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Evaluation and Application of a Priority Programming System in Maryland

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This paper presents the process and results of evaluation, selection, and implementation (on a test-case basis) of a priority programming methodology for the Maryland Department of Transportation that was part of a National Cooperative Highway Research Program project. The methodologies that were evaluated for application to the state of Maryland included (a) the priority programming system (PPS), (b) the highway investment analysis package, (c) the objective priority programming procedure, and (d) the transportation resource allocation model. Other programming techniques were considered but eliminated through a screening process. Criteria were formulated to assist in the evaluation. PPS is a computerized tool for the estimation of the road-user benefits of individual highway improvements as a function of when the improvement is implemented and the subsequent scheduling of implementation of sets of improvements so that total user benefits are maximized. Benefits can be broadly defined (e.g., social, economic, environmental, or travel) costs or focused on user (travel-time, accident, operating) costs depending on the preferences of the state. The PPS was successfully used for the determination of priorities in a test case of 26 of the largest primary state highway projects. The paper concludes by discussing from the Maryland perspective the ways that the PPS in particular and priority programming tools in general can be used in addressing transportation issues of statewide concern.

Transportation agencies face a complex decision-making environment that includes multiple actions and strategies to improve mobility and, given other societal concerns, finite resources. Individual or packaged actions taken by these agencies require a dynamic evaluation process to consider a wide range of issues and potential actions, information about numerous impacts, and a large number of different viewpoints. Such a process for identifying and resolving state-level issues is illustrated in Figure 1 (1). As indicated, techniques and tools to provide this information can vary from surveys to monitoring and models. There is increasing pressure to have tools that are quick to use and sensitive to the issues.

Many states are now also confronted with issues related to revenue shortfalls; the development of multimodal transportation policies, plans and programs; and a host of other concerns.

In 10 of the 13 states consulted in a National Cooperative Highway Research Program (NCHRP) project (1,2), the determination of transportation priorities was identified as a major concern. In the highway mode, it was of concern in 7 states and, in respect to nonhighway modes (transit, rail, and airports), it was of concern in no more than 3 of the states. The multimodal and mode-specific issues come at a time when programmed transportation projects are quite large. This requires hard decisions related to state-level transportation programming that will work toward achieving mobility goals within available resources.

The state transportation departments need a tool to assist them in working with the legislatures, governors' offices, and affected communities in making an objective and rational transportation-priority program. Often different parts of the same organization perceive entirely different transportation program-expenditure cycles. It is necessary to draw these different viewpoints into a common perception so that a more pragmatic approach can be taken in presenting transportation programs to the public, elected officials, state legislatures, and the governors' offices.

This paper discusses an experience of evaluating, selecting, and applying transportation-priority programming methods in Maryland. An actual test case of applying the priority programming system (PPS) developed by the Ministry of Transportation and Communications in Ontario to 26 of the largest primary-highway projects in the state was undertaken for purposes of developing project priorities. This paper discusses the findings of this work and the implications for other state-level transportation-priority programming efforts.

EVALUATION OF PRIORITY PROGRAMMING TOOLS

With the knowledge of issues and views of the various states in mind, an evaluation was made of alternative priority programming tools for assisting the state of Maryland. Because of strong multimodal trade-off pressures, the development of priorities was a significant issue in the development of a 5-year program budget, a long-range master plan, and mode-specific planning and programming processes. The idea was to select a tool to be used, apply it to a test case, document the experience, and through NCHRP disseminate the results to potential users in other states. This section discusses the tools examined, the criteria selected by the Maryland Department of Transportation (MDOT) and the consultant team for evaluation, and the results of the evaluation.

Candidate Tools Examined

Four different tools were examined: (a) the objective priority programming procedure (PRIPRO) (3), (b) the highway investment analysis package (HIAP) (4), (c) the priority programming system (PPS) (5), and (d) the transportation resource allocation model (TRANS) (6). MDOT has computerized versions of these tools available, based on the recommendations of a resource-allocation task force that had functioned in 1974 and 1975. Other tools were evaluated through a Highway Research Information Service search and extensive literature review.

Criteria for Evaluation

After extensive discussions with MDOT, a list of 12 criteria were formulated to broadly evaluate the alternative tools. Ten of these criteria relate to the needs of Maryland, and 2 relate specifically to the needs of the NCHRP project.

Figure 1. Framework for identifying and resolving state-level transportation issues.

