TRANSPORTATION RESEARCH RECORD 742

Program Planning, Finance, and Preconstruction Management

TRANSPORTATION RESEARCH BOARD

COMMISSION ON SOCIOTECHNICAL SYSTEMS
NATIONAL RESEARCH COUNCIL

NATIONAL ACADEMY OF SCIENCES
WASHINGTON, D.C. 1980

Transportation Research Record 742
Price $4.00
Edited for TRB by Frances R. Zwanzig

modes
all

subject areas
11 administration
14 planning
21 facilities design

Library of Congress Cataloging in Publication Data
National Research Council. Transportation Research Board.
Program planning, finance, and preconstruction management.

(Transportation research record; 742)
Reports prepared for the 59th annual meeting of the Transportation Research Board.
1. Highway engineering–United States–Management–Addresses, essays, lectures. 2. Highway planning–United States–Addresses, essays, lectures. 3. Road construction–United States–Finance–Addresses, essays, lectures. I. Title. II. Series. TE7.H5 no. 742 [TE195] 380.5s [625.7'068]
80-18866 ISBN 0-309-03050-1 ISSN 0361-1981

Sponsorship of the Papers in This Transportation Research Record

GROUP 1–TRANSPORTATION SYSTEMS PLANNING AND ADMINISTRATION
Leon M. Cole, Library of Congress, chairman

Management and Finance Section
Ira F. Doom, Midlothian, Virginia, chairman

Committee on Taxation, Finance, and Pricing
Damian J. Kulash, Congressional Budget Office, chairman
Frank A. Maresca, Washington State Department of Transportation, secretary
Robert P. Aex, Bruce Barkley, Kiran Bhatt, Lawrence D. Dahms, Morton Ehrlich, Robert E. Fagley, Barry M. Goodman, John S. Hassell, Jr., Alice E. Kidder, Thomas D. Larson, Bruce D. McDowell, Walter F. Mead, Robert G. Prestemon, Richard H. Shackson, Fred Lee Smith, Jr., Joseph C. Smith

Committee on Manpower Management and Productivity
Raymond J. Colanduoni, New Jersey Department of Transportation, chairman
Chester J. Andres, L. Dean Blake II, Jack L. Brewer, David W. Davis, John T. Doolittle, Jr., Grant S. Fairbanks, Gene K. Hallock, Chester W. Higgins, G. V. Hood, D.L. Howell, Douglas L. Jonas, Thomas D. Larson, Gerald J. McCarthy, Lyle V. McLaughlin, Neil Craig Miller, Charles T. Morison, Jr., Gene Phelps, Wayne D. Pickerill, M. Ed Shaw, Theodore E. Stephenson, Gerald F. Tessman, Anthony R. Tomazinis, David Zaron

Committee on Transportation Programming, Planning, and Evaluation
Henry L. Peyrebrune, New York State Department of Transportation, chairman
Dan C. Dees, Illinois Department of Transportation, cochairman
James G. Chiles, Donald O. Covault, William J. Fognini, Frederick Gottemoeller, William M. Hilliard, Thomas F. Humphrey, John T. Lancaster, Sr., Richard D. Morgan, Monty C. Murphy, Charles William Ockert, Ian V. Oliver, Marshall F. Reed, Jr., Philip D. Robers, L.W. Rulien, Tom K. Ryden, Charles C. Schimpeler, David F. Schulz, Kumares C. Sinha, Pearson H. Stewart, Robert C. Stuart, Theodore G. Weigle, Jr.. James N. Wilson

Kenneth E. Cook, Transportation Research Board staff

Sponsorship is indicated by a footnote at the end of each report. The organizational units and officers and members are as of December 31, 1979.

Contents

NEW APPROACH FOR ANALYZING HIGHWAY PROGRAM CHOICES AND TRADE-OFFS
Lance A. Neumann and Joseph Dresser 1

HIGHWAY RISK MANAGEMENT: A CASE STUDY
Brent O. Bair, William J. Fognini, and John L. Grubba. 8

MATRIX PROJECT MANAGEMENT IN TRANSPORTATION: NEW YORK STATE EXPERIENCE (Abridgment)
William J. McLoughlin 11

SUGGESTED CRITERIA AND PROCEDURES FOR SETTING HIGHWAY PRIORITIES (Abridgment)
David Curry and Guillaume Shearin 14

HIGHWAY FUNDING: ARIZONA CASE STUDY
Judson S. Matthias and Robert H. Wortman 16

METHODOLOGY FOR EVALUATING IMPACTS OF ENERGY, NATIONAL ECONOMY, AND PUBLIC POLICIES ON HIGHWAY FINANCING AND PERFORMANCE
Fred L. Mannering and Kumares C. Sinha 20

SYSTEMS APPROACH TO INCREASING PRECONSTRUCTION ENGINEERING PRODUCTIVITY
Don C. Hoffeditz and Neal X. Jones 28

PRECONSTRUCTION ENGINEERING MANAGEMENT IN WASHINGTON: MANPOWER MANAGEMENT INFORMATION SYSTEM (Abridgment)
Donald L. Lund 34

PRECONSTRUCTION ENGINEERING MANAGEMENT IN VIRGINIA (Abridgment)
Frank E. Tracy. 37

CHANGING CRITERIA FOR PROJECT EVALUATION AND PRIORITY SETTING (Abridgment)
Kumares C. Sinha 40

Authors of the Papers in This Record

Bair, Brent O., Oakland County Road Commission, 31001 Lahser Rd., Birmingham, MI 48010
Curry, David, Crain and Associates, 120 Santa Margarita Ave., Menlo Park, CA 94025
Dresser, Joseph, Wisconsin Department of Transportation, P.O. Box 7916, Madison, WI 53707
Fognini, William J., Oakland County Road Commission, 31001 Lahser Rd., Birmingham, MI 48010
Grubba, John L., Oakland County Road Commission, 31001 Lahser Rd., Birmingham, MI 48010
Hoffeditz, Don C., R.J. Hansen Associates, Inc., 555 Capitol Mall, Sacramento, CA 95814
Jones, Neal X., R.J. Hansen Associates, Inc., 555 Capitol Mall, Sacramento, CA 95814
Lund, Donald L., Washington Department of Transportation, Highway Administration Building, Olympia, WA 98504
Mannering, Fred L., School of Engineering, Purdue University, West Lafayette, IN 47907
Matthias, Judson S., Department of Civil Engineering, Arizona State University, Tempe, AZ 85281
McLoughlin, William J., New York State Department of Transportation, 1220 Washington Ave., Albany NY 12232
Neumann, Lance A., Cambridge Systematics, Inc., 238 Main Street, Cambridge, MA 02142
Shearin, Guillaume, Crain and Associates, 120 Santa Margarita Ave., Menlo Park, CA 94025
Sinha, Kumares C., School of Engineering, Purdue University, West Lafayette, IN 47907
Tracy, Frank E., Virginia Department of Highways and Transportation, 1221 East Broad Street, Richmond, VA 23219
Wortman, Robert H., Department of Civil Engineering and Engineering Mechanics, University of Arizona, Tucson, AZ 85721

New Approach for Analyzing Highway Program Choices and Trade-Offs

Lance A. Neumann and Joseph Dresser

State highway investment decisions have traditionally been based on needs studies, long-range system plans, and midrange or short-range single-option programs. These decision-making tools suffer from a variety of shortcomings—portrayal of enormous and unrealistic dollar requirements to address highway deficiencies, inflexibility, inability to weigh trade-offs between and within program areas, lack of means to maximize statewide benefits over local or project benefits, and failure to consider a broad range of social, economic, and environmental consequences. This paper describes an innovative six-year state highway programming process, developed by the Wisconsin Department of Transportation, that attempts to remove these shortcomings. In this process, the district offices periodically develop, under statewide policy guides, alternative six-year highway programs from alternative project concepts that address deficient segments of the highway system. The low-program option is based on the minimum requirements to maintain the existing system. Higher-level programs are based on alternative future state and federal highway revenue assumptions and policy directions. For budgeting purposes, policy and program choices are presented to decision makers, legislators, and the public by describing for each program its composition, impacts on highway deficiencies and performance, and social, economic, and environmental effects. Key trade-offs within and between programs are identified. The process includes cost/benefit analysis of major projects; allows for staging of investments; is not easily undermined by uncertainty; improves use of staff and budget; informs the public of the department's intentions; and improves coordination of programming and budgeting efforts of state, regional, and local agencies. The department is committed to extending this approach to programming to all modes in the future.

During the past few years, the rate of growth in the revenues available for transportation at the state level has slowed considerably. And increasing gasoline prices, supply shortages, and federal fuel-efficiency standards may result in actual decreases in total revenues for transportation in some states over the next few years. This slowdown in revenue growth, coupled with the tremendous inflation being experienced in the construction industry, increasing routine highway maintenance needs, and necessary expenditures for other modes, has resulted in a sharp decrease in the funds available for highway rehabilitation and improvement.

Wisconsin, like many other states, must make increasingly difficult decisions on how to use scarce highway improvement dollars. Although significant improvements to portions of the primary, secondary, and urban systems appear desirable, it is clear that the design standards reflected in earlier system plans and needs studies will not be met systemwide. Rehabilitation and resurfacing needs are increasing as the system ages, and a large number of bridges, particularly those that have severe load-carrying limitations, are coming due for replacement or further restrictions on use. Uncompleted portions of the Interstate system are facing deadlines set by the Surface Transportation Act of 1978, and Interstate rehabilitation is becoming a critical area of concern.

To assist in analyzing this array of issues and investment choices, the Wisconsin Department of Transportation has, over the past two years, developed and implemented a highway-investment programming process. The primary objective of the process is to provide management with a range of policy choices and an assessment of the transportation, economic, social, and environmental consequences of those choices. This improved programming process and a set of new technical support tools have been used to develop an initial six-year highway program for the years 1980-1985. It is the department's intention to update this program every two years and to expand its scope to cover all modes.

OVERVIEW OF THE PROCESS AND RESULTS FOR 1980-1985

Traditional highway programming in Wisconsin, and in other states as well, has suffered from a variety of problems that include the use of needs studies or system plans that reflect unrealistic revenue assumptions; inability to weigh trade-offs within and between program areas (e.g., bridge replacement versus highway rehabilitation or improvement); lack of systematic methods for maximizing statewide versus local or project benefits; and failure to consider a broad range of social, economic, and environmental impacts. Generally, only one design alternative or potential investment level is considered for each project being programmed and projects are ranked either subjectively or by using a more technical method such as a sufficiency rating, a priority index, or a benefit/cost analysis. For the most part, only one program alternative is explicitly developed and there is little formal program evaluation. In short, program development has been viewed as a somewhat mechanical process of progressing down a priority list until the available funds are exhausted.

Correcting these shortcomings requires that an improved programming process include the following:

1. Provision of a range of policy choices to top management, not simply one recommended alternative;
2. Maximization of system benefits over individual project benefits;
3. Consideration of alternative design concepts (i.e., investment levels) for each project;
4. Explicit development of alternative improvement programs for evaluation; and
5. Use of a range of consistent criteria for evaluation of project and program options.

Because the most important objective of the process is to improve the department's investment-decision-making capability by providing management with fully evaluated policy choices, it is necessary to first develop explicit alternative improvement programs. In turn, to develop meaningful alternative programs requires that project alternatives, that is, alternative levels of improvement for a given highway segment, also be available. Under some program assumptions (e.g., constrained revenue), the appropriate level of improvement for a given segment might be resurfacing or minor reconditioning; under other conditions (e.g., a revenue increase), a higher-level improvement might be warranted. Unless this dynamic relationship between the project improvement-level scale and program alternatives is explicitly recognized, a key element of program choice is ignored and program alternatives are simply different combinations of projects, each having only one proposed design.

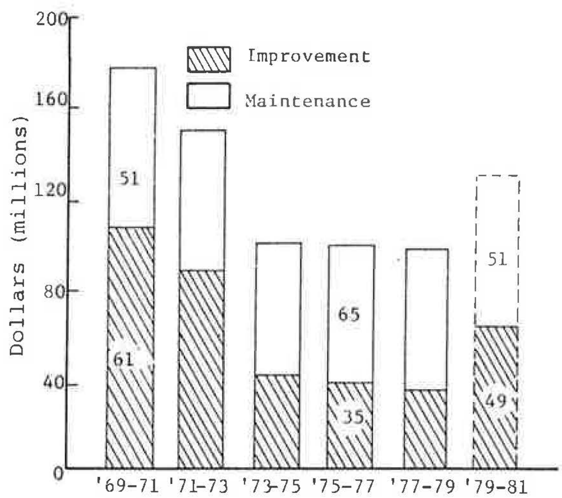
It was recognized that, in many cases, but particularly for candidates for programming in the early years of the program period (1980-1981), project design options could be constrained for any number of reasons. The results of the project development and environmental impact statement process, prior commitments to local units of government, and federal-aid eligibility requirements can all narrow the range of feasible design concepts. Nonetheless, in many cases, more than one feasible design concept was available and the final choice could be determined on the basis of state-level program and policy directions.

