A Resource Allocation Model for Transportation Planning

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This paper describes the methodology used in development of the Interim Master Plan for Transportation in Pennsylvania in the period through 1975. The rationale for development of this plan is based on a three-step approach: (a) determination of goals for transportation development in the Commonwealth; (b) identification of alternative projects and programs to meet these goals, and evaluation of alternative projects and programs under different assumptions about goal values and budget levels; and (c) selection of those projects and programs for the Interim Master Plan that were most beneficial in terms of goal satisfaction and that could be purchased within a specified budget level.

The most important feature of this methodology is a computerized resource allocation model for evaluating and selecting projects on the basis of multiple criteria in terms of their anticipated costs and benefits to meet a set of weighted goals subject to overall cost constraints. The evaluation technique requires an estimation for each proposed project of the out-of-pocket investment cost to the state, and the anticipated benefits in each of nine categories. Those projects selected under all assumptions about goal values and budget levels were included as the "highest priority projects" in the Interim Master Plan; those selected under some goal-value and budget combinations, but not under others, were defined as "second-highest priority projects"; and those projects rarely or never selected under any assumptions about goal values or budget levels were considered as "lowest priority projects."

•THE Franklin Institute Research Laboratories (FIRL) has recently completed the development of the Interim Master Plan for Transportation in Pennsylvania (1) sponsored by the Governor's Committee for Transportation, Commonwealth of Pennsylvania. The Interim Master Plan sought to identify the projects and programs that would best serve Pennsylvania's transportation planning goals in the period through 1975.

Renewed industrial vigor, effective use of natural resources, and success in promoting statewide development all depend significantly on how well Pennsylvania's transportation system anticipates and performs its supporting functions. The proper planning, development, and utilization of Pennsylvania's transport resources and services can stimulate the future growth of the Commonwealth and promote the economic prosperity and social welfare of all Pennsylvanians. This is the challenge addressed by the Interim Master Plan for Transportation: to direct and encourage, through planning, the modifications and adjustments in Pennsylvania's transportation system that will further the economic, social, and strategic objectives of the Commonwealth.

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The Interim Master Plan represents the Commonwealth's first attempt to meet this challenge. As a first attempt it suffers from several deficiencies. It is obvious that a realization of the goals of the future must be founded on a clear understanding of the present. But our ability to analyze, measure, and project socioeconomic data, demands for transportation services, and the performance of present and postulated transportation systems and their interactions—so essential to a constructive solution of a wide range of questions and decisions related to transportation—is presently inadequate. Development of a truly comprehensive and definitive plan must await the collection of vital data and the implementation of more sophisticated methodology for long-range transportation planning (2, 3). However, the forces of change cannot be halted while data are gathered and techniques are refined. Planning must proceed with limited data and simple methodologies in the interim. The approach employed in development of the Interim Master Plan provides a methodology that can be used now by the Commonwealth for evaluating and selecting projects on the basis of multiple criteria in terms of their anticipated costs and benefits. The main feature of this methodology is a computerized resource allocation model developed by The Franklin Institute Research Laboratories specifically for evaluating subjectively determined multiple project benefits on the basis of a set of weighted goals subject to overall cost constraints. The model provides for the selection of those projects that would serve best the transportation planning goals of the Commonwealth and that could be purchased within a specified budget level. Although this technique has limitations associated with the subjective ranking of benefits and estimating of costs under conditions of less than adequate knowledge, it does provide a systematic framework for evaluating and selecting projects as compared with using intuitive judgments for allocating resources. In the following sections, the methodology used for development of the Interim Master Plan will be discussed in more detail.

RATIONALE OF THE INTERIM MASTER PLAN

The rationale used for the development of the Interim Master Plan is shown in Figure 1. A similar framework for transportation planning has been previously described by Davidoff and Reiner (4). As shown in the figure, the planning process starts with consideration of the overall goals for transportation development in the Commonwealth. Even though no formal list of goals for Pennsylvania currently exists, we have, nevertheless, started our development of this plan with a specification of some of the goals expressed or implied by executives of the state government.

