Improving the Process of Programming Transportation Investments

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This paper presents a methodology that integrates regional equity, funding constraints, public acceptance, and uncertainty into a technical programming procedure. Developed for the Massachusetts Department of Public Works, it can be used to generate tentative multiple-period investment programs that are reasonably efficient in an economic sense and comply with a variety of funding, legislative, and community constraints. The program generation procedure is a heuristic one, based on marginal analysis. It handles independent and mutually exclusive investments, project benefit interdependencies, multiple funding sources, regional and other expenditure minimums, and functional classification constraints. It uses a measure of benefits, the capital cost, and an estimate of the political acceptability of each proposed investment to determine its suitability over alternative projects. The procedure can be made to handle virtually any number of potential investments and has been programmed for computerized operation. In the overall framework of an iterative and participatory transportation planning process among communities, regional planning authorities, and state agencies, this methodology provides a valuable and efficient tool for (a) combining a great deal of essential data into tentative programs and (b) clarifying the trade-offs between and among programs. The resulting programs can then serve as the basis for further discussion and compromise.

During the last few years, the highway investment decision environment has grown steadily more complex. The traditional process for deciding whether or not to build has been complicated by a number of newly important criteria. For example, investment programs must now frequently be evaluated on the basis of issues such as regional equity, efficient use of available funding assistance, statutory constraints, community and environmental impacts, and even general public acceptability.

These changes have created enormous backlogs of projects, many of which may never be constructed. A more significant and longer term consequence is the introduction of fundamental changes in the transportation planning process at both the state and regional levels.

Past concerns for highway needs, for forecasting demands to determine the sizing, location, and program budgeting of a facility, and for developing master plans have shifted to include an almost endless list of policy-oriented transportation and transport-related objectives. Responding to any one of these issues poses difficult analytic and planning challenges; responding within the short time frame that is typically present is especially difficult for most states, given their limited resources. Therefore, statewide planning and programming capabilities need to be improved immediately so that state and regional transportation agencies can be responsive to the increased demands being placed on them. This includes improvements in the overall process of planning and programming as well as improvements in the techniques used in that process.

In the past, the decision on which projects made up the best overall program was generally a highly centralized one, made either by the state's transportation planning or programming group or by each of the state's regions with review at the state level. Budget and project data were combined to arrive at a list of projects on the basis of needs. In many states, the initial definition of needs was a highly technical one related to a deficiency in level of service, capacity, or structural quality. In others, lists of projects were generated on a more ad hoc basis. Once such lists were generated, however, priorities were juggled significantly in both cases to account for anticipated impacts, community opposition, and environmental effects and for the political realities of building these projects. The final list of chosen projects was then simply made public.

Recently, however, the project selection process has become considerably more open. The public is voicing its opinions much earlier in the process through both hearings and regional organizations with planning and review powers. Typically the state agency still retains responsibility for overall (statewide) system planning, however, and in that capacity must generate and develop the alternative programs for review and evaluation by the public. This includes determining for each project (and collectively for the investment program) the effects of each alternative. This essentially technical role requires that fiscal plans, transportation system plans, project development activities, estimates of

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community and environmental impacts, and expressed or anticipated public sentiments based on participation and interaction with a wide variety of interest groups be integrated.

Individual projects may be evaluated sequentially by investigating each issue separately, collecting the relevant data, and carrying out a detailed analysis. But synthesizing this information for all projects to form a statewide investment program requires essentially simultaneous consideration of a wide range of factors, and there is simply too much information to be handled well by a subjective evaluation procedure. Well-defined analytic procedures to aid in the comparative evaluation of projects and the formulation and evaluation of alternative highway programs are requisite for systematic and successful program development. This need will become even more critical as the competition among alternative multimodal investment programs increases.

CONSTRAINTS OF THE PROGRAMMING PROCESS

The basic programming process is common to all states. It is designed to produce the investment program over time that most efficiently maximizes the overall general welfare of the state while maintaining an equitable balance among both individuals and regions. Although both the process and procedures vary widely by state, most state programming processes address the six elements discussed below.

Multiple and Conflicting Objectives

Although the basic objective of a programming process is to develop an optimal program of investments over time, the definition of optimal will most certainly differ among interest groups, as will the criteria for declaring any particular project good or bad. The existence of interest groups with different objectives severely complicates the problem of choosing among projects and among programs. Conflicts among national, state, regional, and community goals will have to be evaluated and resolved. Two alternative approaches have been favored by various states to resolve this problem. The first is a relatively subjective one that ignores technical measures and deals with nonquantifiable effects in an extremely ad hoc manner (1). The second approach is a highly technical one that assumes everything can be quantified and that weights can be found to reduce incommensurables to a single common measure (1, 2). Both approaches are unacceptable for what should be fairly obvious reasons.