To meet the requirement that systemwide or statewide benefits be maximized over project or local benefits meant that consistent criteria had to be established to define deficiencies, develop design solutions, and select projects in all eight district offices of the department.

The basic steps of the new programming process are

1. Analysis of existing conditions and deficiencies,
2. Development of alternative programs, and
3. Evaluation of alternative programs.

Figure 1. Decrease in state improvement funds: maintenance versus construction (constant 1970 dollars).



The approach to each of these steps and selected results are described below.

Analysis of Existing Conditions and Deficiencies

The first step in developing the multiyear program was to thoroughly assess the existing situation with respect to revenue availability and highway system physical and service conditions. As in many states, Wisconsin has seen a steady erosion in the buying power of the highway improvement program. In fact, during the 1967-1977 10-year period, the buying power of state funds available for highway improvements decreased by 75 percent, due primarily to inflation in the construction industry and the ever-increasing expenditures on routine maintenance (not including resurfacing) and nonhighway programs. Figure 1 shows the trend in expenditures on maintenance and improvement over the past few bienniums. (The increase in highway improvement funds in the 1980-1981 biennium was due to the approval of more than $60 million in state general funds for highway purposes.)

Another factor that will affect the decrease in improvement funds in the future is the expected slowdown in the rate of growth of overall revenues. Figure 2 shows the trend in the state gasoline tax revenues over the past 10 years. Gasoline taxes, which currently account for more than 50 percent of total revenues, are expected to decrease in the future due to fuel price increases and improved fuel efficiency in the vehicle fleet. As a result of all these factors, it is expected that Wisconsin will not be able to match available federal aid in the mid-1980s.

Parallel with the assessment of revenue availability, the existing highway system physical and service conditions were also analyzed. The assessment of deficiencies for purposes of the six-year program specifically avoided a needs-study approach and reliance on the traditional highway standards. It instead recognized that, as a practical matter, definitions of need and deficiency vary from time to time, depending on a number of factors such as public acceptability of existing conditions, cost of improvements, and revenue availability.

To provide some objective measures of roadway condition, deficiency data were collected for about 9600 km (6000 miles) of the 19 000-km (11 900-mile) system. These data included surface age and pavement condi-

Figure 2. Gasoline tax revenues: 1967-1983.

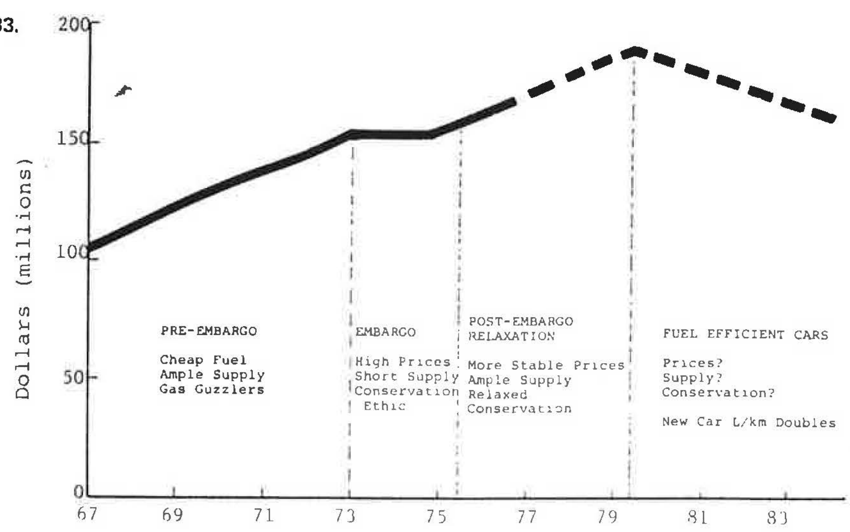


Table 1. Reported lengths of highway that have substandard pavement or shoulder widths or both.

	Pavement Length (km)									
	District									
Functional Class	1	2	3	4	5	6	7	8	9	Total
Principal arterial	238	113	201	172	217	136	258	219	13	1567
Minor arterial	617	456	539	473	455	475	343	632		4031
Major collector	439	159	168	297	293	212	379	159		1989
Minor collector	23	6	8			24				62
Total	1317	774	917	828	966	847	977	1009	13	7648

Notes: 1 km = 0.62 miles.
Numbers may not add due to rounding.

Table 2. Summary of deficiency data.

Deficiency	Avg N	Statewide Avg	Threshold Value	Length (km)	Avg Rate
Accident rate	346	280	At 300	2957	522
			At 500	975	770
			At 750	220	1193
Accident occurrence	277	200	At 300	1225	778
			At 500	446	1239
			At 750	212	1695
Geometrics: percentage passing	56		At 50	2453	31
			At 30	1085	18
			At 20	624	12
Volume-to-capacity ratio	0.40		At 0.60	1092	0.87
			At 0.80	411	1.10
			At 1.00	160	1.37

Note: 1 km = 0.62 mile.

tion, accident rates and occurrences, volume-to-capacity ratios, percentage of no-passing zones, and other geometric and structural criteria. The deficiency data for each segment were placed in a computer file for efficient editing, sorting, analysis, and display.

The computerized information system was used to produce a series of deficiency reports summarizing the extent and severity of various deficiencies statewide and by district, functional class, and such. Tables 1 and 2 illustrate the type of output developed from these reports for identifying the pavement lengths above specified threshold values of deficiency criteria. These reports were then used in the development of specific program alternatives and, subsequently, similar deficiency summaries were used as one means of evaluating program alternatives and summarizing program performance. The computerized information system represented a crucial technical tool to support a process that must necessarily handle a large amount of information and be capable of summarizing that information at different levels of detail, depending on the issues of concern and the decisions to be made.

Parallel with the analysis of deficiencies on the state highway system, system conditions and deficiencies in the other program areas were also identified. In the bridge area, the results of the Federal Highway Administration (FHWA) sufficiency-rating formula and the department's own priority listing based on load-carrying capacity, overall structural condition, and geometrics were used to assess replacement needs. The most recent Interstate cost estimate (1979) prepared for FHWA served as a basis for assessing potential improvements on that system.

After the screening of deficiencies on the state highway system was completed, alternative improvement project concepts were developed for those segments judged most deficient. In identifying potential improvement projects, emphasis was placed on those segments both requiring surface renewal during the six-year period and having safety, geometric, and capacity deficiencies. The minimum improvement alternative proposed for each segment was expected to be a resurfacing project or a resurfacing project coupled with the minimum structural renewal necessary to support a new surface. Depending on the severity of the safety, geometric, and capacity deficiencies present, higher levels of improvement proposed for a given segment varied from minor reconditioning projects to major reconditioning and reconstruction and major projects on new alignments.

Again, the purpose of developing alternative improvement concepts for a given segment was to allow the improvement level to vary, depending on the program parameters assumed (e.g., overall revenue level, allocation of revenue by district, subprogram emphasis, and such). For each alternative improvement concept for each segment, data on the key design elements, potential impacts, cost estimates, and schedule were collected and placed in a computer file that could be cross-referenced to the deficiency data file to produce summaries of the deficiencies addressed by different sets of projects and programs.

For about 30 major project sites, a range of alternatives was identified, based primarily on current or past studies. These 30 projects were subjected to formal benefit/cost analysis by using the highway investment analysis package (HIAP) developed by FHWA. [These results are reported elsewhere (1).] Although it is but one of many factors affecting major project decisions, benefit/cost analysis points out the trade-offs involved in successively increasing investments in one or a few project sites versus funding more-moderate improvements at a greater number of sites. In addition, the testing of a range of alternatives at each site often identified other potentially cost-effective alternatives that ought to be developed and analyzed.

Development of Alternative Programs

The deficiency analysis showed that there was a range of key policy issues that had to be explored in developing alternative programs. These issues included the following:

1. The benefits available from a revenue increase under varying assumptions about how additional revenues might be spent,
2. The benefits of greater emphasis on safety or capacity improvements versus pavement preservation,
3. The most cost-effective mix of resurfacing and reconditioning work for maintaining some minimum pavement quality, and
4. The trade-off of funding a relatively few major improvements versus a larger number of small improvements.

Given the expected trend in gasoline tax revenues, the need to explore the potential for a revenue increase and to demonstrate how additional revenues could be used was identified as the most critical issue facing the department.

Although the number of alternative programs that

Figure 3. Relationship between project and program alternatives.

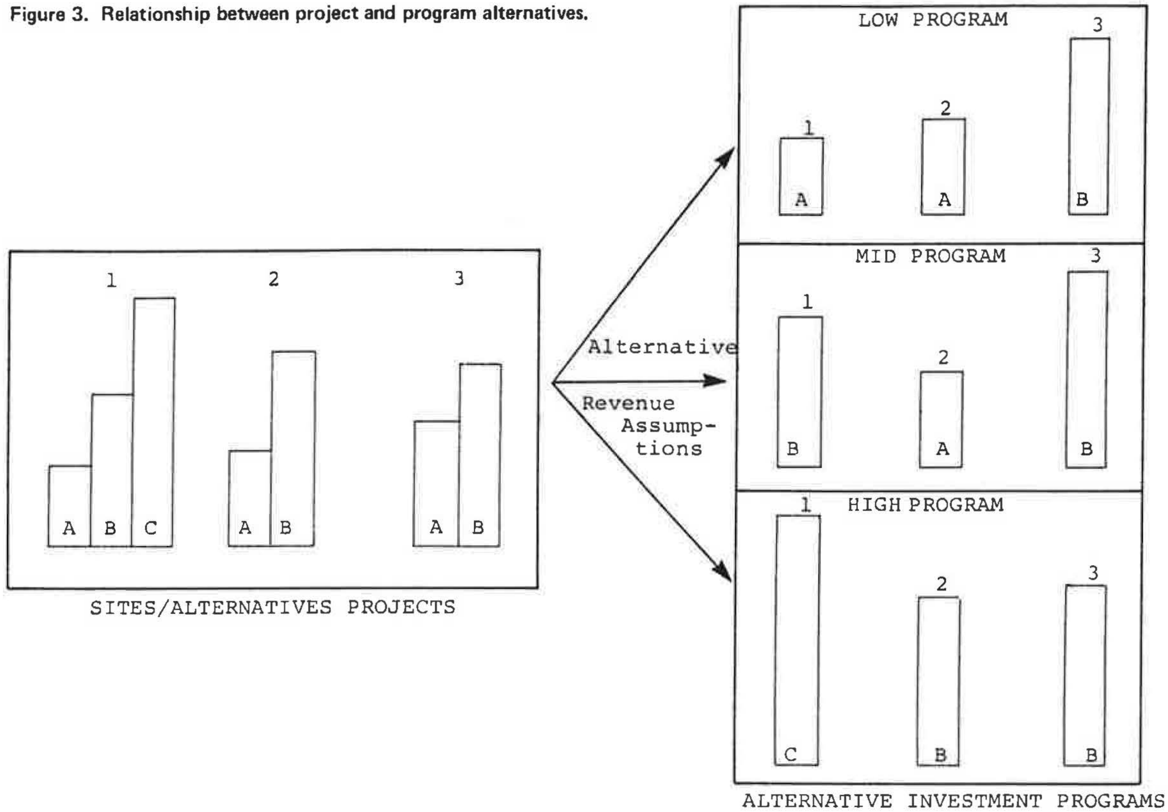


Table 3. Summary of program alternatives: 3R program area.

Program Level	Resurfacing Cost ($000 000s)[a]	Resurfacing Length (km)	Minor Reconditioning Cost ($000 000s)[a]	Minor Reconditioning Length (km)	Major Reconditioning Cost ($000 000s)[a]	Major Reconditioning Length (km)	Reconstruction Cost ($000 000s)[a]	Reconstruction Length (km)	Total Cost ($000 000s)[a]	Total Length (km)
Low	112	3912	24	457	44	643	22	115	202	5127
Medium	100	3279	30	546	84	1105	86	395	300	5487
High	99	3261	35	612	112	904	158	603	404	5960

Note: 1 km = 0.62 mile.
[a] 1978 value.

could be developed and evaluated was limited, a range of reasonable funding levels was defined for each of four program areas: resurfacing, reconstruction, and reconditioning (3R); bridge replacement; Interstate; and major projects.