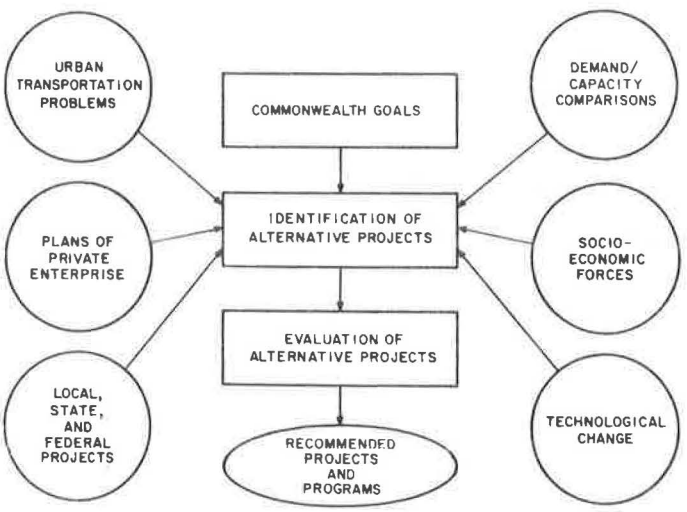

Figure 1. Rationale of Interim Master Plan.

As shown in Figure 1, the second step in the development of the plan involved those projects and programs that would serve to meet the transportation planning goals. Originally, it was intended that a comparison of the projected demands for intercity transport with the capacity of existing systems would suffice to define the elements for the Master Plan (5, 6). However, it became clear that matching of forecast demand with capacity of the existing infrastructure was not sufficient for development of a comprehensive plan. Consideration must also be given to the serious urban transportation problems facing the Commonwealth. Further, it was recognized that socioeconomic forces also dictate transportation needs that must be incorporated in the projects for the Master Plan. Additionally, the plans of local, state, and federal government agencies and private enterprise that require state approval or support must also be considered in the formulation of the master plan. Because new technology will make possible new solutions to transport problems and also raise new problems for the Commonwealth to solve, the recommended Master Plan must also consider the impact of new technology on the Commonwealth. Finally, the plan must allow for the complex interactions between the various transportation modes and between transportation and economic and social development.

The third step in the planning process shown in Figure 1 is the evaluation of the alternative projects and programs to select those that will best serve the Commonwealth's transportation planning goals, given a limited budget for initiating new projects. This evaluation required an estimation for each proposed project of the anticipated benefits in terms of goal achievement and the out-of-pocket investment costs to the state. These estimated benefits and costs were then used to rank and select projects, using a computerized resource allocation model, under different assumptions about the budget for new projects available. Since the relative "value" attached to various goals is a principal factor in determining which projects are selected, several alternative policies were given major priority: (1) Improvements in Transportation Service; (2) Economic Development of the Commonwealth; and (3) Social Development—"Making Pennsylvania a Better Place to Live." The results of these benefit-cost evaluations were used in selecting those projects included in the Interim Master Plan. Those projects that were selected under all assumptions about goal values and all budget levels were clearly preferred and hence are included as "highest priority projects" in the recommended plan. Those projects that were selected under some goal-value and budget combinations, but not under others, were defined as "second-highest priority"; their execution depends on the relative goal values which the Commonwealth wishes to emphasize and the funds that it wishes to make available. Those projects that were rarely or never selected under any assumption about goal values or budget levels are listed under "lowest priority projects."

In the following sections each of the steps in developing the Interim Master Plan will be discussed in more detail.

STATEWIDE GOALS FOR TRANSPORTATION PLANNING

The first step in developing the Interim Master Plan requires defining the objectives and goals that transportation development should serve. Because a formal list of goals and priorities to guide Pennsylvania's future development does not currently exist, it has been necessary to develop one for the study. Unfortunately, very little guidance is available from other transportation planning efforts. In most transportation planning efforts to date, goals have not been defined at all or have been defined in the limited terms of minimizing total transportation dollar costs.

Fundamentally, Pennsylvania's transportation system, like other public improvements, exists for the purpose of serving the citizens and industries of the Commonwealth. To get at the relative worth of a particular transportation project, it is therefore necessary to ask Mr. Citizen how he would evaluate the project himself. Doubtless he would ask at least some of these questions: Will it serve me? My family? For which trips? How much time will it save me and my family? Will it allow me a greater range of places to live while still holding the same job? Allow me to take another job without moving my home? How convenient will it be? How safe? How comfortable? How

much will it cost me to use it or not to use it? How will it affect my property visually, physically, and socially, both now and in the future? From similar standpoints, what about the effect on my neighborhood, my city, my state (7)?

Of course, each individual and family in the Commonwealth will weigh these points in different ways, in accordance with the hierarchy of their own personal value systems. Although a complete list of these personal values would be long and doubtless diverse, there are some goals that are probably shared in common among most of Pennsylvania's citizens: personal security, freedom to choose values and pursue goals, social opportunity, physical and mental development, accumulation of knowledge, physical comfort, serenity, happiness, physical pleasure, meaningful human relationships, acquisition of material goods, and sense of personal worth (7).