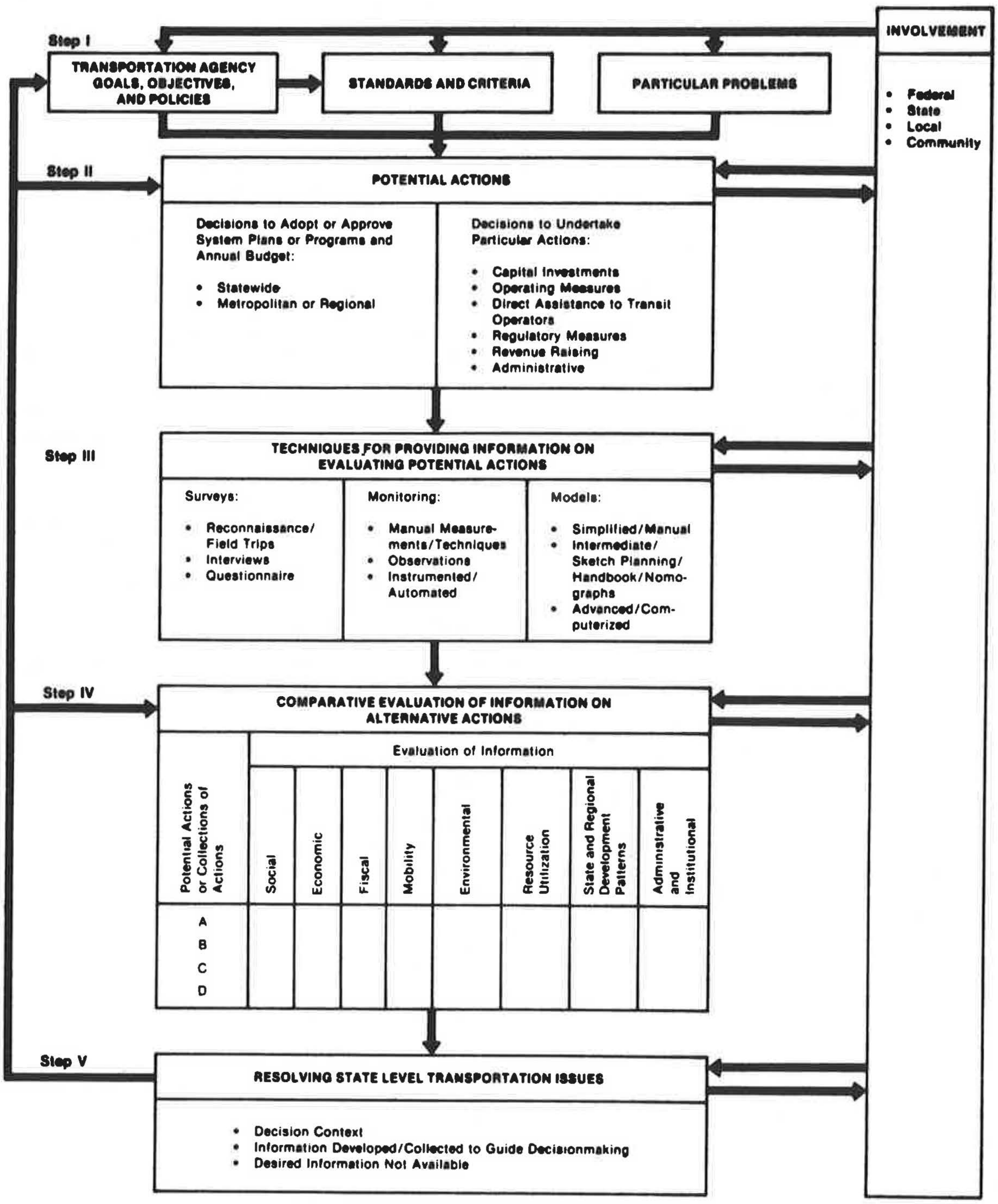


Table 1. Evaluation of alternative priority programming tools.

Criterion	Relative Rating[a]			
	PRIPRO	HIAP	PPS	TRANS
Directly applicable to next cycle	Moderate	Moderate	Moderate	Moderate
Compatible with MDOT capabilities	Good	Moderate	Moderate	Moderate
Usable with available data	Moderate	Moderate[b]	Poor	Moderate
Theoretically sound	Poor	Moderate	Moderate	Moderate
Comprehensible to users	Poor	Good	Good	Good
Shows rationale for priorities	Moderate	Good	Good	Good
Multiyear constraint capability	Poor	Moderate	Good	Poor
Indicates sensitivity to assumptions	Poor	Moderate	Good	Poor
Multimodal capability (long run)	Moderate	Moderate	Moderate[c]	Moderate
System relationships	Poor	Moderate	Moderate	Moderate
Demonstrated use	Moderate	Poor	Moderate	Moderate
Transferability	Good	Good	Good	Good

[a] Ratings are relative.
[b] HIAP can accept needs study files; otherwise HIAP and PPS are equivalent.
[c] The software packages are intended for use on highways only; the underlying methodologies are not limited.