The funding levels selected for each of the program areas were based on the results of the deficiency analyses, expected federal funding availability, previous program commitments, and the policy preferences of top management. The objective was to identify the likely range of expenditures by program area at different total revenue levels and assuming different policy directions. Thus, for the general 3R program area, expenditures of at least $200 million (1978 dollars) were estimated to be necessary during the period 1980-1985 simply to meet surface renewal objectives. On the other hand, even under the most optimistic revenue scenario (i.e., assuming a major revenue increase), the minimum expenditure levels required in other program areas make it unlikely that 3R program area expenditures would exceed $400 million.

As shown below, three program funding levels were selected for each of the 3R, bridge replacement, and Interstate areas. The major projects were grouped into categories identified as committed (e.g., essentially under construction) and high-, medium-, and low-priority candidates without explicit program levels.

Program Area	Program Level (1978 $000 000s) Low	Medium	High
Resurfacing, reconditioning, and reconstruction	200	300	400
Bridge replacement	70	100	140
Interstate	90	135-195	245
Major projects	120	listing of additional projects	

The development of alternative programs for the 3R area was based on guidelines that identified surface renewal target lengths and other priority criteria and on overall funding levels. Although district offices were given initial funding targets, it was made clear that final district funding levels would depend on a statewide evaluation of initial district submittals and the development of a consistent program district to district. Four levels of improvement were defined:

1. Resurfacing—based on criteria of pavement age, maintenance needs, and serviceability index;
2. Minor reconditioning—based on resurfacing criteria plus criteria of pavement width, shoulder paving,

Table 4. Social, economic, and environmental impacts of major-project program alternatives: 1980-1985.

Impact	Program: Low ($160 000 000)	Approved ($260 000 000)	Recommended[a] ($360 000 000)	High[b] ($410 000 000)
Construction jobs generated (person years: 1980-1985)	4500-4800	7300-7800	10 100 to 10 800	11 500 to 12 300
Income generated statewide ($000 000s)	240-480	390-780	540-1090	615-1230
No. of businesses displaced	8	12	25-65	35-89
Improvement in accessibility (peak-period vehicle hours reduced per year)	101 000	379 000	473 000 to 752 000	543 000 to 926 000
Households displaced	45	87	104-217	133-288
Neighborhoods severed	0	0	1-2	1-3
Farmland required (hm^2)	594	610	823-1389	964-1743
Farms severed	53	54	68-109	78-134
Wetland filled (hm^2)	4.0	23	31-95	47-135
Habitat required (hm^2)	147	272	348-605	412-765
Added salt per year (Mg)	3493	4796	5671-6086	6121-6562
Infringement on endangered species	0	0	0	0
Infringement on unique areas				
Total	1	1	3-9	5-13
Historical and archeological	0	0	1-3	1-4
Coastal zone management	1	1	1	1
Air quality				
No. of new pollution sources (projects on new location)	4	4	5-9	6-12
No. of projects on existing location				
Increased CO concentration	1	2	2	2
Decreased CO concentration	1	1	2-4	2-5
No change in CO concentration	1	5	5-6	5-7
Noise levels				
No. of new pollution sources (projects on new location)	4	4	5-9	6-12
No. of projects on existing location				
Exceed present levels by 10 dB(A)	2	5	7-8	7-9
Exceed federal design-year criteria	1	9	2-3	2-4
Energy consumption: materials and construction[c] (PJ)	3.63-5.40	5.90-8.75	7.43-12.0	8.39-13.6
Public acceptability of improvements				
No controversy	1	2	2-4	3-5
Low controversy	4	8	9-13	10-15
High controversy	3	3	4-7	5-8
No. of projects by class[d]				
Type 1	6	11	13-21	15-25
Type 2	1	2	2	2-3
Type 3	1	0	0	0

Notes: 1 hm^2 = 2.47 $acre^2$; 1 Mg = 1.10 ton; 1 PJ = 0.947 × 10^{12} Btu.
Construction jobs and income generated exclude values for completion of I-43 and the connection from Georke's Corners and US-16.
[a] Approved program plus $100 000 000 worth of candidates (3-11 projects, depending on their cost).
[b] Approved program plus $150 000 000 worth of candidates (5-16 projects, depending on their cost).
[c] Energy-consumption values exclude effects of two major bridges.
[d] Under the Wisconsin Environmental Policy Act: type 1 projects are likely to have a significant impact on human environment, type 2 projects may do so, and type 3 projects will not do so.

and minor shoulder widening;

3. Major reconditioning—based on resurfacing and minor reconditioning criteria plus criteria of pavement failure, safety features (isolated curves, crests, and hazards), and federal-aid eligibility; and

4. Reconstruction—based on resurfacing and reconditioning criteria plus criteria of safety, geometrics, capacity, and combinations thereof.

It was, however, necessary to use the overall funding level as well as the deficiency criteria in making project selection. At the lowest funding level for the 3R program area ($200 million), district choices were constrained by the surface renewal target and the majority of projects were resurfacing and minor reconditioning. However, at higher funding levels, there was increasing flexibility to fund major reconditioning and reconstruction projects while still meeting surface renewal goals. The relationship between project and program alternatives is illustrated in Figure 3, and the types of improvements that can be funded by the 3R program alternatives are summarized in Table 3. Additional resources above the $200 million level increase the total length somewhat but dramatically increase expenditures in the higher improvement categories.

Some consideration was given to specifying relatively rigid rules or priority thresholds (e.g., accident rate above a specified level) for projects proposed for higher-level improvements. However, subject to meeting surface renewal goals, the districts were given wide latitude to set priorities. This was a more prudent approach initially, given the variations in conditions district to district and a lack of agreement on an acceptable range for any threshold criterion. More-defensible threshold criteria could be set in future cycles, depending on the degree of variation occurring in initial district submittals.

The development of alternative bridge, Interstate, and major projects also was guided by an explicit set of priority and policy guidelines but, again, the use of a strict formula was avoided. For bridges, primary consideration was given to load-carrying capacity and posted limits, overall structural conditions, and geometrics, as well as to age and traffic levels. For Interstate improvements, priority was given to completion of the system and selected operational and safety improvements on existing facilities. For selected major improvement projects, benefit/cost analysis was performed as one input to priority setting and projects were grouped in priority categories that depended on whether work had been initiated or strong commitments implied and the extent and severity of a range of deficiencies.

Evaluation of Alternative Programs

After the alternative programs had been developed, program evaluation focused on four issues:

1. Summary of each program alternative (e.g., kilometers of improvement by type) and consistency

Table 5. Summary of program options: six-year program.

	State Highway Program		Interstate Program[a]		Bridge Replacement Program[b]		Major Projects Program[c]	
Program Level	Cost ($000 000s)[d]	Key Elements	Cost ($000 000s)[d]	Key Elements	Cost ($000 000s)[d]	Key Elements	Cost ($000 000s)[d]	Key Elements
Low	200	Surface renewal of 5127 km (which does not meet 5500-km target necessary to avoid loss of federal aid); minor structural and safety reconditioning and reconstruction work	90	Work toward completion of I-43; high-priority safety projects including median barriers on I-94 and rest area on I-43; selected bridge deck overlays to preserve existing system; freeway surveillance system in Milwaukee	67	Replacement of 150 bridges [two-thirds of all posted bridges (34 of 49), selected low-capacity bridges, selected bridges in poor structural condition]	120	Work toward completion of $70 000 000 worth of committed projects; begin work on three high-cost projects
Medium	300	Surface renewal of 5487 km (which essentially meets target necessary to avoid loss of federal aid); significant expansion of improvement level	135-195	All elements of low-level program; third-lane projects on I-90 and I-94; park-and-ride lots, rest areas, and bridge fencing; removal of roadside obstacles; improved lighting	103	Replacement of 239 bridges (all those in low-level program, most remaining low-capacity ones, all others in poor structural condition)	>120	All elements of low-level program; additional major projects
High	400	Surface renewal of 5960 km (which exceeds target necessary to avoid loss of federal aid); further expansion of improvement levels	245	All elements of medium-level program; selected interchange improvements on I-94 and I-794; noise-abatement measures, truck weighing stations, additional park-and-ride lots, and expansion of lighting	143	Replacement of 311 bridges [all those in medium-level program, selected functionally obsolete ones (too narrow roadways, restricted clearances, poor alignments), selected ones in marginal structural condition (likely to deteriorate in two-year period)]		

Note: 1 km = 0.62 mile.
[a] Does not include 3R program.
[b] Does not include several high-cost bridges that will require special funding.
[c] Completion of committed projects estimated to cost $70 000 000; construction of other high-priority projects estimated to cost $15 000 000 to $125 000 000 depending on funding availability.
[d] 1978 value.

with guidelines (e.g., surface renewal targets and funding levels);

2. Consistency of program submittals from district to district in terms of deficiencies addressed, levels of improvements proposed for given deficiencies, costs per kilometer by improvement type, and such;

3. Benefits of each alternative in terms of prolonged surface life, accident reductions, capacity improvements, and such; and

4. Potential economic, social, and environmental impacts.

The evaluation relied heavily on the deficiency data produced earlier in the study. Both the extent and severity of deficiencies on segments selected for improvement were reviewed, as well as the improvement level specified, given a certain set of deficiency characteristics. Again, without a well-organized information system that could efficiently match deficiency characteristics with project summary data, this evaluation would not have been possible. Manual methods of estimating potential accident reductions and capacity benefits of each program were developed to augment the information obtained from deficiency files and formal benefit/cost studies. The potential economic, environmental, and social impacts of the alternative programs considered are estimated to meet the spirit of state environmental laws and recent U.S. Council on Environmental Quality regulations. The environmental assessment was done by analyzing the specific impacts of the larger improvement projects and performing a generic assessment of the likely impacts of several classes of lower-cost projects. Selected results of this analysis for the major-project area are given in Table 4.

The availability of program alternatives allowed comparison of the likely impacts of varying funding levels in each area and explicit consideration of the trade-offs within and between each area. Table 5 summarizes the basic elements included in the alternatives for each program area and provides some indication of the trade-offs available by shifting funds from area to area. More detailed descriptions of these trade-offs were used to guide the selection of the proposed six-year program and to document and justify the choices made.

A recommended program was developed based on an assumption that a major revenue increase would not be sought. Subsequently, a change in state administrations required recycling the program-development-and-evaluation activity to produce a recommended program based on a substantial revenue increase. The availability of the key data in the deficiency- and project-summary files made it possible to complete this substantial modification to the program in a few weeks time. This evaluation also focused on the same basic issues, and the results provided the necessary background material to the state legislature for its budget deliberations.

The legislature subsequently passed a biennial budget for 1980-1981 that provides more than $60 million in general funds to supplement the transportation fund. During the current biennium, the department must recommend a permanent funding mechanism to generate additional funds of approximately this magnitude for the transportation fund. The department's recommendations on the relative emphasis between program areas and on specific projects were adopted without any significant changes.

CONCLUSIONS

Several important conclusions can be drawn from this project:

1. A multiyear program, even in an era of constantly changing project development schedules and costs, funding levels and categories, and other factors, can be an extremely useful management tool. However, given the increasingly complex environment within which program decisions must be made, both alternative project design concepts for a given highway segment and alternative programs must be explicitly considered to thoroughly explore important policy choices. Simply setting priorities among a list of projects for which only one design concept is proposed is often overly simplistic and ignores a key dimension of program choice.
2. Storing, editing, and analyzing the data necessary to develop and evaluate a range of program alternatives requires a well-designed computerized information system and a range of evaluation support tools, both manual and computer assisted. On an ongoing basis, similar capabilities will be needed to monitor and update the program in light of project schedule and cost increases, new funding constraints, and changes in management policies and priorities. Developing this ongoing capability is the final element of the Wisconsin programming project.
3. A range of evaluation and priority criteria should be used to select project and improvement levels. Although benefit/cost analysis and other technical criteria can be useful, rigid-formula approaches lack the flexibility required to make final project selections in cases where subjective and nonquantifiable factors must also be considered.
4. On an ongoing basis, longer-range system planning and detailed project development activities must be closely coordinated with the program development function. Much of the information on system conditions, surface renewal needs, and such can be a routine product of a periodic system planning report. Similarly, information on project alternatives and impacts is routinely collected during project development studies. In addition, close coordination is needed to maintain alternatives for a given project as appropriate and to minotor project cost and schedule changes. Although it is desirable to maintain a stable multiyear schedule of projects, program modifications will always be necessary and the programming function should be used to identify and analyze the uncertainties and risks inherent in any proposed program.
5. Program-level environmental analysis can provide useful information in formulating proposed programs. Obviously, the level of detail of program-level analysis cannot, and should not, approach that of a project environmental impact statement. Also, the processing and administrative requirements of any formal program environmental report must allow annual or biennial budget decisions to be made and program implementation to proceed smoothly. Nonetheless, U.S. Council on Environmental Quality regulations suggest that program-level environmental analysis is required and, based on the Wisconsin experience, it can be accomplished.