The approach described in this paper lies between these two extremes and consists of two phases: (a) efficient development of a number of good alternative investment programs, each seeking to maximize some quantifiable measure of effectiveness in meeting a particular objective (for example, economic benefits or a decrease in anticipated accidents), and (b) introduction of nonquantifiable factors and the evaluation of the alternative programs with respect to both quantifiable and nonquantifiable factors. The object of the second phase is to resolve differences among competing programs through a negotiable, interactive bargaining process.

Total Budget Constraints

Although there are many possible types of budgeting constraints, a limitation on overall expenditures is undoubtedly the most common. Based on projections of future revenues, needs, and allocation policies, an estimate of overall funds available for programming in each period is usually made, which establishes an upper bound on expenditures. As straightforward as this constraint seems, its implications to programming are paramount. First, it is the justification for the process itself, inasmuch as with unlimited funds we would not need to choose among projects; we would simply build every reasonable project now. Second, and less obvious, it affects how projects should be implemented in terms of timing and scale. All too often, alternative project scales (e.g., the number of lanes of a proposed highway) are initially considered but then dropped before the programming process is begun. However, it is imperative that alternative scales be carried into the programming phase, since the optimal scale cannot be determined prior to programming. As will be demonstrated later, in the presence of an overall budget constraint, the best alternative is not always the one with the highest total benefit-cost ratio.

Geographical Constraints

In appropriating money for highways, state legislatures often establish guidelines controlling its allocation among the various areas in the state by designating minimum (and possibly maximum) expenditures for each area. California, for example, requires a 40 to 60 percent north-south regional split as well as county minimum expenditures that must be met over a 4-year period. These geographical restrictions on expenditures are designed to achieve some kind of equity within the state, on the basis of growth policy, needs, contributions to a fund, or some other measure. Unfortunately, such restrictions can result in the selection of relatively poor investments in some regions, from a benefit-cost perspective. On the other hand, they can prove useful in preventing a highly inequitable allocation of funds.

Special Purpose Allocations

Budget constraints may be imposed by designating funds for specific purposes. For example, states may design their investment programs in a way that maximizes the use of federal-aid funds. Although such a policy can lead to the selection of relatively inefficient projects (on the basis of benefits per dollar invested), the overall effect on a given state may be beneficial.

Network and Project Interrelationships

Another programming difficulty is accounting for the interrelationships among projects. For example, if two alternatives are available for a single location, they are typically mutually exclusive; that is, at most only one can reasonably be programmed.

The opposite of mutual exclusivity is contingency; i.e., a certain project cannot be programmed unless another specific project has already been selected. This is the relationship in staged expansion plans. To a certain extent, every project is contingent on every other project chosen and on the entire existing multimodal transportation system. For example, traffic demand for any particular link, a key factor in determining benefits, is dependent on the links it competes and connects with. Thus, project benefit interdependencies are the result of system demands and flows and are quite difficult to determine. However, in many cases, it may be possible to ignore them for all but the most major projects because the benefit interdependencies among most projects are small enough not to significantly affect programming decisions.

Uncertainty

Perhaps the most difficult factor to consider in programming is uncertainty over demand, funding availability, and community acceptance of specific projects. For example, we cannot accurately predict what the cost of fuel will be 20 (or even 5 or 10) years from now or how much capital will be available for construction. However, to prepare effective long-range programs, we must estimate these variables and address the uncertainty surrounding them.

Construction also faces a new kind of uncertainty: the power of an aroused public to halt indefinitely the construction of specific transportation facilities. This veto power over projects is unlikely to be rescinded in the future, and thus the implementation of projects will continue to rely on a successful bargaining process. The implications of this veto power on programming are significant. First, after a project has been programmed, study on it continues, which consumes both money and personnel. If the project is subsequently dropped, limited planning and programming resources have been wasted. Furthermore, there may not be a suitable alternative to fill its place in the investment program or to satisfy the minimum expenditure constraints of the capital budget. This void can lead to construction of relatively unsuitable projects simply because they are readily implementable or happen to be at the right stage of development at the right time. In a study of an actual case of this kind in Santa Barbara, California, Neumann and Pecknold (3) developed a decision analysis approach to addressing the uncertainty of community acceptability. The second implication of an unanticipated community veto can be even more significant. If the rejected project has strong interrelationships with other programmed improvements, rejection can lead to highly undesirable system flows.

