assist the RPA staff and state staff in doing technical transportation planning work (this could be expanded to cover things such as administrative procedures and report preparation);
7. A comprehensive set of training programs must be established; and
8. A well-structured and comprehensive research program should be initiated that will result in the development of new and improved planning techniques.

This has been a most worthwhile effort. It appears that we are well on the way to achieving great success in making the planning process an integral part of the decision-making process in Massachusetts. However, much remains to be done, and a significant effort must be made by all participants to maintain the momentum that has been established.

A number of key elements associated with the revitalized planning process in Massachusetts should be emphasized. The planning process that has been established will be the mechanism used to identify projects for implementation that are mutually agreeable at all levels of government. This will assist in bringing them to the design and construction stage faster than has been possible in the past. The revitalized planning process is multimodal in nature. We will consider not only highways but also public transportation, airport facilities, railroad facilities, ports and harbors, and all movement of people and goods in our efforts to achieve our objective of establishing a balanced transportation system throughout the commonwealth. In addition, the establishment of priorities will no longer be the responsibility of state government alone. Priorities will be established jointly by state, regional, and local agencies. Those priorities will deal with the identification of problems to be resolved and projects to be implemented. Finally, it should be emphasized that the planning process must be, and will be, open and broadly participatory. Every effort possible will be made to ensure that responsible citizens will have an opportunity to participate fully at all stages of planning and decision-making.

SPONSORSHIP OF THIS RECORD

GROUP 1—TRANSPORTATION SYSTEMS PLANNING AND ADMINISTRATION
Charles V. Wootan, Texas A&M University, chairman

Committee on Transportation Programming, Planning and Evaluation (as of December 31, 1972)
Michael Lash, Federal Highway Administration, chairman
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