If Pennsylvania is to provide an environment that encourages the maximum fulfillment of such personal goals, consistent with necessary constraints on socially undesirable acts, then the collective goals of public agencies in the Commonwealth must reflect these personal values. Clearly then, monetary or economic concerns are but one area whose values must be reflected in planning goals.

Given the complexities of dealing with all modes of transportation and the wide range of social impacts that transportation changes can bring about, it is clear that the goals used to evaluate projects for this plan must be based on the broadest possible aims for the Commonwealth and rooted in the basic values of its citizens.

We have therefore abstracted a list of goals for transportation planning, most of which were stated or implied by executives of the state government. Because goals are the ends to which planned courses of action are directed, it has been necessary to define them in operational terms so that either the existence or nonexistence of a desired state or degree of achievement can be established. Based on these considerations, we have defined the following general goals that seem most appropriate for transportation planning in the Commonwealth:

1. Transportation service—Provide capacity to meet transportation requirements when private capital or equipment cannot; increase freight and passenger transport speed; improve comfort and convenience of transport for passengers, and convenience of freight movement to shippers.
2. Fiscal—Reduce cost and increase efficiency of transport.
3. Safety—Identify safety hazards related to transportation and take steps to reduce or eliminate them.
4. Economic—Provide more employment in Pennsylvania; upgrade skills and education of Pennsylvanians and increase their annual incomes; stabilize state's economy by diversifying industrial base, and encourage development of service industries; renew competitive free-enterprise spirit that sparked Pennsylvania's economic growth in 19th century.
5. Land use—Add transportation facilities to provide access to open space and increase use of recreational facilities; increase industrial land use in chronically depressed areas of the Commonwealth.
6. Social—Make the state a more pleasant and stimulating place to live in; reduce pollution and dispose of wastes in a socially and ecologically acceptable manner as well as control noise and beautify the state.
7. Balance competing interests—Help each transportation mode to find its comparative advantages in Pennsylvania and develop them fully for the benefit of all Pennsylvanians; help balance economic development among the state's 13 geographical planning regions.

These goals for economic and social development of the state can be further refined into more specific objectives (8):

1. Attract to our cities small industry fleeing from the high-cost areas of neighboring states.
2. Help Pennsylvania manufacturers in competing with manufacturers in other states and other countries.
3. Fully utilize opportunities afforded by federally funded programs for advances in technology, education, transportation, urban renewal, and economic revitalization; pro-

vide the locational characteristics desired by industry that responds to the needs and programs of the federal government.

4. Capitalize fully on Pennsylvania's proximity to the world's richest markets; facilitate the marketing of Pennsylvania's products and services in "megalopolis."

5. Encourage the pioneering of new technological developments and growth in the life sciences, urban engineering, coal and nuclear energy, and the forest products industries.

6. Promote and encourage materials research and production in Pennsylvania.

7. Make Pennsylvania the "Transportation Research and Development State" to insure full participation in growth industries.

8. Keep more young people in the state, particularly those who are dynamic and have potential for making great contributions to industry, services, or the arts.

9. Attract to Pennsylvania more of the nation's influential decision-makers from the business, education, and science.

One could argue with the goals and objectives just mentioned, or perhaps add to the list the goals and objectives that seem equally worthy of pursuit. However, the goals and objectives, as presented, do give direction for the purposes of planning. They provide the first step toward development of the Interim Master Plan for Transportation. The next step is concerned with the identification of alternative projects that will serve the foregoing enumerated goals.

IDENTIFICATION OF ALTERNATIVE PROJECTS AND PROGRAMS

The second step in the planning process was to generate ideas for alternative transportation improvement programs and projects that could be directed toward meeting the goals and objectives. In most instances this meant finding suitable ideas for adding to the existing transportation and socioeconomic infrastructure in Pennsylvania and for connecting with developments in contiguous states. Also it is often possible for the Commonwealth to add support to ongoing plans of existing organizations or favorably alter their plans by initiation of appropriate projects. Even the administrative and regulative aspects of transportation-related improvements can provide the genesis for possible programs and projects.

It was necessary to conduct a systematic search through several sources for candidate activities to include in a master plan. The sources that most often give rise to ideas for transportation-related projects and programs worthy of consideration are shown as follows: advances in technology; programs of federal government agencies; programs and activities of state and local agencies; transportation-related plans and activities of private enterprise; extrinsic and intrinsic social, economic, and geographic forces; and existing rules and regulations that apply to transportation-related construction, financing, and operations. A preliminary effort was made to generate ideas by exploring these sources. In all a total of 93 projects and programs were identified. However, these 93 projects and programs represent only a selection of principal projects and programs from a universe of possibilities, and some elements of federal, state, and local plans were purposely omitted. Other transportation developments, such as improved locks on navigable rivers, the SST, new facilities for unloading oil from supertankers, etc., are largely the responsibility of the federal government or private industry. These projects have been purposely excluded since they require little if any state funding or guidance.