Several areas for further research and development are apparent:

1. The trade-off between highway and bridge maintenance versus improvement and replacement needs to be more thoroughly explored. Additional methods are needed to characterize program benefits and performance to allow more systematic consideration of the trade-offs implied by different programs. Although a start was made on estimating environmental impacts, improved methods are required.
2. Future cycles of the programming process should incorporate all modes of transportation that the state is involved in. Again, expansion to other modes will require the development of explicit evaluation criteria and methods so that program trade-offs can be explored.

ACKNOWLEDGMENT

We would like to acknowledge the contributions of Terry Mulcahy, William Hyman, Richard Lange, and Ed Byrkit of the Wisconsin Department of Transportation to the development and implementation of the programming approach described in this paper. In addition, Wayne Pecknold, Scott Nason, and John Suhrbier of Cambridge Systematics, Inc.; James Batchelder of Multisystems, Inc.; and Bruce Campbell of Fay, Spofford, and Thorndike provided valuable assistance throughout the project. The opinions and conclusions expressed in this paper are ours alone and do not necessarily represent the views of the Wisconsin Department of Transportation.

REFERENCE

1. J. Batchelder, R. Lange, T. Thodes, and L. Neumann. An Application of the Highway Investments Analysis Package. TRB, Transportation Research Record 698, 1979, pp. 1-5.

Publication of this paper sponsored by Committee on Transportation Programming, Planning, and Evaluation.

Highway Risk Management: A Case Study

Brent O. Bair, William J. Fognini, and John L. Grubba

Immunity for action taken by governmental agencies has almost disappeared across the United States. As a result, transportation agencies and their agents are being held accountable for improper design, construction, maintenance, and traffic engineering of their roadways. Thus, the Oakland County [Michigan] Road Commission, because of very high insurance costs, has launched a safety-first program. Safety has always been included in road design, but it has often been compromised due to the presumed necessity to provide for more capacity. The Oakland County Road Commission has reversed this priority; this paper describes the Oakland County risk-management program, which is intended to place safety first in all areas (including safety for employees). Risk management is new to the transportation field. However, its operation is simple—(a) reorganizing the management decision process; (b) encouraging all employees to participate in a road-hazard-identification process; (c) analyzing all identified hazards, traffic accidents, and legal claims; (d) documenting and determining priorities for planning project programming; (e) providing countermeasures for the identified risks; and (f) evaluating the results and feeding this information back into the planning process.

That the amount of major highway construction is decreasing and attention given to better management of existing systems is increasing is of course old news. The transportation system management requirements in the planning process have been around for several years now. However, there is one pressure for change that has seldom been addressed directly that may provide an unexpected stimulus for specific types of improvements. This pressure comes from liability exposure, and the resulting improvements will be in the area of greater highway safety. With the majority of the states having little or no immunity today and the courts adopting the theory of comparative negligence, the liability problem is growing and requires direct attention. The number of lawsuits and the sizes of awards and settlements have been increasing steadily. In the past, many public agencies have viewed liability as simply an insurance problem but, today, with many insurance companies abandoning the public liability market because of the high probability and severity of losses, it is becoming clear that more must be done than to simply look for another insurance carrier to write the risk.

Road liability represents perhaps the greatest liability exposure to public agencies. There is simply no other activity involving public agencies in which so many people are killed and maimed each year. Although highway safety has always been viewed as important and various amounts of funds have been set aside for safety improvement activities, safety has, at the same time, generally taken a back seat to improved mobility and decreased travel time. The relatively low level of expenditure for highway safety-related improvements over the past 20 years is perhaps the best evidence of this secondary position. It is possible, however, that the growing liability problem may provide the necessary stimulus to boost safety improvements to a much higher priority.

In fact, this is exactly the case in Oakland County, Michigan. The Oakland County Road Commission has designated safety as its number-one priority. A decision of this type, although admirable, is not necessarily easy to implement. The implications of this decision have had a wide range of effects on the agency's policies, one of which is that all decisions, including the budget, must be made with safety as the first consideration. Once the decision was made, it quickly became apparent to the road commission management that a comprehensive approach to the implementation of this priority was needed. The road commission, consequently, began developing a program referred to as highway risk management. This represents an organized management approach to decision making. Although risk management is not expected to be a cure-all to liability and safety problems, it does promise to improve the situation.

EXTENT OF THE PROBLEM

It may be helpful to begin by reviewing the background of the Oakland County Road Commission, including the extent of its safety and liability problems and the general reasons why it has come to put such emphasis on risk management and highway safety. The Oakland County Road Commission is not a small, unsophisticated, backwoods, local agency. Rather, it is the agency responsible for approximately 4000 km (2500 miles) of road system immediately adjacent to the sixth largest city in the nation, Detroit. This road system represents the second largest system under one jurisdiction in the state of Michigan, second only to the state highway system. The road commission's current annual operating budget is approaching $40 million. Oakland County covers 2300 km^2 (900 miles^2) and contains approximately 1 million people in 61 separate municipalities, almost as many people as reside in the city of Detroit. Due to the size of the county and the population involved, the roads under the Oakland County Road Commission's jurisdiction range from congested multilane facilities in the urbanized area to lonely rural gravel roads in the outer regions.

As was typical nationally, after World War II, Oakland County experienced rapid suburbanization that created demands for smoother, wider roads at a pace that far exceeded the road commissions's funding resources. While trying to keep pace with mobility needs, the road commission could not give adequate attention to less-pressing considerations such as future safety on the system. It was not that the road managers did not care or were ignorant of safety measures, it simply seemed logical to give highest priority to the demand for mobility. In addition, at that time, road managers were not constrained by liability considerations because road entities were immune from such. Without the liability pressure, the demand for safety could not balance the demand for mobility. In addition, the general rules of the road and existing laws required that the other driver compensate accident victims for damages.

That situation changed dramatically in the 1970s. Road commissions in Michigan lost most of their immunity, and no-fault automobile insurance was enacted into law. No longer can accident victims collect from the other driver, except under special circumstances. It appears that people involved in automobile accidents have begun to feel victimized by the system as well as by the crash. They have begun to seek other means to collect for their losses. Of the three elements involved in highway accidents—driver, vehicle, and road environment—the vehicle and the road environment are now receiving increased legal attention. With the recent adoption of the theory of comparative negligence by the Michigan court system, road agencies can now expect to participate financially to some level in many more court cases.

The Oakland County Road Commission has certainly

Figure 1. Risk-management approach.

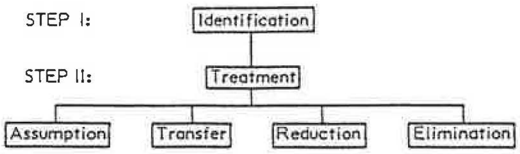


Figure 2. Risk-management organization: Oakland County Road Commission.

not been overlooked in the liability arena. In the five-year period from 1973 to 1978, the road commission's liability insurance premiums jumped from a little more than \$60 000 to \$1 500 000. In 1978, the road commission had approximately \$72 million worth of liability lawsuits pending against it, compared with its annual revenues at that time of about one-third that amount. Road commission policymakers and management began to look for causes of these problems and found that they did not have to look very far. Accident statistics showed that, over a five-year period, more than 820 persons had died and more than 87 000 had been injured on Oakland County roads. It was estimated that the cost to the public of all accidents in the county during that five-year period had been almost \$0.5 billion (and that is without placing a dollar value on human suffering). It became apparent that what the road commission was seeing in liability claims and insurance premiums was only a reflection of the carnage on the highways. It also became apparent that partial answers, such as increased insurance coverage, were not enough. Statistics alone proved that half measures, such as programs to make the car and the driver safer, fall woefully short. The road commission came to the conclusion that the third factor in highway accidents—the road environment—had been receiving too little safety-related, before-the-accident attention. Consequently, in September 1977, the road commission's policymakers directed its staff to develop a comprehensive program. On January 30, 1978, the highway risk-management program was launched.

RISK-MANAGEMENT APPROACH

The term "risk management" is borrowed from private industry. Only the addition of the term "highway" signals something new. The risk-management approach has been used extensively in private industry for decision making directed at managing risks of financial loss to the firm.

The basic risk-management approach involves two steps—risk identification and risk treatment—and four alternative elements under the risk-treatment step—risk assumption, risk transfer, risk reduction, and risk elimination (see Figure 1).

IMPLEMENTATION

The road commission, however, is incorporating the risk-management approach into a systems approach. Five general steps in the process are being used, and they are as follows:

1. Reorganization,
2. Risk identification,
3. Analysis,
4. Planning and programming, and
5. Countermeasure implementation and evaluation.

Reorganization

Considerable emphasis is being placed on reorganization of the management decision process. The adoption of a priority such as safety is only as effective as the commitment of the staff carrying it out. One way to ensure involvement and eventual commitment is through the committee process. At the road commission, three levels of committees have been established to review safety problems and identify and implement improvements (see Figure 2).

At the top management level, an executive committee has been established to direct the program and to establish policies. This committee includes the managing director, the chief engineer, the general counsel, the assistant managing director, and the risk-management coordinator (who serves as staff officer to the committee). The executive committee sets policy and general procedures.

At the middle management level, a risk-management-program coordinating committee has been established. This committee includes primarily department heads, and the risk-management coordinator serves as chairperson. This committee reviews technical and procedural questions, develops new programs, and makes recommendations to the executive committee.

At the field and office employee level, an employee risk-management committee has been established. This group includes both hourly and supervisory personnel. Although the primary interest of this committee is employee safety, it also reviews the road safety problem. The employee risk-management committee makes recommendations to the risk-management-program coordinating committee. Although these recommendations are reviewed and commented on by the risk-management coordinating committee, all employee risk-management committee questions are forwarded to the executive committee for consideration. This creates more confidence among the field level employees that their ideas are being seen and are taken seriously.

Risk Identification

The road commission has five risk-identification projects under way. These include a procedure analysis, a claims analysis, inspection and inventory, police liaison, and accident and accident-data investigations. An early step was to determine and analyze all existing policies, procedures, and operations. The staff surveyed all of the more than 500 employees of the road commission and asked them to document procedures and make recommendations for improving safety. Employees in every department were asked for descriptions of every operation and procedure, as well as if and when a procedure is not followed and what priority the particular activity is given. Consequences of not following procedures were also identified. Employees were asked for any comments or suggestions they might have concerning the individual activities they were involved in. This approach was used because it was recognized that field employees are frequently a key to the identification of existing problems. Because they are exposed to road conditions at all seasons of the year, they are generally aware of what is going on and where the problems are. The road commission investigating staff actually found that many employees had been frustrated when previously noted problems were not corrected.

An ongoing road-hazard-identification program for employees was also developed. This involved the use of a road-hazard-report form on which employees could record and trace actions taken on anything they had called to the agency's attention. For example, all employees (including clerks, secretaries, and others) were asked to watch for such things as damaged signs, serious potholes and edge ruts, and other potential road problems. If a problem was noted, the employee was asked to fill out a report form and send it to the appropriate department. The department receiving the notice was then required to record the action taken on the report form, send a copy of the completed form to the originating employee, keep a copy in their own files, and forward the original completed form to risk management for review. An intensive employee training program on what to look for and how to use the road-hazard-report form was conducted as part of this hazard identification effort.

Analysis

A detailed analysis of claims against the road commission that were handled by previous insurance carriers has been conducted. The degree of liability and the frequency of accident types were examined and, from this, priorities were established and some specific activity recommendations for targeted countermeasures were developed. For example, because of the frequency and occasional severity of claims related to road maintenance problems such as snow and ice removal, pothole repair, and shoulder maintenance, additional resources have been directed at those activities.

An in-depth analysis of selected activities having high loss potential was also carried out. After specific activities had been identified through the employee survey and follow-up conversations, certain ones were selected for additional review and specific road improvement programs were developed.

Because the claims analysis indicated that staff were unaware of many things happening on the road system and many of the procedures analyses pointed up the lack of timely information or notice concerning potential problems, two different road inspection programs will be attempted in 1979 and 1980.

A detailed inventory of the entire paved road system will also be conducted in 1979 and 1980. This inventory will include the identification of roadside hazards, the inspection of problem sites such as railroad crossings, and the incorporation of road geometrics into accident data.

A policy liaison program is being established with all 62 police departments in Oakland County. Police officers are an important element in highway safety, both for enforcement and problem identification. Due to their high level of exposure to the road and their responsible position, police are an important resource that should not be wasted. Consequently, their additional input is being actively solicited.