The MDOT criteria were that the selected procedure (tool) should be

1. Directly applicable in the next state programming cycle;
2. Compatible with the staff and computer hardware capabilities;
3. Usable with currently available data;
4. Theoretically sound;
5. Comprehensible and acceptable to the full range of MDOT users and their clientele;
6. Able to show not only the priorities established, but also the rationale for these priorities;
7. Able to deal with multiyear budget constraints, including staging questions and delay versus deletion of improvements;
8. Able to indicate sensitivity of priorities and project evaluations to changing conditions or assumptions;
9. Able to deal, in the long run, with multimodal improvements; and
10. Responsive to system relationships among projects.

The NCHRP criteria were that the selected procedure should have

11. Demonstrated applicability to issues of interest to statewide users and
12. Transferability of experience to other states.

Evaluation Results

By using the criteria listed above, an evaluation of the alternative methodologies was made as shown in Table 1 and summarized below.

Tool	No. of Ratings		
	Good	Moderate	Poor
PRIPRO	2	5	5
HIAP	3	8	1
PPS	5	6	1
TRANS	3	7	2

There were certain criteria that were particularly important to MDOT in their selection decision: multiyear constraint capability, sensitivity to different assumptions and uncertainty, long-run multimodal capability, and system relationships.

Multiyear constraint capability was important because MDOT has a series of revenue models and desires to test the impact of multiyear budget scenarios. The priority programming tool must be able to work with this type of financial data base. MDOT is in the midst of evaluating and formulating state-level transportation policies, plans, and programs through its Maryland Transportation Plan process and wanted a priority programming methodology that would be sensitive to factors such as assumptions and uncertainties of budget rates, traffic growth, and interest rates. On a long-run basis, MDOT wants a priority programming capability that can be expanded to determine priorities for all modes of transportation or, as a minimum, provide guidance to the secretary of transportation on modal emphasis for transportation investments by time period. Finally, the sensitivity of the priority programming methodology to system relationships was judged to be important because of the traffic impacts of decisions on interconnected systems.

Based on this evaluation, PPS was selected by MDOT for the demonstration as part of the NCHRP test case study. MDOT has experience in testing the other three tools. Although PPS requires input data in a form not normally available, it was decided to use this tool for testing purposes as part of the statewide transportation planning and programming process.

APPLICATION OF THE PRIORITY PROGRAMMING SYSTEM TO MARYLAND TEST CASE

After the decision to use PPS was made, four basic steps were undertaken to obtain and interpret the results:

1. Development of an annotated manual noting the procedure and caveats in the flow of information in the program,
2. Development and coding of a test case of 26 statewide primary highway projects,
3. Installation of PPS on the MDOT computer, and
4. Analysis and interpretation of the results.

These steps are described below. Caveats are noted.

Step 1: Development of Annotated Manual

As a first step, the existing documentation (5) was augmented by the addition of an annotated manual (7) that clarified the procedures noted in the existing documentation. Figure 2 shows the general flow of information in PPS. The PPS flow is illustrated through three packages: (a) user-benefit package; (b) edit and update, inflate and discount package; and (c) linear programming package. General inputs and outputs are illustrated and defined in greater detail for each of these packages in Table 2. Key concerns in applying PPS in Maryland were (a) to link the data input requirements for the PPS to the data normally available to MDOT and other state users and (b) to highlight the output results so that the information could be better used in making statewide transportation decisions.

Step 2: Development and Coding of Test Case

The input variables and project information were obtained from codification of 26 highway projects located in urban and rural areas throughout the state. This codification was critical to the analysis. Care was exercised to ensure that other highways related to the project were linked into the project description. This is the place where knowledge of the proj-

Figure 2. General information flow for PPS.