TABLE 1

SAMPLE PROJECTS FOR EVALUATION

PROJECT			ESTIMATED COST RANGE	PERCENT STATE-FUNDED
NO.	TITLE	DESCRIPTION		
U. URBAN COMMUTING AND METROPOLITAN TRANSPORTATION				
U-4	DEMONSTRATE ELECTRIC CARS	DEMONSTRATE USE OF ELECTRIC CARS IN PHILA. FOR 1976 BICENTENNIAL	$1,000,000 TO $5,000,000	17%
U-5	RAILBUS DEMONSTRATION	FINANCE RAILBUS DEMONSTRATION PROJECTS AT PHILA., HARRISBURG, AND PITTSBURGH	$700,000 TO $1,000,000	17%
U-6	STUDY AERIAL TRAMWAY AT PITTSBURGH	STUDY COSTS, BENEFITS, AND SOCIAL IMPACTS OF AN AERIAL TRAMWAY FROM GOLDEN TRIANGLE TO DUQUESNE HEIGHTS	$5,000,000 TO $20,000,000	17%

The 93 projects and programs were grouped according to their nine principal characteristics, e.g., (R) Intercity Railway Improvements, (H) Intercity Highway Construction, (U) Urban Commuting and Metropolitan Transportation, etc. In some cases, such as that of "Keystone Corridor" construction, the complexity of alternatives associated with the program dictated subdivision into several numbered project components. For some projects and programs the study and implementation also were considered separately. The numbers attached to the projects are for purposes of identification and in no way reflect any assigned priorities of importance. A sample of the identified projects and programs is shown in Table 1. It will be noted that many of the projects are in the nature of "feasibility studies." Such studies are not to be confused with "engineering studies" made after the decision to implement has been made; e.g., a decision to build an Interstate Highway through a corridor across the state implies a subsequent engineering study to determine the best specific route within the corridor.

Costs were assigned to projects and programs by placing them in one of 16 cost range categories to reflect the uncertainties involved in cost estimation. In many cases these costs were very far from precise because of lack of available cost information.

Finally, Table 1 shows in the right-hand column estimated percentages of the total project investment costs that the state government would incur in carrying out the projects and programs listed. The costs to the state were used in the next step of the planning process to evaluate the relative merits of the alternative projects and programs in order to select the ones for inclusion in the recommended Interim Master Plan.

EVALUATION OF ALTERNATIVES

The third step in the development of the Interim Master Plan was the selection of those projects that would best serve the transportation planning goals of the Commonwealth. Almost any project to modify Pennsylvania's transportation system outlined in the preceding section will seem desirable to some citizens and undesirable to others. For example, construction of an urban freeway will immediately satisfy the goals of reduced travel time and increased travel opportunities, but may also be contrary to the social goals of reduced noise, enhanced visual aesthetics, and reduced air pollution. Furthermore, many proposed projects will involve localized benefits with the costs spread statewide. How then can decisions be made about what transportation improvements to make for whose benefit? It is clear that there is no "right" answer to this question and that there never will be. A resolution of this problem requires a definitive statement of the relative importance of all possible planning goals, and the difficulty, previously illustrated, is that pursuing one objective will typically deny another. Thus, the only theoretically valid procedure for ranking projects would be by a vote of all citizens of the Commonwealth, and even that ranking would doubtless be of ephemeral interest, since what people value highly today may be of little concern tomorrow.

In the absence of any empirical data about the relative values Pennsylvanians attach to transportation planning goals, one approach for initiating project evaluation is to set forth a number of "reasonable" divergent goal sets and examine the sensitivity of project selection to the alternative weightings. This is the approach that has been followed in the development of this plan.

The recommended Interim Master Plan was based on selecting from all the alternative projects and programs those that were most beneficial in terms of multiple goal satisfaction and that could also be purchased within a specified budget level. The following steps were involved in this evaluation process:

1. Defining benefit categories;
2. Rating each proposed project in terms of anticipated relative benefits in each benefit category;
3. Normalizing benefits assigned in step 2;
4. Estimating anticipated project costs to state;
5. Ranking transportation goals and benefit categories;
6. Determining probable project budgets; and
7. Calculating benefit/cost to select projects.