The Oakland County Road Commission has had one of the most sophisticated accident-data systems available for at least nine years. Accident data have been computerized; both links and intersections are ranked according to various indices, such as accident frequency rates, severity rates, and accident rates per distances of vehicle travel. The incorporation of road geometrics into the existing accident-data collection will, in the future, allow an even higher degree of sophistication in these analyses.

One of the problems of an extensive identification program is that, once you know about a problem, it is mandatory that you do something about it, regardless of your ability to do so. Once you have identified a problem, you are on notice. Because of this, many highway engineers in the past have avoided such identification processes, hoping that a plea of ignorance would be an adequate defense in court. The road commission has rejected this because, for a long time, the courts have been telling us that not knowing about a problem does not mean that the agency is not liable. If the problem has existed long enough, it is believed that the agency should have known about it. This theory is referred to as constructive notice.

The road commission has developed several steps for dealing with this problem of being on notice. For example, the agency's legal counsel, rather than occupying the traditional position of counselor available to answer specific questions and to provide guidance, has taken a much more active position in the day-to-day risk-management process. The legal counsel helps in identifying potential exposure and by assisting in the formulation of countermeasures. Thus, counsel is involved before the accident to try and prevent it, rather than only in defense after it has occurred.

Planning and Programming

Being on notice also has its positive aspects. By aggressively seeking out potential problems, it is much easier to establish and document need when asking for outside funding. The Oakland County Road Commission is very aggressive in seeking sources of additional funds. The risk-management program has helped to specify funding needs.

Accident data and other information are currently being used to reevaluate multiyear construction and maintenance programs to ensure that safety problem areas are being addressed first. In addition, a review of proposed projects by a multidisciplinary team to identify additional safety improvements is being explored.

Finally, considerable effort is being expended on improving documentation and record keeping of all road commission activities, including maintenance. Better documentation of safety-related decisions should make possible improved decision making through subsequent monitoring and evaluation.

Countermeasure Implementation and Evaluation

Funds have been set aside to provide specific countermeasures for problems noted in the identification program. The Oakland County Road Commission is attempting to do something about the problems identified, not just leaving them sit. Many of these countermeasures have been developed in the form of in-house demonstrations.

Numerous countermeasure programs have been initiated. These include a shoulder paving program, an intensified winter maintenance program (which includes testing alternative snow and ice removal actions and materials), and a guardrail and roadside-obstacle improvement program. All of these are in addition to those safety improvement programs using specific federal safety funds. The road commission has applied for and received at least its share of the categorical federal highway safety funds in past years, and applications for these funds continue to be submitted.

IMPORTANCE OF EMPLOYEE INVOLVEMENT

Agency experience indicates that the importance of employee involvement at all levels simply cannot be stressed enough. Unless there is a commitment on the part of the people responsible for making the necessary improvements, any program, but especially one of this magnitude, will fail. This commitment is not easy to come by; rather, it must be earned. It must be proven to engineers and field laborers alike that the new priority should become an operational habit and not simply a temporary exercise in paperwork. This can be done through direct employee involvement in decision making and by repeated evidence from top management through obvious changes in top-level decisions. The committee process, although cumbersome at times, provides a mechanism for such employee involvement. If the committees are charged with developing recommendations within time constraints and many of those recommendations are implemented, the commitment is reinforced.

Another mechanism is to make individuals more directly responsible for failures in the system. This approach is being tried by the Oakland County Road Commission through the assignment of liability claim losses against appropriate departmental budgets. Department heads thus become directly accountable for financial losses in areas where they have some degree of control.

Even the employee-survey process, such as the analysis of procedures described above, can be useful. It allows the seldom-heard-from employee to vent frustrations and at least feel that he or she has had a chance to be heard. There may also be fringe benefits that are not necessarily reflected in the original instrument. For example, although more than 700 road-hazard-report forms have been turned in by road commission employees, there has also been a notable increase in radio and oral notification of problems. Thus, the forms themselves may not reflect the actual increase in employee awareness of problems and corresponding reporting. Again, through follow-up confirmation of suggested improvements, the commitment toward continued reporting is reinforced.

Repeated educational and training programs are also mandatory. The messages of priorities and duties relating to those priorities must be repeated again and again so that there is little question that the new program is here to stay. Finally, there must be continued reinforcement from top management. Commitment from the top must be the most evident.

FUTURE DIRECTIONS

Many of the programs and activities described in this paper are in the form of in-house demonstrations, and staff will be analyzing and improving them. Eventually, the staff hopes to develop a system for the allocation of all road commission resources in the interest of safety. But, although determining the priorities of link and intersection improvements is not always an easy and clear-cut process, the allocation of resources among the numerous construction and maintenance activity alternatives is even more difficult.

Through the adoption of safety as its number-one priority and the implementation of the highway risk-management program, it is believed that the Oakland County Road Commission has taken a more significant step toward improving highway safety than any other road agency in the nation.

An informal survey of approximately 70 public agencies responsible for streets and highways indicated that major safety improvement programs generally correspond directly with available federal safety funds. The Oakland County Road Commission's program far exceeds the federal program limitations. It is believed that the road commission's program will demonstrate that substantial improvements can be made in highway safety at existing levels of funding and that road agencies need not wait for new federal programs. There is no question that additional funding is warranted at all levels, but progress can be made in highway safety without waiting.

Publication of this paper sponsored by Committee on Transportation Programming, Planning, and Evaluation.

Abridgment

Matrix Project Management in Transportation: New York State Experience

William J. McLoughlin

The topic of matrix project management in transportation is explored, and the results obtained after two years of experience by the New York State Department of Transportation are described. The major problems of increased complexity of the transportation-project development process and the effects of inflation on project delays led to the creation of the program planning and management group in the fall of 1976. This new organizational structure, of which the program-project management section is a part, allows primary units that interact during critical stages of the project development process to be located within the same major unit. The organizational structure of the program-project management section and the duties of its members are discussed. An analysis of the first two years of operation, 1977 and 1978, is presented based on decreased project slippage and dollar value of projects let. The average project slippage on 100 sample projects in the period January-December 1976 was 5.11 months and that on projects monitored in 1977 and 1978 was 2.45 months. By applying this slippage reduction against the 1977-1978 average inflation rate of 10 percent per year on a total letting of monitored projects for the same period of $1.364 million,

a cost saving of $30 million can be calculated. During the period 1977-1978, the 91 monitored let projects represented only 14 percent of the total projects let but composed 68 percent of the total dollar value of the program. The average value of these projects was in excess of $10 million. These relatively simple findings indicate a great amount of success at a minimal investment of staff and resources.

Following the completion of a study by the Management Improvement Bureau in the summer of 1976, the New York State Department of Transportation (NYSDOT) formed a new group called the Program Planning and Management Bureau.

This paper will explore the management theories of matrix project management as used by one part of this group—the program-project management group—and the results achieved in its first two years, 1977 and 1978, in reducing project slippage and, consequently, in reducing added costs due to inflation.

MANAGEMENT THEORY

To understand the development of project management, it is necessary to explore the customary view of the matrix organization. This is a structure in which authority flows both horizontally and vertically, and there is a key person who is the focus of activity and has the capability of cutting across lines of authority to accomplish the ends of the project. Matrix organization, as an advanced concept of organization structure, is typically associated with complex technologies, in particular the aerospace and computer industries.

Matrix project management is a form of project management in which the actual work on a given project is performed within the functional departments but the flow between functional areas of assigned programs and priority projects is overseen by a project manager assigned to bring it to a successful completion.

Although the key person, called the project manager, has some formal authority, much of his or her success comes from the ability to influence functional managers and reach understandings with them. The effective project manager exercises power outside of that formally granted by the formal organization.

The role of the project manager is to see that the time, quality, and cost standards for the project are met. He or she acts as the advocate for the project in each of the functional departments that do work on it. This is in contrast with the functional managers who are responsible for the project only while it is under progress within their own functional areas. The functional manager handles the more specific tasks of assigning staff and facilities and ensuring that requirements are fulfilled according to deadlines, technical accuracy, and other criteria as needed within the functional area. Only recently have project managers shifted their attention to the problems of lateral relationships and the corresponding problems of coordination and integration. Perhaps the reason for the rapid growth of this organizational development is that observant managers have recognized that the most crucial problems concern improving cooperation and coordination between departments, managers, and subsystems.

TRANSPORTATION FACILITY PROJECTS AND MATRIX PROJECT MANAGEMENT

The time required to develop a transportation project varies considerably by the type of project. Planning, designing, and constructing a new facility may take many years, but resurfacing an existing highway may take only a few months.

Every proposed project results in social, environmental, and economic effects that must be assessed in the development process. To ensure that such effects are consistently and systematically considered, each state has been required to develop an environmental action plan, a formal document that serves as the organizational framework for considering those effects throughout the project development process. To comply with the provisions of the National Environmental Policy Act of 1969, the environmental impacts of each individual project must be assessed so that final project decisions are made in the best overall public interest.

The complexity of this procedure and the added state and local requirements have caused lengthy delays and added costs to projects. In 1971-1972, these delays became so pronounced that the U.S. Congress held committee hearings to explore the causes of a near halt to road construction nationwide.

At the average inflation rate of 9 percent of the early 1970s, the average increase of design time (44 months) meant increases in the costs of projects of more than 30 percent. These increased costs became a matter of great concern to the states as highway costs escalated at a rapid rate while local available tax dollars receded at an equal rate.

Due to the complexity of the project development process found in the environmental action plan and the need for detailed coordination among the various functional areas, it became difficult for the functional managers to keep the various projects on a set schedule, which made it apparent that changes in the management system were necessary. The complexity of the process of managing a project through the various functional areas justified the consideration of matrix project management.

Four criteria can be cited as guidelines for the use of the matrix approach:

1. A time schedule must be met.
2. Cost constraints are critical.
3. Coordination of specialized skills is required for completion of the project.
4. The required actions are in some way new or unfamiliar to the personnel involved.

Thus, NYSDOT management decided to establish a management mode based on matrix project management. There were two reasons for this: (a) the process through which a project must travel is very time-consuming and complicated and requires the interaction of many bureaus and (b) the large number of projects makes it impossible to have one project manager assigned to each project. Matrix project management is conducive to the multiple approach.

MATRIX PROJECT MANAGEMENT IN NYSDOT

The Organization

The centralized program planning and management group created in the fall of 1976, which reports to the office of the commissioner, consists of

1. The Program Planning Section (previously located in the Planning Division),
2. The Capital Projects Coordination Bureau (previously assigned to the Finance Division),
3. The Environmental Analysis Section (previously assigned to the Development Division), and
4. The Program-Project Management Section (which oversees critical projects).

This staff organization was established to limit the impacts of outside changes on the delivery of systems and to provide a bridge for the functional organizations when new or significantly different programs are introduced. The new group brought together three existing functions having departmentwide responsibility for project advancement and created a small group of problem solvers to assist in advancing programs and high-priority projects. This new organizational structure allows primary units that interact during critical stages of the project development process to be located within the same major unit. It also allows a closer working relationship between the units involved in project advancement, which provides shorter, simplified lines of communication.

The only new group introduced into the organization was the Program-Project Management Section. Because this group reports directly to the office of the commissioner, the following benefits can be anticipated:

1. Provision of a central focal point for the early detection and prompt resolution of potentially significant problems,
2. Availability to the executive staff of better and more current information on the status of programs and projects and the impacts of various options involved,
3. Capability for quicker actions and decisions on new programs,
4. More efficient use of department resources and a decrease in the time needed to bring a project to completion, and
5. Integration of programming and scheduling factors.

The Program-Project Management Section consists of a small group of problem solvers whose task is to assist in advancing programs and high-priority projects. This section implements the program-management concepts and is responsible for obtaining the management decisions necessary to complete programs and related projects on schedule and within budgeted costs.

Duties are broken down so that a project manager has responsibility for various regional offices and specific programs. The chief program manager has similar responsibility for regions and programs, along with overall direction of the group, and represents the section at staff meetings and assigns projects and program duties to the four project managers. The principal project managers handle larger and more complicated projects and program areas. They also act in a supervisory, advisory capacity to the associate project managers.

Each program manager is assigned specific programs and high-priority projects for which he or she accepts responsibility. The duties of the program-project manager in this system can be broken down into several major areas, the most comprehensive of which is the directive to manage the flow between functional areas of assigned programs and priority projects and bring them to a successful conclusion. In meeting this responsibility, the project manager has the duties of directing overall implementation efforts; the preparation of program plans, schedules, and necessary instructional materials; and the formulation and implementation of revised plans and of providing clarification where necessary. Other functions that are performed by the project manager include establishing and maintaining liaison with other state and federal agencies, performing continual review of assigned projects to ensure that schedules are being met, resolving issues and problems beyond the scope of the functional managers (which includes identifying problem areas), and recommending remedial courses of action.