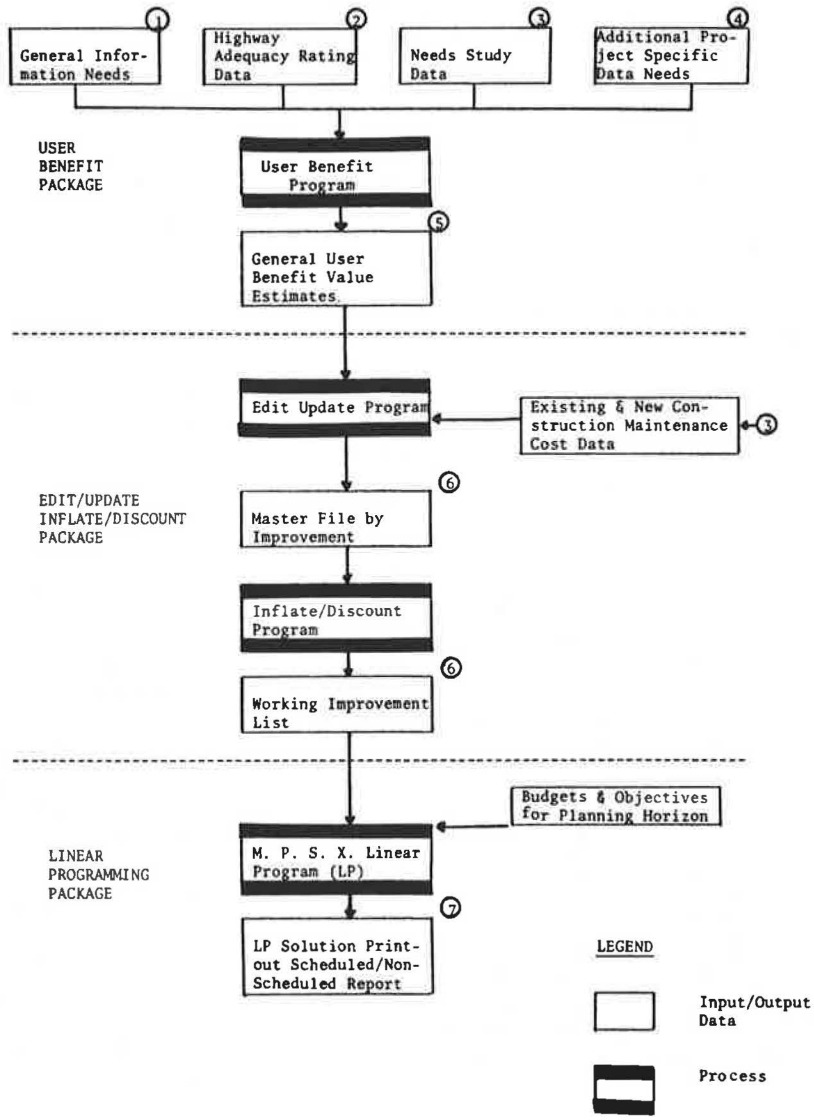


Table 2. PPS information requirements and output.

Inputs		
General Information Needs	Specific Variables and Project Information	Outputs
Vehicle operating costs	Highway adequacy rating	From user-benefit package
Fuel	Control of access	Vehicle operating costs
Oil	Lane width, number and type of lanes	Time
Tires	Shoulder width	Accidents: fatal
Mechanical labor	Passing sight distance (percent)	Accidents: injury
Vehicle depreciation	Length (miles)	Accidents: property damage
Time	Accidents/million vehicle miles	From edit and update, inflate and discount packages
Accidents	Grade	Master improvement list
Traffic inventory	Curvature	Salvage value
Permanent traffic-count station data	Type of pavement	Annual added-maintenance calculation
Avg one-way flows	Capacity (volume per hour)	Surface maintenance-savings calculation
Ratio of traffic-link flow to saturation flow	Needs study	Working improvement list
Percentage of trucks [base year and projected (assumed constant)]	Average daily traffic (base and projected years)	From linear programming package
	Planning costs	Inflated cost streams
Terrain	Engineering costs	Discounted benefit streams
Mountainous (western Maryland)	Right of way costs	Cost-benefit ratios
Rolling (central and southern Maryland)	Construction costs	Project starting dates
Level (Eastern Shore)	Other	
Occupancy rates (persons/vehicle)	Median width (field survey)	
Urban = 1.5	Average highway speed (posted speed)	
Suburban = 1.6	Number of intersections (field survey)[a]	
Rural = 2.0	Cycle length (seconds) (estimated)[a]	
	Number of hours parking allowed (field survey)[a]	
	Environmental factor (not used)[a]	
	Maintenance Costs (estimated)	

[a]Needed only for urban projects.

ect situation and travel patterns are important to a successful PPS application.