Definition of Transportation Benefits

In order to evaluate the extent to which the goals will be achieved by the alternative projects proposed, it was necessary to define benefit categories that could be used to measure goal achievement. The benefit categories used in the development of this plan are defined in the following.

The benefit of increased capacity pertained to improvements in the throughput capability of a given transportation facility that did not necessarily make increased travel speeds possible. It could be measured as the expected volume of additional freight or passenger traffic to be moved per unit time.

The benefit of increased travel speed given was considered to result from improvements that decreased travel time. It could be measured by the expected amount or percentage of total trip time to be saved on a given journey.

The benefit of improved safety was included to reflect the decreased hazards achieved by transportation improvements. It could be measured by the expected reduction in accident rates and the decreased rates of death, injury, and property damage attributable to such accidents.

The benefit of improved comfort and convenience pertained to the comparative comfort and convenience of the alternatives. In the case of public transport projects it can be measured in terms of the anticipated headway between conveyances.

The benefit of cost savings and efficiency pertained to the dollars per year of savings anticipated from a given project and/or to the expected increased amount of utilization of currently idle capacity.

The enhanced economic development benefit pertained to the amount of anticipated increase in the employment base of the state for each given industry group. It was intended to encompass all the economic development goals.

The increased tourism and enhanced recreational opportunities benefit pertained to increasing tourism and recreation by improving access to Commonwealth facilities. It could be measured by the estimated increase in visitor-days per year, for example.

The improved land use benefit was included to reflect the altered land uses expected to result from modifications in the transportation network. It could be measured by the number of acres shifted from one category of use, such as residential land use, to another category, such as industrial and commercial land-use.

The benefit of enhanced social values was intended to encompass all the social goals and was considered to involve both subjectively judged factors, such as the amount of aesthetic enhancement achieved by a particular project, and objectively measurable factors such as changes in air pollution and noise levels.

Obviously, some of the benefits could be expressed in quantitative terms (if data were available) such as the amount of increased capacity, the amount of decreased travel time, the amount of cost savings and/or the amount of available excess capacity utilized, the amount of additional employment generated per industry group, the type and amount of anticipated land-use change, and the number of additional tourist days anticipated. However, other benefits that embody definitely nonquantifiable values, such as comfort and convenience, are clearly only subjective judgments.

Project Benefit Ranking

The relative ranking of the nine benefits anticipated from each project was accomplished by a committee of technical experts. The mechanics of the procedure involved assigning a number to each benefit for each project; an arbitrary numerical scale from -5 to +5 was used in which +5 was defined to represent 100 percent or greater improvement, +4 represented a 50 to 99 percent improvement, +3 represented a 25 to 49 percent improvement, +2 represented a 10 to 24 percent improvement, +1 represented a 5 to 9 percent improvement, and 0 represented insignificant improvement (less than 4 percent), with the negatives representing similar amounts of dysbenefit. However, the choice of the scale used was immaterial so long as the degree of achievement of each benefit for each project relative to all the other benefits of that project could be conveniently represented.

TABLE 2

ALTERNATIVE GOAL RANKINGS USED IN PROJECT EVALUATION

BENEFIT	BENEFIT RANKING		
	TRANSPORTATION-SERVICE IMPROVEMENT	ECONOMIC DEVELOPMENT	SOCIAL DEVELOPMENT
INCREASED CAPACITY	100	10	20
INCREASED TRAVEL SPEED	100	20	10
IMPROVED SAFETY	20	10	20
IMPROVED COMFORT AND CONVENIENCE	100	20	50
COST SAVINGS AND EFFICIENCY	20	50	10

Normalization of Benefit Ratings

The benefit ratings assigned in the preceding step were normalized in terms of the percentage of the state population anticipated to receive them. This was necessary so that two projects with equal benefit ratings were not weighed equally when one was of statewide impact and the other of local interest only. Clearly, other normalizations reflecting the number of different interest groups affected by a given project and scaled to reflect their relative importance are also of interest, but such refinement attach more precision to the benefit estimates than is meaningful.

Estimation of the Anticipated Project Costs

If infinite amounts of money were available to the Commonwealth to spend on transportation projects, then all the transportation planning goals could be satisfied and discrimination among projects would be unnecessary. However, as the Commonwealth has to operate within a limited budget, project costs had to be included as an element in the evaluation. The costs employed were the out-of-pocket investment costs to the Commonwealth, because it is these costs that are charged against the state budget for new programs (admittedly this approach is less than justified from a "national" standpoint). The cost estimates and probable share of the costs to be funded by the Commonwealth for each project were given in Table 1. Use of these estimates in the evaluation involved taking the midpoint where a cost range was shown or the probable cost where it was known, and then multiplying the appropriate cost by the percentage to be funded by the state.