Currently, NYSDOT must coordinate more than 30 programs. These are constantly in flux as some programs are added, some are combined, and others are eliminated. The program management group assists the functional managers in coping with these changes and in enlisting the timely support of others whose actions are critical to advancing the programs. There are also a relatively small number of projects that require individual and concentrated attention to bring them to completion. Those projects in which there is a great deal of public interest and those that were previously assigned to outside consultants have lost large amounts of time due to coordination problems. In addition, the program managers are assigned projects that have routinely fallen behind schedule, as shown on the exception reports produced by the Capital Projects Coordination Bureau, and that the bureau is unable to return to schedule. It is estimated that more than 100-150 projects will receive this detailed review each year.

It should be emphasized that the project managers are not responsible for substantive aspects of the programs or projects and therefore are not substitutes for the functional managers, who have the responsibility for controlling activities and the performance of work. Project managers should have full knowledge of all aspects and requirements of programs and assigned projects and serve as a bridge across functional lines. For new or significantly changed programs, the project manager ensures that responsibility is assigned, that all involved parties are kept informed, that plans are prepared, and that proper priorities are assigned. Once a program is running smoothly, project management personnel will withdraw and rely on the basic monitoring system to identify new problems. For individual projects, the project manager will uncover problems caused by lack of policy or delays in decision making and bring these to the attention of the appropriate functional manager. The group will also ensure that higher-level management is informed of delays that are beyond the control of department personnel so that administrative action can be taken.

Results: 1977 and 1978

Two measures were used in the evaluation of the first two years of operation of the program: (a) project slippage and (b) percentage of dollar value of projects let. These measures were chosen because they are major items set forth as goals and objectives for the Program-Project Management Section and because the data they require are easily obtainable.

Those projects identified for detailed monitoring were those that had engendered a great deal of public interest and also those projects that had routinely fallen behind schedule and could not be returned to schedule.

In 1977, some 100 projects were monitored in detail and, in 1978, 116 projects had the same detailed monitoring. Sixty of the 100 projects monitored in 1977 were let in that year, and 31 of the 116 projects monitored in 1978 were let in that year. The average value of the projects was in excess of \$10 million. During the two years, the 91 let monitored projects, although representing only 14 percent of the program, composed 68 percent of the total dollar value of the program. Thus, the Program-Project Management Section monitored the larger, more complicated projects.

A major factor in the success of the matrix-project-management concept is its effect on slippage or time delays, that is, its efficiency in holding projects within time constraints. The 100 projects monitored January-December 1977 represent a high percentage of projects in the later part of the project development stage. The 116 projects monitored January-December 1978 offer a more-representative cross section of the total project development process. The analysis of the average slippage is based on the total time span, i.e., January 1977 to December 1978.

Using the 100 projects monitored January-December 1977 as a base, an examination of the slippage experience by these same projects January-December 1976 shows an average of 5.11 months and a high for 12 projects in one regional office of 10.33 months. During the period January 1977-December 1978, the average slippage per project monitored was reduced to 2.45 months, a reduction of 53 percent.

If this slippage reduction is applied against the average inflation rate for January 1977-December 1978 of 10 percent per year on a total letting of monitored projects for the same period of $1364 million, the cost saving calculated is $30.0 million.

Another success factor is the support shown by higher-level management in the efforts of the Program-Project Management Section. Monthly status reports on the monitored projects were developed by the section and reviewed at regular monthly meetings with this management. At these meetings, decisions are made on those problems beyond the control of the project manager and action is taken to correct the situation. Although many other factors are involved in the measured success, without this visible follow-up to major delays, it is doubtful that the section would have achieved such results in the first two years.

Future Years

The future course of the matrix-project-management concept is dependent on recognition of the possible failings of the system: inability to identify the responsible person, the fostering of power struggles, being considered redundant during economic recession, and fear of high costs associated with the matrix organization. Recognizing and dealing with these and other problems associated with the matrix approach can improve the group's chance of future success. Continuing on course without acknowledging some of the possible failings of the matrix organization would be shortsighted.

Over the past two years, the major area of concentration of the Program-Project Management Section has been on the highway mode; there has been only minor emphasis on other modes of transportation. From projected trends, however, it is apparent that, in the future, more of the activity of the section will be given to the various other modes.

Publication of this paper sponsored by Committee on Transportation Programming, Planning, and Evaluation.

Abridgment

Suggested Criteria and Procedures for Setting Highway Priorities

David Curry and Guillaume Shearin

A practical system for setting the priorities of highway projects for the California Department of Transportation has been developed. This includes formula and rating instructions for setting priorities based on project merits for 12 of the 15 highway capital-outlay programs and guidelines for the remaining three maintenance programs. The general technique for rating projects consists of calculating a benefit/cost ratio or a cost-effectiveness index closely related to project objectives. The numerator of the ratio or index represents the benefits of the project, measured either in dollars or in weighted rating scales; the denominator is the project cost. This ratio or index is then used to rank projects within each program area. The project ranking is then subject to technical, financial, legal, scheduling, and political considerations that are not addressed by the formula. This priority-setting system, which has been used for a year with only minor adjustments to formulas and weights, is a major step toward rational spending of highway monies that are projected to cover only 25 percent of the anticipated need for improvement over the next six years.

In the study described in this paper, a practical system for rating and ranking improvement projects in each of the 15 components of the highway capital-outlay program of the California Department of Transportation (Caltrans) was developed. The capital-outlay program has a budget of $2.4 billion over the next six years, an expenditure rate that will meet only 25 percent of the anticipated need for highway improvements. New highway construction is the largest of the program components, constituting 53 percent of the total budget. Seven maintenance and rehabilitation components constitute about 20 percent of the budget, and six operational-improvement components and a very small (0.4 percent) bicycle facilities component constitute the remaining 27 percent. Even among the maintenance programs, the available funds will meet less than half the anticipated need, which thus emphasizes the need for careful project selection.

The technique for rating projects varies by program component, but the general approach is that intensity-of-impact variables [such as highway-user time saving per vehicle or decibels of noise reduction (each derived from project objectives)] are multiplied by breadth-of-impact variables (vehicle kilometers or number of affected housing units) to give impact ratings. Different impacts can be weighted if they are not all measurable in dollars. (A typical weighting and scoring system is described below for the HB33—safety roadside rest areas—program component.) The sum of the project impacts or ratings is then divided by the project costs to give either a benefit/cost ratio (when impacts are measured in dollars) or a cost-effectiveness index. This ratio or index serves as the criterion by which projects are ranked to determine their formula priority.

The formula priorities are only advisory, because additional considerations (such as financial, legal, scheduling, and political) are introduced in the process of developing the annual state transportation improvement plan (STIP). Also, there are some types of projects for which criteria were not developed in this study, usually either because they are legislatively mandated, are reaching completion within the present STIP, or would require excessive data or analytical cost. Even for projects that are rated by this scheme, there will often be technical or cost considerations not covered by the variables in the rating formula that will make exceptions to the formula priority desirable. Because of such exceptions and because of the other considerations and constraints, not all projects will have final priorities corresponding closely to the formula priorities.

The approach used in developing a priority index in the 15 program components was influenced by the current Caltrans priority methods. However, in some programs, there was a general lack of familiarity with or even a dislike of an economic or benefit/cost approach. Some distrust of computerized quantitative methods also existed, especially at the district level, and even the existing computer-based data and project indices were not always used in setting priorities. On the other hand, most Caltrans staff were familiar with deficiency- or sufficiency-factor methods. Some program components either had invested or were investing significant time in developing a priority method based on deficiency factors, generally without considering project cost.

The resulting criteria and rating scales are therefore very much a joint Caltrans-consultant product, based on applying engineering economy and scoring principles to the diverse requirements of each program component. A benefit/cost approach was found to be better suited to HA1, maintenance lands and buildings; HA3 and HA22, resurfacing and roadway reconstruction and restoration; HA4, protective betterments; HB1, safety improvements; HB4, traffic operations improvements; and HE1, new highway construction. For HA21, bridge reconstruction, a sufficiency-rating approach is most appropriate, and HA25, highway planting restoration, uses a combined benefit/cost and cost-effectiveness criterion. Cost-effectiveness is used by the other six program components: HB33, safety roadside rest areas; HA26, safety roadside rest-area restoration; HB32, highway planting; HB34, vista points and roadside enhancement; HB31, noise attenuation; and HE3, new bicycle facilities. Interim use of deficiency factors was recommended for HB32, HA1, HA22, and HA3 until the suggested preferred approach can be developed, because time did not permit completion of the recommended approach for those program components during this contract. Also, the use of a simplified form and rating procedure was recommended for calculating the community-impact index in HE1, new highway construction, until more detailed procedures can be tested and refined. Some technical assistance or added staff, similar to the financial analysis and assessment staff office that has been introduced at the Ontario Ministry of Transportation and Communications in Ontario, Canada, was thought necessary to develop the suggested refinements for HA1, HA22, HA3, and HE1.

Caltrans has used the procedures described below to develop a recommended STIP for 1980. For example, 290 projects have been ranked out of the 500 projects submitted for HE1, new construction. The six-year budget is sufficient to fund the first 110. Only minor adjustments were made in the rating weights and formulas during this first year. In subsequent years, project ratings will be updated based on any new data and on any rating system refinements.

HB33: SAFETY ROADSIDE REST AREAS

The HB33 program component funds designs and contracts for improved and additional safety roadside rest areas at acceptable standards of comfort and spacing. Caltrans' objective is a maximum of 96 km (60 miles) distance between rest areas in nonmetropolitan areas. The incidence of climate problems (such as rain and high winds) and existing roadside rest deficiencies are additional priority considerations. The cost-effectiveness (C-E) criterion for safety roadside rest areas is

$$\text{C-E index} = \text{AADT score} \times (w_1 \text{ alternative stops} + w_2 \text{ climate} + w_3 \text{ deficiency reduction}) \div \text{project costs} \quad (1)$$

where

AADT score = average annual daily traffic translated to a 0-to-1 scale on which 1 = 250 000 AADT (both linear and logarithmic scales are available) and

w_1, w_2, and w_3 = percentage weights.

Costs are in millions of dollars. The variables themselves—alternative stops, climate, and deficiency reduction—are each rated on a 10-point scale and $w_1 + w_2 + w_3 = 100$; thus, the potential total score in the numerator is 1000 points.

HA4: PROTECTIVE BETTERMENTS

The HA4 program funds construction to prevent damage to or loss of service on state highways. The program work categories are

1. Drainage and slope stabilization,
2. Earthquake restraint,
3. Truck scales,
4. Loss of lateral support (shoulder drop-off), and
5. Pavement edge drains.

Benefit/cost (B/C) methods can provide an excellent basis for determining HA4 priorities, but only the first work category has a sufficient backlog of projects to warrant implementation of this method. A B/C criterion for this category is described by Equation 2.

$$\text{B/C index} = 100 \times \text{probability of loss of service and damage} \times (\text{user costs from loss of service} + \text{Caltrans' cost of repairing damage}) \div \text{project cost} \quad (2)$$

This criterion approximately maximizes the expected project savings in loss of service and damage costs for a given budget by accounting for the uncertainty involved.

HE1: NEW HIGHWAY CONSTRUCTION

The HE1 program component, construction of new highway facilities, accounts for about half of Caltrans' capital outlay budget. Project types include upgrading substandard facilities, adding lanes, and providing new connections and cross-traffic improvements. New construction is planned "only when an adequate level of service cannot be provided by any other effective means". Previously, HE1 project priorities were determined by professional judgment supported by (a) a great deal of information on transportation benefits and on social, economic, and environmental impacts developed through a project report or an environmental impact statement (EIS); (b) public and local and regional government views, obtained through the same processes; and (c) sometimes, the calculation of delay or safety indices. These are benefit/cost ratios, multiplied by 100 to produce the index numbers, that show the values of expected travel-time savings and of accident cost savings, respectively, in relation to project costs.

A staged development plan is recommended in this study for future determination of HE1 project priorities. Four steps were suggested for the first year:

1. Refine the procedures for computation of the safety and delay indices.
2. Combine the delay and safety indices with a new community-impact index that uses simplified procedures for rating public acceptance, social, environmental, and economic impacts. The resulting priority formula is

$$\text{B/C index} = (\text{delay index})^{1/2} + \text{safety index} + \text{community-impact index} \quad (3)$$

3. Supplement the B/C index by obtaining narrative comments on any other considerations of potential importance to the priority of the project.
4. Test more-detailed procedures for rating community impacts on selected HE1 projects (those that have an EIS) to (a) refine the suggested procedures, (b) compare the refined procedures with the simple procedures suggested for immediate use, and (c) determine the extent to which the community-impact index affects the transportation benefit/cost index in typical projects.