Much of the general information needed for traffic inventory, terrain, and occupancy rates was available in MDOT files. The permanent count-station data did require some manipulation to place it in the format required by PPS. Relationships for vehicle operating costs were supplied to MDOT (7) by the consultant team. Key project cost assumptions needed for the relationships were discussed with MDOT.

The data related to each project set were available in urban areas through the continuing coordinated comprehensive (3C) process and in rural areas through sketch-planning-type processes.

Table 3. Twenty-year benefits by type and project: Maryland test case.

	Benefit (millions of 1978 dollars)			
Project No.	Vehicle Operation[a]	Travel Time[b]	Total Accident	Total User
1	3.954	57.354	-0.250	61.058
2	5.442	24.822	1.490	31.754
3	-9.268	15.257	2.092	8.097
4[c]	83.120	651.429	-0.787	733.762
5	0.903	19.477	0	20.380
6	2.223	44.077	0.507	46.807
7	2.810	63.450	0.397	66.657
8	2.127	18.357	0.250	20.734
9	6.160	42.879	0.194	49.233
10	0.211	16.515	0.184	16.910
11	2.237	43.806	0	46.043
12	0.447	7.270	0.070	7.787
13	0.290	2.968	0.212	3.470
14[c]	1.050	20.059	1.892	23.001
15[c]	0.248	2.279	0	2.527
16	-2.724	12.990	1.673	11.939
17[c]	-20.295	-44.314	-0.675	-65.284
18	0.759	23.931	-0.720	23.970
19	1.558	33.969	3.183	38.710
20	6.176	141.237	0	147.413
21	3.923	70.377	0.988	75.288
22[c]	2.512	55.704	0.802	59.018
23	-7.888	0.819	-1.182	-8.251
24	2.282	2.880	0.356	3.518
25	0.198	1.315	0.117	1.630
26	0.000	0.039	0.001	0.040

[a]Peak summer volumes not emphasized because of use of annual daily traffic.
[b]The value of travel time = $4.70/passenger automobile, $8.00/single-unit truck, and $12.00/tractor trailer.
[c]These were treated as split projects and staged into a series of improvements.

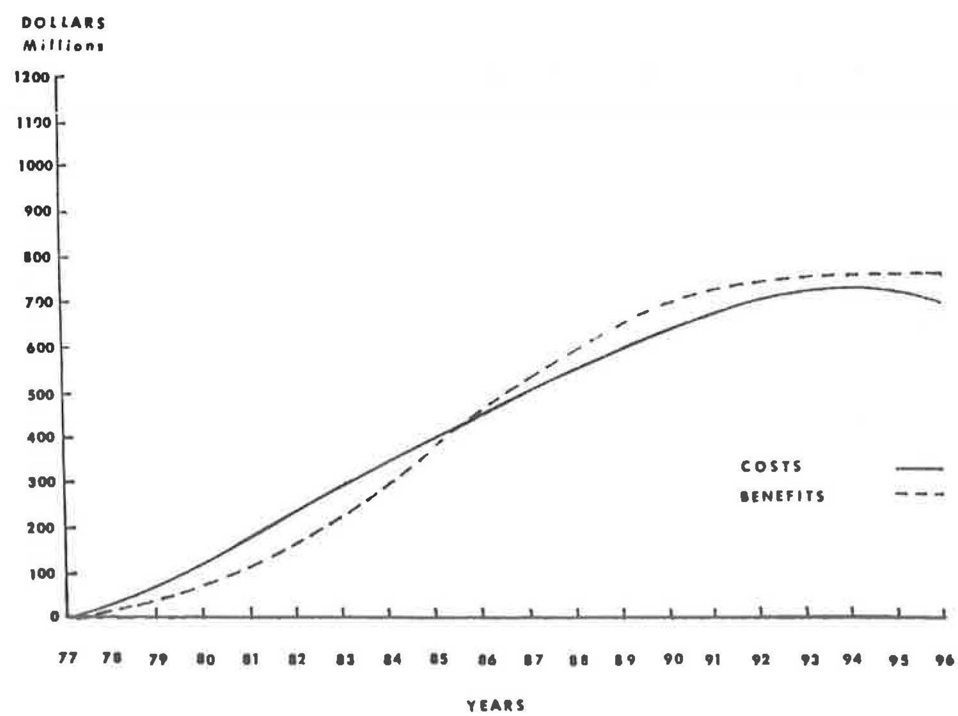
The test case assumed budget constraints of $35 million in year 1, $45 million in year 2, and $75 million each year thereafter. These budget constraints excluded right-of-way costs because of technical problems. A total $800 million expenditure, therefore, is related to projects whose costs exceed $1 billion when right-of-way costs are added. The total project costs for all projects was $1.4 billion. For purposes of the test case, costs beyond the horizon year were not included. The linear program, which solves for staging of projects, selected projects that optimized the discounted net benefits by assuming a 5.5 percent discount rate subject to the above budget constraint. This discount rate represents the cost of borrowing to the state rather than total opportunity costs.