Ranking of Transportation Goals

As mentioned previously, the most crucial aspects of the evaluation of alternative projects involved ranking, relatively, the goals of transportation planning. To circumvent the difficulties involved in basing a master plan on such completely subjective and arbitrary choices, the approach followed was to develop a number of different sets of goal weightings (termed overall development goals) and examine the sensitivity of the project selection to the alternative weightings. Three overall alternative transportation development goals were, therefore, emphasized in the evaluation as follows: improve transportation service; develop state economy; and make Pennsylvania a better place in which to live (social development).

A partial listing of the individual benefit rankings used for each overall goal is given in Table 2. Although a ranking scale of 0 to 100 was used, the choice of scale is immaterial so long as the value attached to each goal relative to all other goals can be conveniently represented. Alternative goal weightings could, of course, be employed. Indeed, the development of a means for establishing a consensus of goals is a political task of the first magnitude for the state government. Several methods and techniques have been proposed for ranking or weighting goals (4, 9, 10, 11, 12, 13, 14).

Determination of Probable Budgets for New Projects

Because the determination of the budget that the Commonwealth should spend for new projects will be very much related to the projects for which expenditures are proposed, it was necessary to examine the sensitivity of project selection to the assumed budget. Two somewhat arbitrary budgets were assumed. The first budget for new projects was simply the existing state-funded new project budget for the Pennsylvania Department of

Highways, estimated to be approximately $300 million per year or $2.0 billion in the period through 1975 covered by this plan. The other budget was defined as the amount required for all of the separately numbered projects that were mutually exclusive; this budget amounted to $4.9 billion.

Benefit-Cost Calculations

The usual procedure in the benefit-cost approach to project evaluation is to place the benefits and costs on some commensurate scale. The most popular approach to this scaling problem has been to use the dollar as the scaling unit. For example, in transportation planning, values are often assigned to travel times and accident rates so that these benefits can be combined algebraically with costs. Then projects are ranked on the basis of some measure of total minimum transportation cost. Although this approach is very convenient, it is clearly inadequate for assessing the many important qualitative benefits of transportation programs. Thus, it was necessary to adopt some other evaluation technique. We have employed for this purpose a computerized resource allocation model developed by The Franklin Institute Research Laboratories specifically for evaluating subjectively determined program benefits in the light of a set of weighted goals subject to overall cost constraints. This model was originally developed to assess cultural exchange programs for the U. S. Department of State (15) and has been adapted for use in developing the Interim Master Plan. Similar concepts for plan evaluation have been proposed by Alexander (16) and Manheim (17). Basically, this model selects the combination of projects that will maximize the procurement of benefits, given specified project costs and a budget level that is to be spent but not exceeded.

The model can be exercised in either of two modes. One mode assumes that the procurement of additional amounts of a given benefit is of decreasing marginal utility [see Jessiman et al (11)]; the other mode assumes that procurement of additional amounts of a given benefit is equally as valuable as the original procurement of that benefit. Both modes were used in this evaluation as another test of the sensitivity of project selection.

The inputs to the model are the elements of information derived in the previously described steps of the evaluation. Forms similar to that shown in Table 3 were completed for each project. This information was next transferred to punch cards along with descriptions of the relative goal rankings and the budget levels to be tested. The resource allocation model was then exercised using a computer to select projects for inclusion in the Interim Master Plan.

The resource allocation model utilizes a technique related to linear programming, but very much simplified to reflect the approximations used as inputs. Basically, a project-by-benefits matrix is formed from Table 3; this is multiplied into a vector of benefit rankings (from Table 2), and divided by a project costs vector (from Table 1). The result is a vector containing a cost-effectiveness number for each activity. The model then "buys" the project with the highest cost-effectiveness number.

TABLE 3

COST/BENEFIT DATA FOR PROJECT EVALUATION (ILLUSTRATIVE)

PROJECT	EVALUATION ELEMENT						NORMALIZING FACTOR
	COST TO STATE ($ X 1000)	CAPACITY INCREASE (THROUGHOUT)	SPEED INCREASE (TIME SAVING)	COST SAVING AND EFFICIENCY	ECONOMIC DEVELOPMENT	IMPROVED SAFETY	
RENOVATE HARRISBURG RAIL TERM.	360	0	0	0	1	0	0.03
ESTABLISH FOREIGN TRADE ZONES IN PA.	75	0	0	5	5	0	0.60

At this point, if the model is being exercised in the "marginal utility" mode, the benefit ranking numbers are reduced to reflect partial satisfaction of the benefits; the amount of this reduction is in proportion to the relative amount of each goal provided by the "purchased" project.