Effect of Constraints

The six factors discussed will become even more significant in an era of scarce resources and an aware and questioning public. To cope with these constraints, many states will place increased emphasis on the development of an improved programming process. In most cases this will result in a complex, iterative, participatory process involving multiple sectors, many regional inputs, and a great deal of subjective judgment. Based on the factors just discussed, how can reasonable alternative programs be developed for further evaluation by both regions and states? This problem of program generation is the subject of the remainder of this paper.

PROPOSED HEURISTIC PROCEDURE

A number of previous studies (4, 5, 6, 7) have attempted to address this complex problem by using procedures such as integer and linear programming, dynamic programming, and decision analysis but without much success. All were extremely limited in the problem size they could handle or in their ability to deal with the large number of constraints that characterize the problem. [Pecknold (7) provides a review of various applicable programming and time staging techniques.]

The procedure chosen for the methodology presented here is a heuristic one based on marginal analysis (8). In a straightforward manner it can handle

1. Overall budget constraints,
2. Category, area, or functional classification minimums,
3. Scale or sizing of projects (i.e., multiple alternative scales or sizes for any project location), and
4. Project benefit interdependencies.

It has also been extended to include a measure of the uncertainty of community acceptability of a project. The procedure has been programmed for computer operation and is capable of solving virtually any size problem quite economically (a significant consideration if sensitivity analysis is to be performed). How the procedure addresses the problem is described below.

Handling Multiple Project Scales Under Budget Constraints

Although the difficulties of project programming are generally understood and effectively described in the literature (9, 10), in many cases total benefit-cost measures are still improperly used for ranking projects. Under the restriction of an overall budget constraint, maximization of total net benefits can be achieved only by maximizing the return or benefit measure received from each successive dollar invested. This requires consideration of each project's marginal contribution to the overall program benefit.

Benefit measures may be any measure of effectiveness for which increasing values signify better situations. Perhaps the most common measure in generating programs is some form of economic benefit or net present value that includes all benefits and disbenefits associated with a project. This should take into account the traditional elements such as travel time savings, operating costs, and safety impacts as well as other benefits and costs such as induced economic activity. Because projects have long economic lives and program decisions are required for multiple periods, the value of each alternative project must be calculated for each possible period of implementation and discounted to the present.

The following example demonstrates the inappropriateness of using a total benefit-cost ratio when there are both mutually exclusive alternatives and a total budget constraint to consider. Two alternative scale investments (labeled A and B) are proposed for project site 1, and a single investment alternative is proposed for site 2. The overall budget for this example is \$10 million (Table 1).

The total benefit-cost ratio approach to this problem would be to choose projects in order of decreasing benefit-cost (b/c) ratio until the maximum budget is reached. In this case, sequential selection on the basis of total b/c would result in programming project 1A, followed by project 2, to yield a program benefit-cost ratio of 1.8 (assuming one discards project 1B after choosing the mutually exclusive alternative 1A). Such a procedure is equivalent to prescreening the alternatives for each site and discarding all but the one with the highest benefit-cost ratio. (Unfortunately, this approach will not always select the best projects, since the proper alternative for each site depends on the availability of funds and the benefits of all the other alternatives under consideration.) However, the best program for this example is obviously project 1B, with a total benefit-cost ratio of 2.3; thus ranking by simple benefit-cost ratios fails to yield the best program.

To make the correct choice, the algorithm must either determine the best choice directly or it must iteratively test and consider the desirability of all mutually exclusive alternatives throughout the selection process. For a sequential algorithm, the former approach is infeasible because project 1A is actually the best choice for the first \$5 million; the availability of additional funds ultimately makes project 1A suboptimal in the example. The solution to the dilemma lies in the latter approach. Whenever a project is chosen, a calculation must be performed for each project with which it is mutually exclusive. This calculation determines the marginal benefit-cost ratio of discarding the newly chosen project and replacing it with the mutually exclusive alternative. (If this marginal benefit measure or cost is less than or equal to zero, the alternative may be eliminated from further consideration.) The algorithm then calls for sequentially selecting the project with the highest total or marginal b/c whose (total or marginal) cost is less than or equal to the remaining total budget. When no such projects with positive benefit-cost ratios remain, the process is completed.