Among the refinements suggested for the delay index are (a) a method for estimating the value of travel time as a function of the amount of time saved (time savings are not valued highly until they exceed about 5 min/trip) and (b) a pricing correction factor to adjust user benefits for the underpricing of highways and their consequent overuse (which creates undue or premature congestion and the associated tendency to overbuild). The pricing correction factor reduces user benefits as a function of the price elasticity of demand for highways, which is a measure of prospective induced travel—hence, urban highway improvements are more affected by this adjustment than are rural improvements. A parallel measure for new facilities, the tendency to induce residential growth in undesired locations, is included in the proposed community-impact index.

Among the variables considered for inclusion in one of the HE1 indexes, but eventually dropped, was fuel savings. In this case, the net effect will generally be too small to justify the necessary estimates and calculations.

In subsequent years, it will be necessary to decide whether to use the refined procedures for computing the community-impact index, either in general or for projects having an EIS available.

HB4: SYSTEM OPERATION IMPROVEMENTS

HB4 is the largest program component after new highway construction; it uses about 11 percent of the six-year highway capital-outlay budget. It entails increases in the efficiency and quality of traffic service through projects that reduce freeway congestion (such as climbing lanes, high-occupancy-vehicle lanes, priority ramp treatments, and fringe parking facilities), improve freeway traffic service (such as improved lane delineation and signs), and improve conventional highways and expressways (such as traffic signals, left-turn and passing lanes, and shoulder widening). Many of these types of projects have measurable and predictable effects on traffic flow or accident risks, so it is recommended that the delay and safety indices be calculated for all applicable projects and combined in a single criterion, the transportation benefit/cost index, as follows:

$$\text{Transportation B/C index} = \text{delay index} + \text{safety index} \quad (4)$$

For HB4 projects that do not have significant effects on traffic flow or safety, continuation of the present Caltrans effort to develop separate cost-effectiveness indices is recommended.

Publication of this paper sponsored by Committee on Transportation Programming, Planning, and Evaluation.

Highway Funding: Arizona Case Study

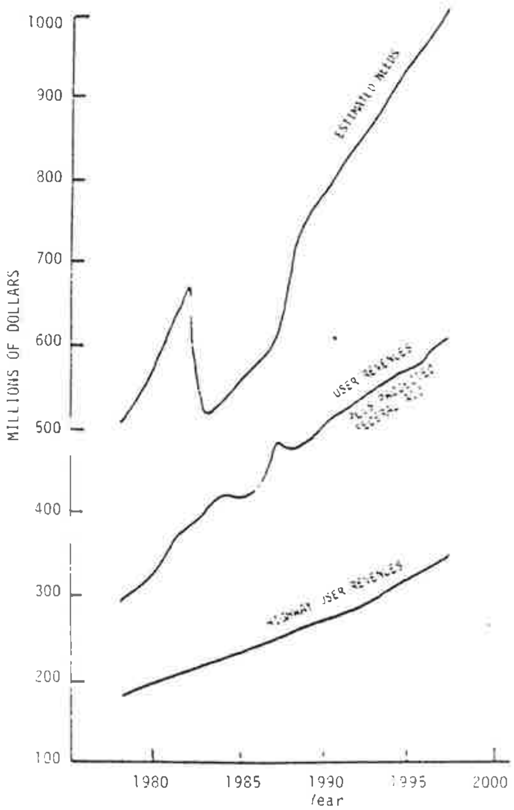
Judson S. Matthias and Robert H. Wortman

During the summer of 1978, the highway funding situation in Arizona was reviewed and the alternatives for overcoming the anticipated future deficit were studied. Although a number of user, as well as nonuser, revenue sources are potentially available, the emphasis was placed on increasing user charges. Based on this study, it was recommended that revenues be increased by (a) staged increases in the fuel tax, (b) increases in registration fees, and (c) increases in third-structure taxes. In all cases, it was recommended that user taxes be tied to a consumer price index so that additional increases will offset the effect of inflation.

In January 1978, the Arizona Department of Transportation (ADOT) submitted the Biennial Statewide Transportation Needs Report to the state legislature in accordance with the law passed by the 31st legislature in 1974. This Needs Report represented the culmination of a comprehensive examination of the current estimates of future transportation needs in the state.

Basically, the report indicates that Arizona faces major problems with respect to the funding of the highway system over the next 20 years. Figure 1 illustrates the comparison between the anticipated needs and the funding available from current revenue sources and indicates a considerable deficit. Even though the results of the needs study are considered to be conservative estimates of the resources that will be required, it is expected that the deficit will be at least approximately

Figure 1. Estimated needs and forecast revenues.



$7.5 billion (based on estimated revenues from the Arizona highway-user revenue fund and projected federal aid). The financial resources from the highway-user fund are used to support highway programs of the cities and counties, ADOT, and the highway patrol activities of the department of public safety (see below).

Item	Percentage of Total
Source of revenue	
Fuel taxes	63
Vehicle registration fees (prorated), weight fees, and nonresident permits	23
Motor carrier (passenger and freight) taxes (gross receipts)	7
License (motorcycle, chauffeur, and operator) fees	2
Other (title, dealer licensing and plates, oversize permit, inquiry and miscellaneous) fees	5
Expenditure	
State highway fund	57
Highways in incorporated cities and towns	17
Highways in the counties	15
Department of public safety	11

Obviously, the lack of sufficient financial resources will affect transportation agencies at all levels of government throughout the state.

The needs study indicated that highway financing in the state should be reviewed and that options that would generate additional revenues for the highway-user fund should be developed. Thus, in response to a request from the state legislature, Arizona State University, Northern Arizona University, and the University of Arizona initiated a study of funding for Arizona highways. The basic purpose of this study was to examine the ways and means of generating additional funds for the highway-user revenue fund so as to make available the necessary financial resources.

The financial resource requirements as estimated and projected in the Needs Report were used as the basis for the total revenues that will be necessary over the 20-year forecast period. These estimates were accepted as reported; the focus of this project was on the alternatives for generating the required additional revenues. The implications of failure to meet the transportation needs are documented in the needs study and show that there will be serious consequences if the transportation needs are not met.

CURRENT ISSUES

At present, transportation agencies at all levels of government in Arizona are faced with the difficult tasks of maintaining existing highways and providing new facilities in response to public demands. The current highway financing situation poses major problems in terms of the ability of the agencies to carry out their responsibilities for the provision of services to the public. (It is recognized that the problems associated with highway financing are not unique to Arizona but are of concern in almost every state.)

A number of underlying issues bear directly on existing and anticipated future highway financing problems. In many cases, these issues are the result of situations or problems such as energy constraints, growth, economic conditions, and taxation; nevertheless, their impact has been on and potentially will have major implications for the funding of highway facilities.

Effects of Inflation

In the provision of highway facilities and programs, inflation is a major concern because it increases the costs of transportation agency services and facilities. The rate of inflation has increased significantly over the last decade, and current forecasts indicate that this trend will continue. Basically, this means that budgets for highway operations, maintenance, and construction must be increased even if the levels of activities and programs are fixed. If the available financial resources do not permit budgets to be increased commensurate with inflation, then it will be necessary to reduce highway services.

The magnitude of the problem is shown by an examination of the funding requirements as outlined in the Needs Report. In the needs study, the difference between the total 20-year needs and the expected revenue was found to be approximately $2.4 billion in terms of 1977 dollars. When the effect of inflation is considered, however, the difference is approximately $7.5 billion for the same period. Thus, inflation alone will cause the deficit to almost triple over the study period.

A review of the major revenue sources for the highway-user revenue fund, however, indicates that these sources are generally insensitive to inflation. The revenue generated is not a function of the price changes for highway services and facilities. Gasoline and use fuel taxes are based on a fixed tax per unit volume, and registration, operator licensing, and weight fees are assessed on a set-fee basis. Thus, the most important sources of revenue do not reflect inflationary conditions, which in view of both current and anticipated future inflation patterns is a major concern.

Increased Fuel Economy

The energy shortage and the continuing concern about energy have had and will continue to have significant impacts on the highway funding problem. The American public has begun to shift to more fuel-efficient vehicles, and mandates have been imposed that are aimed at increasing the fuel efficiency of future automobiles. It is expected that this trend toward greater fuel efficiency will continue.

Estimates provided by ADOT indicate that the average fuel efficiency for gasoline-powered vehicles in Arizona for 1978 was 5.67 km/L (13.33 miles/gal). By the year 2000, this is expected to improve to 10.42 km/L (24.50 miles/gal). Corresponding estimates for diesel-powered vehicles are 3.53 km/L (8.30 miles/gal) in 1978 and 4.94 km/L (11.60 miles/gal) by the year 2000.

These increases in fuel efficiency are certainly necessary in view of the energy situation; however, improved fuel efficiency means reductions in highway revenue for given levels of vehicle travel. For example, if the fuel efficiencies for the years 1978 and 2000 are compared, the revenues from gasoline taxes will be reduced by almost 50 percent for a given amount of vehicle travel. In essence, the gasoline tax cost per kilometer of travel will be greatly reduced; for use fuel, the situation is similar but of a lesser magnitude.

Highway-User Tax Burden

Transportation systems and facilities are necessary to provide the mobility required for broader societal objectives. In this respect, the need for transportation facilities is a function of the mobility that is required to support socioeconomic activities and, thus, expenditures for transportation facilities should be related to the economic activity of an area.

An examination of the highway-user revenue fund indicates a general decrease in highway-oriented tax revenues relative to personal income in Arizona. For example, the highway-user revenue fund was 1.45 percent of personal income in FY 1961, increased to 1.74 percent in FY 1967, and then decreased to 1.29 percent in FY 1974 when a motor-fuel tax increase increased the percentage slightly; however, it is estimated that in FY 1978 the highway-user revenue fund revenues were 1.23 percent of personal income. During a time when the overall tax burden has increased relative to personal income, the highway-oriented tax burden has decreased.

Another measure of the highway-user tax burden is the tax revenue relative to vehicle kilometers of travel. Again, there has been a general decrease in the tax burden relative to travel. For example, if the highway-user revenue fund revenue per vehicle kilometer traveled for FY 1978 is compared with that for FY 1974, there is an approximately 16 percent decrease in the tax burden. Although the public is traveling more, the tax burden on a distance-traveled basis is decreasing.

State Spending Limitations

In the November 1978 election, the voters approved a referendum that limited state spending in a given year to 7 percent of total personal income. The types of problems that this restraint places on state agencies are being recognized; however, the full ramifications of the limit may not be fully understood for several years.

The state is approaching or may have reached the limit already. The effect on highway spending is fairly obvious; the needs gap cannot be closed by increasing highway revenues unless there is also a substantial reallocation of funds or a reduction in some other agency spending. Because of the magnitude of the added revenues that are required to fill the highway needs, it is doubtful that closing the gap will be possible unless expenditures are reallocated.

Beyond the obvious problem of restraints on expenditures, there are more subtle issues surrounding the 7 percent spending limit and the relationship with highway finance. Possibly the most important of these is that ADOT will be limited in its ability to catch up in high-revenue years on maintenance or construction that had been deferred during low-revenue years. Under the mandate, funds will be appropriated for ADOT each year, and only that amount can be spent. If highway revenues exceed appropriations, the excess funds are put aside to be appropriated the following year. Given that the costs of road maintenance and road construction increase over time due to both inflation and the additional wear on existing roads, this constraint represents an inefficient use of highway funds.

Inadequate Funding

In addition to the tax burden, highway users must also pay the operating and maintenance costs of their vehicles. Poorly maintained highways result in increased vehicle operating and maintenance expenses. For example, tire wear, suspension system wear and damage, and fuel use all tend to increase as the condition of the roadway is degraded. Also, accidents increase, which again increases the user cost for a facility, due to accident and insurance costs.

If adequate maintenance funds are not available, transportation agencies may be forced to delay necessary maintenance activities. In using such a practice, the agencies risk dramatic increases in the cost of restoring the roadway at a later date. Although delays in maintenance activities may contribute to short-term budget reductions, they can be expected to increase the overall cost of providing serviceable roadways.

The needs study cost estimates assumed timely maintenance programs; thus, if maintenance activities are deferred, these estimates will have to be significantly increased. At the same time, a reduction in the efficiency of the highway system, whether from inadequate maintenance or lack of adequate facilities, results in an economic ripple across the entire economy—road-user costs increase, the costs of goods and services (which include transportation costs) increase and, ultimately, almost all costs increase.

Similar increases in cost to the road user can be expected if highway development fails to keep pace with the growing demands for travel and improved facilities that are caused by population and economic growth. In this case, the added cost can be attributed to congestion, delay, and accidents. The road user, therefore, is placed in the position of supporting the cost of highway construction, maintenance, and operation. If adequate funding is not provided, the road user suffers the increased costs associated with inadequate or poorly maintained facilities.