The model then recomputes the cost-effectiveness numbers of the remaining projects, and "purchases" a second project. This iterative process continues until the budget is exhausted.

TABLE 4

PRELIMINARY RESULTS OF PROJECT EVALUATION

PROJECT		BUDGET = $ 2 MILLION			BUDGET= $
NO.	TITLE	IMPROVE TRANSPORTATION SERVICE	ECONOMIC DEVELOPMENT	SOCIAL DEVELOPMENT	IMPROVE TRANSPORTATION SERVICE
U-4	DEMONSTRATE ELECTRIC CARS	√	√	√	√
U-5	RAILBUS DEMONSTRATION	√			√
U-6	STUDY AERIAL TRAMWAY AT PITTSBURGH		√	√	

RECOMMENDED INTERIM MASTER PLAN FOR TRANSPORTATION

The resource allocation technique described in the preceding section was used to evaluate the 93 projects and programs previously delineated. As indicated previously the technique was based on estimating the project investment cost to the state and the extent of benefits to be provided in each of nine categories. These estimates were manipulated using three goal-ranking assumptions to allocate benefits in combination with two assumptions about the budget for new projects. A portion of the results are shown in Table 4. Those projects and programs chosen under each of the combinations of assumptions are indicated by "√'s." Those projects and programs that received a √ under all combinations of assumptions were assigned the highest priority in the Interim Master Plan for Transportation. Those projects and programs that did not receive any √ were assigned the lowest priority; also projects with two √'s or less were assigned the lowest priority. The remaining projects and programs were assigned to the second highest priority, their execution depending on the relative goal values the Commonwealth wishes to emphasize and the funds that it wishes to make available.

The results of the benefit-cost evaluations were then used to prepare the recommended Interim Master Plan, a portion of which is shown in Table 5. The table shows the projects, project cost to state, and total project cost for each priority group. The order of projects within each priority group is arbitrary and has no significance.

Assuming that the Commonwealth will be able to continue spending at the current level of the Pennsylvania Department of Highways, approximately $2.0 billion in state funds will be available for new projects in the period to 1975. This will be sufficient for all projects in the highest priority and the second-highest priority categories. (It will be recalled that many of the projects are in the nature of feasibility studies.) Hence, the projects in these two categories comprise the recommended Interim Master Plan for Transportation in Pennsylvania to 1975. This Plan is estimated to cost approximately $1.9 billion to the state and $4.1 billion on an overall basis. This does not include the estimated costs for implementing those projects requiring prior feasibility studies. Assuming that each of the projects studied will be found worthy of implementation, it is estimated that an additional $5.0 billion in state funds and $7.2 billion in total (state plus federal and local) funds will be required to imple-

TABLE 5

RECOMMENDED PROJECT PRIORITIES FOR INTERIM MASTER PLAN

PROJECT		PROJECT COST	
NO.	TITLE	TO STATE	TOTAL
	1. HIGHEST PRIORITY		
U-4	DEMONSTRATE ELECTRIC CARS	$ 510,000	$ 3,000,000
H-2	COMPLETE MAJOR HIGHWAY IMPROVEMENTS	$ 750,000,000	$1,500,000,000
T-1	CONSTRUCT TOCKS ISLAND ROAD	$ 22,300,000	$ 44,600,000
	2. NEXT-TO-HIGHEST PRIORITY		
R-17	IMPROVE SELECTED RAIL STATIONS	$32,000	$190,000

ment these projects. Thus the total out-of-pocket investment cost for studying and implementing all projects included in the Interim Master Plan is estimated to be $11.3 billion of which the Commonwealth's share amounts to $6.9 billion.

LIMITATIONS OF METHODOLOGY

On this first effort at developing a master plan, it is, of course, unlikely that all of the goals and objectives that might be served by transportation development have been treated in sufficient depth. Nevertheless, a first attempt has been made at providing goals with projects appropriate to their achievement. Although the analysis and ranking of the projects will provide some guidance for initial actions by the Commonwealth, the important point is that this approach illustrates a methodology for evaluation that can be used until the more sophisticated methodology is available. Goals must be specified, in the interim, and the contributions of various projects to their achievement must be evaluated. Although this technique has merit for the initial efforts at shaping a Master Plan for Transportation, it clearly has the disadvantages associated with the arbitrary ranking of benefits and estimating of costs under conditions of less than adequate knowledge. Nevertheless, it is still a refinement on using intuitive judgments to allocate resources when benefits are difficult to quantify in terms of dollar values.