For the example above, the marginal benefit of project 1B, given the prior choice of project 1A, is $8 million (i.e., 23 15) and the marginal cost is $5 million (i.e., 10 - 5). Thus its marginal b/c is 8/5 = 1.6. After choosing project 1A, the algorithm would next choose project 1B with the remaining funds (implying elimination of project 1A) because its marginal benefit-cost ratio is greater than that of the only other remaining project (project 2). Total program benefits would now be $23 million (i.e., the sum of the marginal benefits) for project 1B plus the total cumulative benefits of investing in all prior choices, i.e., project 1A, and total program cost would be $10 million (again the sum of the marginal value for project 1B and the cumulative cost of all preceding selections). Thus the new algorithm properly solves the problem of dealing with multiple alternatives under a budget constraint. Figure 1 shows this process.

Table 1. Example with $10 million budget constraint.

Project Site Alternative	Total Cost ($)	Total Net Benefits ($)	Net Benefit-Cost Ratio
1A	5 000 000	15 000 000	3.0
1B	10 000 000	23 000 000	2.3
2	5 000 000	3 000 000	0.6

Figure 1. Cost-effectiveness curve.

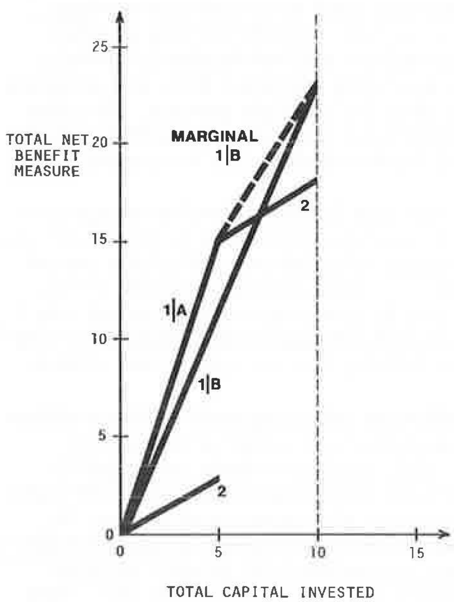
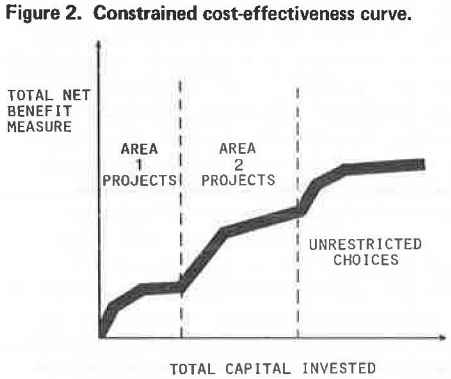


Figure 2. Constrained cost-effectiveness curve.



Satisfaction of Minimum Constraints

Unfortunately there is no guarantee that the marginal b/c selection rule will lead to satisfaction of any minimum budgetary constraints that have been established. For instance, the most efficient projects may all be in urbanized areas so that rural functional class minimums will not be met. Therefore, the selection rule must be modified to ensure satisfaction of such minimum expenditure constraints.

One way this can generally be accomplished is by successively restricting the list of available projects (i.e., those not already chosen or eliminated from further consideration) to those in a particular area, functional class, or other category whose minimum expenditure constraint is unsatisfied. [Development of this aspect of the algorithm and a large-scale computer package capable of handling thousands of alternative projects is currently in progress (11).] For example, projects could be chosen first from among those in area 1; after that minimum was met, selections would be made only from those in area 2 and so on until all minimum constraints were satisfied. The remaining funds (if any) could then be expended on the most worthwhile projects remaining (i.e., still available), regardless of area, class, or category.

In certain circumstances, the algorithm may initially fail to satisfy all minimum constraints before budgeted funds are exhausted. In such cases, doubly restricting the choices may prove effective. For example, if one is making selections to satisfy a particular area minimum and some functional class minimums have not yet been met, the choice would be further restricted to projects in these functional classes.

A typical cost-effectiveness curve illustrating this procedure (for the simple case with two area minimum constraints only) is shown in Figure 2. The existence of minimum constraints restricts the ability of the procedure to sequentially choose the best project until all the minimums have been satisfied; until then, choices are always made from a subset of the proposed projects, which may not contain the best one available.