The unusual features of the linear programming package are the use of diversion estimates and the ability to define dependency between projects and expected lags in construction or right-of-way acquisition. Other features are the use of varying inflation or discounts and varying time periods for benefit-stream or cost-stream calculations. In addition, projects are defined in kind of specific-improvement types related to incremental changes in capacity, so that two- to four- to six-lane projects are evaluated sequentially. The application of the PPS methodology in Maryland is based on the following assumptions: (a) the bond rate of financing used in Maryland was assumed to be the discount rate and (b) link-access costs were assumed to be negligible.

The outputs analyzed for the Maryland application were limited to user benefits and costs; the full complement of social, economic, and environmental (SEE) factors was not introduced. This decision to limit the analysis was based on the following reasons:

1. In Maryland, the 3C and state action plan processes screen through a great number of projects for SEE effects in the planning, rather than the programming, cycle. SEE effects have different values in different parts of the state. Environmental concerns in wetland areas near Chesapeake Bay are viewed

Figure 3. Comparison of cumulative benefits and costs: Maryland test case.



differently than environmental efforts in more urban areas where social and economic effects may be weighed higher than the physical environment. Therefore, projects entering the programming cycle were assumed to have already considered SEE effects to the point where costs to mitigate negative SEE impacts were determined.

2. In a report prepared by the Ontario Ministry of Transportation and Communications (MTC) (8), it was found that the difference between including SEE impacts in trial runs for highway projects and not including SEE effects resulted in only a 10 percent different in the benefit calculation and very minor differences in the determination of priorities. Because of this, the Ontario MTC has dropped SEE effects in their determination of priorities of highway projects.

Step 3: Installation of PPS on MDOT Computer

The PPS was installed on the MDOT computer after adding certain measures that were not apparent in available documentation. These were as follows: (a) a special PL 1/OS software library that was not available in Maryland and (b) MPSX/OS, a linear programming

Table 4. Priority schedule for highway projects: Maryland test case.

Project No.	Costs ($000) 1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
1	1 732	13 731	15 622	15 622	15 622	13 890	1 890			
2	4 839	4 840	4 840	4 840	4 840					
3						12 393	18 380	18 380	18 380	18 380
4										
5	4 619	4 620	4 620	4 620	4 620					
6								3 533	3 533	3 534
7							1 979	1 980	1 980	
8										
9				2	6 441	8 358	8 361	8 361	8 358	1 918
10										4 154
11										5 135
12							5 170	5 170	5 170	5 170
13							4 873	4 874	4 874	4 874
14				4 949	4 950	4 950	6 384	1 434	1 434	
15										
16										
17	8 057	8 058	8 058	8 058	8 058					
18	12 217	12 218	12 218	12 218	12 218					
19	8 639	8 640	8 640	8 640	8 640					
20								20 067	20 068	20 068
21					12 400	12 400	12 400	12 400	12 400	
22				3 940	3 940	3 940	3 940			
23	Not programmed									
24							4 299	4 300	4 300	
25			1 366	1 366	1 366	1 167	4 160	2 793	2 793	2 794
26			2 466	2 466	2 467					
Total	40 103	52 107	57 830	66 721	85 562	57 298	71 836	83 292	83 290	66 027
Cumulative total		92 210	150 040	216 761	302 323	359 621	431 457	514 749	598 039	664 066

Project No.	Costs ($000) 1987	1988	1989	1990	1991	1992	1993	1994	1995-1996	Total
1										78 109
2										24 199
3	5 986									91 899
4	9 998	29 259	29 259	25 259	29 261	19 262				142 298
5										23 099
6										10 600
7										5 939
8		3 153	3 153	3 153						9 459
9										41 799
10	4 155	4 155	4 155							16 619
11	5 136	5 136	5 136	5 136						25 679
12	5 170									25 850
13	4 874									24 369
14										24 101
15	10 899	10 901	10 901	10 135	10 135					52 971
16		4 259	4 260	4 260	4 260	4 260				21 299
17						4 391	4 391	4 392		53 463
18										61 089
19										43 199
20	20 068	20 068								100 339
21										62 000
22			3 940	3 940	3 940	3 940				31 520
23	Not programmed									0
24										12 899
25	2 794									20 799
26										7 399
Total	69 080	76 931	60 804	51 883	47 596	31 853	4 391	4 392		1 010 996
Cumulative total	733 146	810 077	870 881	922 764	970 360	1 002 213	1 006 604	1 010 996		

Note: Project expenditure cycles assume constant expenditure during construction except for split projects.