Because so large an element of subjective judgment is now, and always will be, involved in assessing transportation benefits, it is important that participation by legislators, governmental executives, officials of private enterprises, and public interest groups be solicited in the evaluation process. In this context there are two distinct problems: weighting benefits and ranking goals. Although many benefits are quantifiable and thus can be evaluated with precision by technical experts, the evaluation of qualitative social benefits is clearly a political problem. As such, it cannot be resolved solely by technicians or even by deference to the opinions of decision-makers. The determination of transportation goals, involving as it does the basic values of our society, and the ranking of these goals, are likewise a political problem, solvable only through the political process. No one group is competent to decide which goals should dominate Pennsylvania's development or to assess the benefits of implementing alternative programs. These matters must be resolved through the political process of free, democratic debate.

It must be recognized that the development of the Interim Master Plan is based only on the evaluations of a few selected experts using arbitrary sets of goal weightings; it must also be evaluated in the forum of public opinion by the citizens of the Commonwealth. The real utility of any transportation system to the Commonwealth lies not in the demonstrable benefits calculated by a systems analytic framework, but in the perceived benefits measured by individual citizens whose economic, social, and cultural activities will be served through improved transportation.

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Discussion

ROBERT H. MURRAY, Texas Instruments Incorporated—The authors maintained a commendable consistency in the level of detail employed throughout this evaluation. For example, they avoided the pitfall of plunging into the depths of cost analysis while leaving the overall goals undefined, or vice-versa. Instead, they cut through the problem using the "committee of experts" approach. This enabled them to immediately estimate (a) the relevance of benefits to very general goals, and (b) the effectiveness and relative impact of each project-benefit combination. This level of detail seems quite appropriate for the type of first-cut evaluation and the time frame (1975) specified.

In view of this, it is not surprising that the authors have also produced a very lucid description of their work and the supporting rationale. Since cost-effectiveness evaluations are ineffective until communicated, this is no idle compliment.

It is surprising, however, that a computerized model is cited as the most important feature of the methodology. The innovative mechanisms, the key assumptions and their impact, and the application of such an approach to transportation planning are more interesting, and far more important, than the utilization of one tool or another.

In evolving a formal cost-effectiveness approach to social systems engineering, in which transportation planning occupies an important role, several additional suggestions might be useful, using the work described in this paper as a point of departure.

First, goals should be carefully defined and should address the basic desire for an improved quality of life. These goals should be projected ahead in time to be valid in the time frame of goal achievement. Value forecasting is integral to this task, and work is only recently under way in this area. Value forecasting is also central to normative technological forecasting, another argument in favor of increased emphasis on this discipline.

Second, quantitative evaluation parameters should be defined and mapped into the previously defined goals. Intermediate levels, such as objective and mission definition, can be employed if the problem requires such detail and/or visibility.

The traditional reluctance to quantify subjective factors is inappropriate in view of the fact that all decisions are made quantitatively. An example can be seen in any city's annual budget: the park department, the traffic control department, and the police department are each allocated a different amount of money. This demonstrates a collective decision that somehow quantitatively balances the desires for recreation, transportation convenience and safety, and protection. It would be better to admit this and face the problem directly so that explicit assumptions, definitions, and relative weights can be developed, discussed, revised, and voted on.

Also, expert assistance in quantifying subjective parameters might be obtained more readily if these people realized the normal inaccuracies in our forecasts of objective parameters such as dollar costs.

Third, when identifying and formulating alternative choices, all projects that produce a significant benefit should be considered, especially when the cost is largely borne by another agency. This not only permits consideration of extremely cost-effective projects, but also encourages coordination with other governmental and industrial elements having mutual interests. This was precluded in the authors' evaluation, since projects that were largely the responsibility of industry or the federal government were not considered.

Fourth, when a committee of experts approach is used to evaluate candidate projects, attempts should be made at achieving a consensus. One possibility would be to qualify two or three panels and correlate their findings.

The DELPHI technique, combining quantitative expert opinion, iteration, and consensus-without-confrontation, would seem to be an appropriate vehicle for this type of evaluation, but requires significant commitments from many key people over a period of time to be effective.

One final comment is that the authors' commitment to maximize the received benefit-cost ratio is commendable. This underscores the need for innovative mechanisms that can utilize some evaluation technique to present alternatives to the public, and for collecting and compiling their choices. The people will be heard, and this approach may be a means for an interested public to get directly involved in running their own affairs.