The order in which the minimum constraints are satisfied may affect the results of this process, particularly if the sum of the minimum constraints of any given type (e.g., areas) approaches the overall budget maximum for the period. Unfortunately no one particular order will universally yield the best results; hence, constraint processing should be tried in various orders to determine the one that produces the best investment program for the problem under study. Because the algorithm handles mutually exclusive projects by a process that includes replacing an already chosen project by another project, it is possible that replacement might alter the status of a previously satisfied constraint. To prevent this, each set of mutually exclusive alternative projects should share the same values of all constrained characteristics (e.g., they should be in the same geographical area or functional class); if this cannot be achieved, satisfaction of all constraints cannot be guaranteed. An example application of this algorithm can be found in Juster (8).

Incorporating Other Constraints Into the Programming Process

At least two remaining constraints should be incorporated into the programming algorithm: uncertainty and project interdependencies. They are the most difficult to handle because they are the hardest to define and measure, conceptually and in practice. Although the techniques presented for dealing with these two factors are clearly the weakest elements of the proposed methodology, they represent an initial attempt at solving a difficult problem. It is hoped that their presentation will stimulate discussion and lead to further efforts to effectively deal with these important aspects of the programming problem.

Uncertainty

Uncertainty in investment programming is commonly dealt with through decision analysis (3, 7, 12). Unfortunately this technique has severe limitations when it is applied to a statewide programming process involving a large number of constraints.

The method suggested here is a heuristic approach for incorporating a measure of the probability of each project's political acceptability (3) into the basic programming process. (Officials in both Massachusetts and California indicate that they can generally estimate this probability, and, in California, such estimates are already being used in evaluating programs.) This is accomplished by simply multiplying the project's benefit measure by a factor between 0.0 and 1.0, which serves to indicate the utility (i.e., the value to the decision makers) of the uncertain benefits to be derived from including the project in the investment program. (The product of the calculated benefit measure and the factor is called the adjusted benefit measure.) The relationship between each project's probability of acceptance and the factor used to adjust its benefit measure is a matter of choice, inasmuch as it defines exactly how one chooses among projects that have different (unadjusted) benefits and probabilities of acceptance. A wide variety of functional relationships are reasonable, but only two are considered here: expected value and risk averse factors.

1. Expected value factors—The expected benefit from programming a project is simply the product of its probability of acceptance and its benefit measure. Hence, the expected value factor is equal to the probability of acceptance.
2. Risk averse factors—Researchers have noted (12) that people often have a measurable aversion to risky situations; that is, a person may prefer a less risky, smaller return to a very risky, larger return (e.g., a 90 percent probability of receiving $100 rather than a 10 percent probability of gaining $1000) even though the latter may have a higher expected value. A benefit adjustment factor that is less than the corresponding probability of acceptance indicates risk aversion.

For the benefit measure in item 1, the assumption is made that the benefit resulting from rejection of a project after it is programmed is zero. The actual benefit obtained is typically nonzero since the budgeted funds are available for use on alternative projects, but its value is not generally available a priori, so an assumption is required.

Project Interdependencies

Under certain circumstances, the benefits of building two separate projects may considerably exceed the sum of the benefits from each if it alone were constructed. This type of interdependency of benefits may be incorporated into the basic proposed methodology by the use of a construct called a joint project. As an example, a new joint project C (construction of both projects A and B) would be given a cost equal to the sum of the costs of the two original projects (A and B); its benefit measure would be that gained if both A and B are built. If projects A, B, and C are then treated as mutually exclusive alternatives (i.e., considered by the procedure to be located at the same site), the programming procedure will automatically select the best investment.

This is true except that the interdependency benefits are most easily incorporated if both projects (A and B in this case) are programmed into the same period. Actually, because the algorithm proceeds sequentially (and therefore never goes back to alter a period already programmed), the procedure can be adapted to handle these interrelationships between projects programmed in different periods. This is best accomplished by stopping at the end of each period and modifying the benefits of still unchosen projects to reflect the effect of those previously programmed.

It is important to realize that the interdependency benefits (i.e., the amount by which the benefits of C exceed the sum of those for A and B) will be realized only if both A and B are constructed. Hence, the political uncertainty associated with these benefits is extremely important to consider. The adjusted benefit measure of joint project C equals the sum of the adjusted benefit measures of each of the component projects, plus the calculated interdependency benefit measure times a factor representing its probability of being realized. For example, if expected values were being used and projects A and B were considered to have independent probabilities of success, the interdependency benefit measure would be multiplied by the product of the probabilities for projects A and B.