(LP) package, available only through IBM. Both of these were obtained by MDOT during the test application.

Step 4: Analysis and Interpretation of Results

The PPS was then applied to the test case of 26 highway projects. Table 3 shows the vehicle-operation, travel-time, accident, and total-user benefits for each of the projects by project number. (Names of the projects are omitted because of the sensitive nature of some.) These benefits shown are in 1978 dollars, cumulative over the 20-year planning period, and not discounted over time.

Figure 3 illustrates the cumulative project benefits versus the project costs and shows that (a) the cumulative project costs are within the $0.8 billion budget constraint and (b) between 1985 and 1986, the benefits begin to exceed the cumulative costs. Table 4 shows the priority schedule for the projects and how the PPS can be used to determine which of several projects should be started first to optimize the user benefits over time. This table also indicates a spending pattern that is at variance with the previously developed consolidated transportation program (CTP). The comparison indicates that, in light of budget constraints, the CTP 5-year program should be extended to a more realistic 10-year program.

In addition to preparation of a schedule for implementation of projects based on the optimization of user benefits, the packages in PPS might also be used to rank-order projects based on specific factors. Table 5 shows the ranking of projects based on vehicle-operation, travel-time, accident, and total-user costs. This ranking resulted from the user-benefit package, which was run before the inflate-discount package (see Figure 2). The table also shows a ranking of projects based on the benefit-cost ratio, which was obtained from the output of the linear programming package. This information can be used to adjust the priority schedule based on different state policies.

Table 5. Ranking of projects: Maryland test case.

	Ranking Based On				
Project No.	Benefit-Cost Ratio (discounted benefits for planning horizon)	Vehicle-Operation Benefits	Travel-Time Benefits	Accident Benefits	Total User Benefits for 20-Year Period
1	13	5	6	22	5
2	6	4	12	5	11
3	20	25	17	2	18
4	25	1	1	25	1
5	11	14	14	19	15
6	1	10	8	8	8
7	15	7	5	9	4
8	2	11	15	11	14
9	8	3	10	13	7
10	9	20	16	14	16
11	3	9	9	18	9
12	17	16	19	16	19
13	19	17	20	12	21
14	10	13	2	3	13
15	26	19	22	21	22
16	14	23	18	4	17
17	23	26	26	23	26
18	16	15	13	24	12
19	12	12	11	1	10
20	5	2	3	20	2
21	7	6	4	6	3
22	4	8	7	7	6
23	21	24	24	26	25
24	18	18	21	10	20
25	22	21	23	15	23
26	24	22	25	17	24

IMPLICATIONS TO STATEWIDE DECISION MAKING

The evaluation of alternative priority programming tools and the application of a specific tool (PPS) in Maryland indicated that these tools can assist a state in obtaining information (see Table 6). Several areas of application were identified in Maryland:

1. Development of the Maryland Transportation Plan (MTP)--MDOT is completing a statewide multimodal transportation plan. The MTP uses as input for highways a 20-year highway-needs study prepared by the Maryland highway administration and based on an adequacy rating system. Some of the needed highway improvements are at present contained in the 5-year CTP. The MTP classifies those items that are in the CTP for construction within the 5-year period as category 1 and those that are in the CTP for project planning or other preconstruction activities as category 2. Based on various financial projections for the 20-year period, MDOT through the MTP is attempting to identify those unprogrammed needs that have higher priorities and benefit-cost ratios as category 3 in the plan, as opposed to those unprogrammed needs, category 4, that have lower priorities and would fall outside the 20-year projection of available funding. The PPS can be used to help determine the category 3 versus category 4 split in future updates of the MTP.

2. Systems planning and special studies--MDOT conducts many areawide and modal systems planning studies where the PPS could be used to test alternative financing assumptions, facilities, or corridor alignments. Examples of these ongoing studies in-

Table 6. Comparison of information needs for priority programming tools.