Multiperiod Programming

Thus far we have concentrated on selecting projects for a single investment period; however, the extension of the algorithm to multiple periods is reasonably straightforward. (However, it does not account for the differential effects of delayed inplementation on project benefits.) The key lies in the development of the list of projects available for investment in each succeeding period. Each list will typically include both new projects (which could not have been constructed in an earlier period) and projects available earlier but not chosen. Except for staged investment projects (11), however, the list must exclude any projects at sites where improvements have previously been programmed. It should be noted that benefit and cost data for all available projects should be updated before each new period is processed to reflect the effects of delayed implementation. Otherwise, the multiperiod algorithm is identical to the single-period procedure presented earlier.

After a reasonable multiperiod program has been produced and any necessary sensitivity testing has been completed, the entire process should be repeated by using other benefit measures to produce investment programs designed to meet other alternative objectives.

Ultimately, the programming process requires the development (through participation with the various interest groups) of a reasonably efficient and equitable overall investment program. The programs produced by the algorithm for each of the alternative objectives serve as input to this process and provide a measure of the maximum attainable levels of each of the objectives and of the trade-offs involved in substituting one objective for another. An advantage of the programming algorithm presented here is the ease with which many different programs meeting the various constraints can be generated. As a technical tool, the algorithm can increase consistency and reduce thousands of potential investment programs to a relatively few good prospects.

SUMMARY AND CONCLUSIONS

The investment decisions facing state and regional transportation agencies today are enormous. Agencies have been forced to expand their role and deal with much more complex problems, often in an environment of public hostility. In many cases, they have had to improve their decision-making process with essentially the same resources as before. Further research is required to help them continue to refine this role, to provide not only an improved programming process but also improved programming techniques.

This paper has presented a set of techniques developed to assist in improving an evolving programming process. Essentially, this methodology deals with the integration of budget constraints and project data to form reasonably good investment programs for further evaluation and modification. It handles

1. Multiple periods, each with an overall expenditure limit,
2. Legislative minimums on amounts that must be invested in counties or regions,
3. Functional classification constraints, and
4. Interdependencies among projects.

In addition, the procedure has been extended to incorporate estimates of acceptability as one way of handling the uncertainty surrounding a community's response to investment decisions.

The procedures presented here are not intended to replace the technical function of the state's programming groups, but rather to extend their existing tools and to aid in formulating alternative programs to serve as a starting point for discussion, compromise, and review. In addition, the methodology should prove useful for evaluating any proposed programs or changes to programs that may be of public interest and for analyzing some of the impacts of uncertain budget constraints and other aspects of program sensitivity. The ability to evaluate changes to publicly proposed programs is essential, since the overall programming process is an iterative one in which citizen groups seek modifications and the technical team determines the impacts of each proposal. Only through such an open process, supported by sound technical analysis, can essential agreement on a course of action lead to approval and implementation of the best possible investment plans.

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REFERENCES

1. Objective Priority Programming Procedures. General Analytics, Inc., and Comsis Corp., Final Rept., March 1973.
2. Evalution Criteria and Comparison Methods. Barton-Aschman Associates, Progress Rept. 2, March 1972.
3. L. A. Neumann and W. M. Pecknold. Application of the Time-Staged Strategic Approach to System Planning. HRB, Highway Research Record 435, 1973, pp. 20-31.
4. F. Ochoa-Rosso. Application of Discrete Optimization Techniques to Capital Investment and Network Synthesis Problems. Department of Civil Engineering, MIT, Cambridge, Research Rept. R-68-42, 1968.
5. G. Bergendahl. Models for Investment in a Road Network. National Road Administration, Stockholm, Nov. 1968.
6. Y. Mori. A Highway Investment Planning Model: An Application of Dynamic Programming. MIT, Cambridge, SM thesis, 1968.
7. W. M. Pecknold. The Evolution of Transport Systems: An Analysis of Time-Staged Investment Strategies under Uncertainty. MIT, Cambridge, PhD thesis, Sept. 1970.
8. R. D. Juster. A Methodology for Statewide Programming of Transportation Investments. MIT, Cambridge, SM thesis, Jan. 1974.
9. M. Wohl and B. V. Martin. Traffic System Analysis for Engineers and Planners. McGraw-Hill, New York, 1967.
10. R. Winfrey. Economic Analysis for Highways. International Textbook Co., Scranton, Penn., 1969.
11. R. D. Juster and J. H. Batchelder. Guide to the Highway Investment Analysis Package. Multisystems, Inc., in preparation.
12. H. Raiffa. Decision Analysis—Introductory Lectures on Choices Under Uncertainty. Addison-Wesley, Reading, Mass., 1968.