	Priority-Programming Tool			
Information Need	PRIPRO	TRANS	HIAP	PPS
Ranking highway projects	Based on sufficiency ratings and cost effectiveness[a]	Based on effectiveness measures such as cost and weighted indicators	Based on benefit-cost indicators	Based on benefit-cost indicators
Ranking highway projects and introduction of budget constraints	Not applicable	Heuristic optimization procedure	Marginal analysis approach	Optimization through linear programming[a]
Ranking highway projects and introduction of budget constraints and SEE impacts	Considers SEE impacts but not budget constraints	SEE impacts considered by using weighted indicator factors	SEE impacts considered as constraints to eliminate projects[a]	SEE impacts outside of PPS; MTC found small difference in benefits; screen projects for SEE impacts before PPS
Ranking multimodal projects and introduction of budget constraints and SEE impacts	Highway oriented: could be made multimodal	Multimodal	Highway-oriented theory: could be made multimodal	Multimodal approach[a]

[a]Subjective judgment is the most direct and inexpensive approach to obtaining information needed.

clude the (a) northern Charles County transportation system study, (b) MD-100 corridor systems study, (c) Garrett County economic planning study, and (d) toll-revenue utilization study.

The last study, now under way, attempts to evaluate candidate toll facility or highway improvements that could be constructed from surplus revenues from an existing toll road. This type of analysis should consider that certain improvements would generate a revenue stream that should be factored into the cost-benefit calculation.

3. Program development--MDOT is using the PPS to develop various 5-year programs based on the status of projects and various constraints for state, federal, and bond revenues, as well as on production capabilities.

4. Project planning studies--PPS, specifically the road-user benefit package, can be used to evaluate alternative alignments in a project planning study.

SUGGESTIONS FOR FURTHER RESEARCH

Some improvements could be made in the existing program. For example, the linear program was run by using the procedure that maximized net present worth of benefits within budget constraints, but the mathematical programming system extended version can also use multiple objective functions. These might be the maximization of the net present worth of benefits minus the costs or the minimization of the present value of costs. A comparison of the priority rankings obtained by using the three objective functions would provide useful insight into the selection of the most appropriate of them. Another option of the PPS is to produce priority rankings in the linear program that maximize one of the three benefits components (vehicle operating, travel time, and accidents). This would be useful, for example, if a state is interested in saving energy and hence maximizing vehicle-operating benefits.

Some improvements could be made by revising the existing documentation for application of the PPS so that other users could apply it with greater versatility and flexibility.

Another area for further research is the development of user benefits programs for other modes that are comparable to the highway-mode program. The routine for the determination of priorities is applicable to all modes. This multimodal application may suggest a longer planning horizon (more than 20 years as is assumed for the highway mode). The successful application developed in Maryland involved a transfer of methodology as well as a review of areas in which further improvement is possible. These improvements would facilitate the use of this program by states concerned with user-cost trade-off evaluation for maintenance, new construction trade-offs, the determination of priorities in budget constraints, and the many other possible applications of benefit-cost analysis and linear programming in transportation decision making.

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REFERENCES

1. Evaluating Options in Statewide Transportation Planning/Programming: Issues, Techniques, and Their Relationships. Planning Environment International, McLean, VA; System Design Concepts, Washington, DC; and NCHRP, Rept. 179, 1977.
2. Techniques for Evaluating Options in Statewide Transportation Planning/Programming, State-Level Issues, and Information Needs. Planning Environment International, McLean, VA; System Design Concepts, Washington, DC; and NCHRP, Technical Memorandum 1, April 1976.
3. Objective Priority Programming Procedures: Narrative and User's Documentation. General Analytics, Washington, DC; Comsis Corp., Wheaton, MD; and U.S. Department of Transportation, 1973.
4. Highway Investment Analysis Package. Multisystems, Cambridge, MA; U.S. Department of Transportation, March 1976.
5. Priority Analysis: Systems Manual. Priority Programming Branch, Ontario Ministry of Transportation and Communications, Sept. 1974.
6. A Transportation Resource Allocation System for North Carolina. Ernst and Ernst, Washington, DC; North Carolina Department of Administration, June 1972.
7. Evaluating Options in Statewide Transportation Planning/Programming: Techniques and Applications. Planning Environment International, McLean, VA; System Design Concepts, Washington, DC; and NCHRP, Draft Rept., Jan. 1978.
8. Development of a Methodology for Planning Improvement Priorities: Phase 2. Ontario Ministry of Transportation and Communication, Working Paper, Aug. 1972.

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