These increased costs are also passed on to the nonuser as well, because transportation costs are included in the production and distribution of goods and services. Thus, adequate transportation facilities are of interest to society as a whole as well as to the road user. It may be said, therefore, that the citizens of Arizona will pay the total cost of highway transportation in one way or another. If adequate funding for highway construction, maintenance, and operations is not available, then the added costs will be paid in the form of additional vehicle operating and maintenance costs, time delay costs, and insurance premiums.

HIGHWAY FUNDING ALTERNATIVES

Funding alternatives of highways must ensure that the current issues associated with highway financing are addressed. In this respect, they must be sensitive to the effects of inflation, and the recommended solution should contain a mechanism that accounts for both inflation and deflation of construction, operation, and maintenance costs. At the same time, the solution should overcome the deficiencies in highway funding, both current and projected, and the requirements for new highway development due to increased travel should be accommodated. The change in vehicle technology with respect to fuel use poses new problems in terms of the current heavy reliance on motor-fuel tax revenues. All of these aspects of the overall problem must be considered, even with the restraints that have been placed on taxing and spending in Arizona.

Approaches to Overcome Effects of Inflation

There are two approaches that could be used to offset the effects of inflation with respect to highway revenues. The first would be to apply a cost or price index to some revenue base so that tax rates would be adjusted according to the price or cost index. In this way, revenues would increase or decrease based on price or cost changes. Ideally, highway-user tax rates should be adjusted according to a construction cost index. A consumer price index (CPI) is being developed for Arizona, and it may be possible to apply this index to highway-user changes. The use of a CPI has the advantage of being accepted for other applications in the state, and the use of a common index would simplify the situation.

The second approach to offsetting the effects of inflation would be to establish the level of highway funding as a percentage of personal income. Generally, this would have the same effect and would adjust revenues on a basis of personal income changes, provided those changes were directly related to inflation.

Both approaches would require initial increases in revenue to overcome the current deficiencies in funding. But once that was achieved, the indexing scheme would provide for increases in revenue to overcome the price or cost changes.

Period of Implementation

Although the needs study indicates a current deficiency in terms of available revenues, it is reasonable to expect that transportation agencies would require a transition period to prepare for programs that are commensurate with higher levels of funding. Because of the magnitude of the current deficit, a period of several years would be necessary, during which it would be necessary to increase revenues to overcome the deficiencies and to modify the programs to account for inflation.

During the transition period, some needs will not be met. It will be necessary for transportation agencies to reassess impacts on anticipated needs where programs must be delayed due to inadequate funding. It is likely that future needs will increase and that the funding levels will have to be increased accordingly.

Funding Source Alternatives

There are two general options that could be pursued relative to providing highway funding in Arizona. The first is to modify the current tax and fee structure of the highway-user revenue fund. The second is to supplement or replace the current funding structure with taxes and revenues from new sources.

Modification of the existing tax and fee structure would not require new taxes. All highway-user taxes such as fuel, registration, weight fees, and such would be increased. This would distribute the increase to all groups of road users and could be done so that the increase would affect all classes of road users in the same manner. Alternatively, some rather than all taxes could be increased. Taxes could also be increased by stages as the needs increase.

New revenue sources could be either new taxes or the allocation of existing tax monies from the general fund into the highway-user revenue fund. The main problem with this approach is that general fund monies available for other purposes would be decreased unless other (nonhighway) tax rates were increased. The use of the general fund as a source of additional highway funds would require no increase in the tax collection administrative structure.

The new-tax option would require the enactment of new taxes. A new tax or taxes should be highway-user oriented to maintain the user-benefit concept. Any new tax should be readily identifiable as a tax on highway users.

A combination of general fund diversion and current tax modification is also possible. This approach would tend to mitigate the unattractive features of each. The administrative costs of tax collection would not increase, and the realization that everyone benefits from the highway system would reinforce the user-tax concept.

In the course of the study, the following revenue alternatives were selected for detailed examination:

1. Gasoline and use taxes (increases in the volume-based tax, sales taxes on the nontax price, taxes based on a percentage of price, and variable fuel taxes),
2. Motor vehicle license (in lieu or personal property) taxes,
3. Sales taxes on automobile-related sales,
4. Sales taxes on private sales of automobiles,
5. Vehicle registration fees,
6. Motor carrier taxes (third-structure taxes),
7. Lodging taxes,
8. Bonding, and
9. Taxes on increases in property value due to highway improvements.

CONCLUSIONS AND RECOMMENDATIONS

Based on the study of the various tax alternatives, it was concluded that the state should maintain the user-tax concept for highway funding. Although no tax is popular, the user-tax concept appears to be acceptable if the need for revenue is properly identified. The user tax appears equitable, that is, those who benefit should be prepared to pay the cost of that benefit, an idea that was included in the recommendation by increases intaxes for all groups of road users by approximately the same rates as under the existing tax structure.

The recommended package includes increases in the fuel tax, automobile registration fees, truck weight fees, and the various truck permits and is as follows:

1. First year: The fuel tax should be increased \$0.0026/L (\$0.01/gal), vehicle registration fees (private automobiles and trucks) should be increased \$8.00, and truck weight fees and associated prorated and permit fees should be increased 10 percent. All of these taxes should be tied to the CPI and adjusted annually.
2. Second year: The fuel tax should be increased \$0.0026/L in addition to any change indicated by the CPI.

3. Third and fourth years: The fuel tax should be increased $0.0026/L, if necessary to close the gap between identified needs and revenues, in addition to any change indicated by the CPI.

The forecast revenue under the recommended plan and the needs in five-year increments are compared below.

Period	Needs ($ millions)	Federal Aid Plus Revenue ($ millions)	Needs Met (percentage of total)
1978-1982	2945.3	1892.4	64.3
1983-1987	2827.5	3010.1	106.5
1988-1992	3966.5	3580.2	90.3
1993-1997	4734.7	4759.5	100.5

The rationale for the recommended package includes all of the factors discussed above. The user concept is maintained in the package by using the existing road-user tax structure. This also means that the collection machinery already exists; no significant new administrative organization is required, which will minimize administrative costs. The package provides for the effect of inflation by tying the user taxes to automatic changes in the state CPI (which will be prepared regularly). This is an important feature because the current user-tax structure is not responsive to inflation. The first-year increase will bring the tax rate to where it would have been if highway-user taxes had been tied to the inflation rate since the last fuel-tax increase in 1975. Population growth and travel are accounted for by increases not only in the fuel tax but also in vehicle registration and truck fees.

The taxes are spread over a broader base. This feature of the package reduces the reliance on the fuel tax as the primary source of revenue. Because of the technological changes that are occurring, proportionally less income will be realized from the fuel tax.

(Because the federal government is currently carrying out a weight allocation study to determine the effects of heavy trucks on highway costs, weight fees were not discussed in this report; the entire problem of weight allocation costs should be reviewed when the federal study has been completed.)

The opportunity for periodic review is a feature of the recommended package. Because the transition period for implementation covers several years, it will be possible to review needed increases in light of updated needs studies.

Because of the transition-period feature, the first-year increase to users will be approximately $16/passenger-type vehicle or about 10 percent. The transition period will allow for timely planning by the various highway agencies that use the funds and permit a gradual increase in state highway spending with respect to personal income.

It should be noted that these recommendations are specific for the state of Arizona. Although many states currently face funding problems, it is not possible to set forth recommendations that would be applicable to the travel and taxing situations in all states. This study did provide a set of recommendations that would address the problems in Arizona.

ACKNOWLEDGMENT

This paper is based on a project conducted by the Arizona State University, Northern Arizona University, and the University of Arizona for the Arizona State Legislature. We thank the many organizations and individuals who provided data, information, and guidance for their efforts and assistance. The contents of the paper, however, reflect our views; we are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the state of Arizona. This paper does not constitute a standard, specification, or regulation.

Publication of this paper sponsored by Committee on Taxation, Finance, and Pricing.

Methodology for Evaluating Impacts of Energy, National Economy, and Public Policies on Highway Financing and Performance

Fred L. Mannering and Kumares C. Sinha

The need to conserve energy, inflationary pressures, decreasing user tax revenues, and recent national automotive policy decisions have created problems that have seriously affected the state highway financing process. This paper discusses the development and application of a computer model that can be used to analyze and estimate the complex interactions among the factors influencing highway financing and their ultimate impacts on highway performance. The model uses the national energy and economic forecasts developed by Data Resources, Inc., along with a set of possible highway policy options, and simulates their effects on factors such as vehicle fuel efficiency, commercial and noncommercial vehicle travel, fuel consumption, revenue generation, and highway maintenance and capital expenditures. Application of the model to the Indiana problem indicated that an overall deterioration in highway performance can be expected because the revenue required to stabilize or improve highway performance is enormous. However, the scenarios tested showed that highway policy options such as revised highway performance criteria and programs to reduce future highway use can have a significant impact on future highway performance. Thus, combinations of increased tax rates and non-revenue-generating highway policy options may be necessary to ensure the sustenance of a tolerable level of highway performance in the future.

The current state highway financing process is confronted by a number of serious problems that are being aggravated by recent economic conditions and national policy decisions. On the one hand, highway construction, operation, and maintenance costs have increased drastically in recent years while, on the other hand, road-user tax revenues have remained the same or decreased. These problems have led to the deferral of many needed highway improvement projects and, consequently, overall highway performance has suffered. Moreover, the long-term impacts that national and regional energy-conservation policies will have on the state highway financing process are not clearly understood.

It is clear that there is a definite need to examine possible legislative actions to substantially change the state revenue-generating structure and tax rates (or both) in order to provide sufficient resources for highway construction, operation, and maintenance. The intent of the study reported in this paper was to provide a tool, in the form of a computer model, that could be used to systematically evaluate the impacts that various proposed highway-related legislative decisions may have on highway performance in Indiana. [This paper is a brief summary of the study; details of model development and application are given elsewhere (1).]

The 1976 National Highway Inventory and Performance Study (NHIPS) (2) was the first major study to apply the exacting methods of measuring highway performance that were introduced in the 1974 National Highway Needs Report (3). This made possible detailed projections of highway service, physical conditions, and operating conditions under various highway-revenue scenarios. However, the 1976 NHIPS, and most other studies in this area, did not explicitly consider many of the interactive economic factors that affect future highway-financing and performance forecasts.

An overview of the modeling procedure used in the study reported here is shown in Figure 1. National macroeconomic forecasts are used as input to make projections of fuel efficiency, fuel consumption, state highway-user revenues, highway performance, and highway improvements. Fuel-efficiency projections, made on the national level, are a critical component in the determination of fuel-consumption projections, which are, in turn, used in the estimation of future state highway-user revenues. In addition, Indiana population projections were made by the cohort survival method and used to estimate the number of registered vehicles and the number of licensed drivers, both of which are also used in the calculation of state highway-user revenues. Revenues from sources such as federal aid are estimated exogenously and combined with the internally projected state highway-user revenues to determine the total funds available for highway expenditures. Finally, current highway conditions are simulated internally and used with projections of highway improvements and other factors to estimate future highway performance—which is the final step of the modeling procedure.

MODELING PROCEDURE

National Macroeconomic Forecasts

The three national macroeconomic forecasting models developed by Data Resources, Inc. (DRI), TRENDLONG 0978, CYCLELONG 0978, and PESSIMLONG 0978, were used to provide a probable range of future economic conditions to the target year 1990 (4). TRENDLONG essentially represents a long-run stable U.S. economy. CYCLELONG simulates a cyclical economic behavior and forecasts the business cycles that have historically characterized the U.S. economy. The projected 1990 gross national product (GNP) resulting from CYCLELONG is 2.2 percent less than that projected by the TRENDLONG model. PESSIMLONG projects essentially the same price, exogenous factors, and final demand behavior that has typified the U.S. economy in the past 10 years. The resultant 1990 GNP is less than that projected by either of the other two models.

The basic assumptions underlying these macroeconomic forecasts are given in Table 1 (4). The results of these models provided national projections of new car sales, automobile ownership, gasoline price deflators, industrial production, iron and steel production, and deflators for highway improvements, all of which were used at various stages of the present study.

Fuel-Efficiency Projections

Fuel efficiencies were projected on a national level and applied to Indiana. Five vehicle types were considered: (a) automobile, (b) motorcycle, (c) bus, (d) single-unit truck, and (e) combination truck.

The projection of automobile-fleet fuel efficiencies was made by using a cohort survival technique to project the automobile population by model year. The modeling approach considered the possible effects of the national economic climate and included a high degree of interaction between prevailing economic conditions and the model parameters. The basic elements of the model are to (a) project the number of automobiles in use by model year, (b) project automobile fuel efficiencies by model year, and (c) establish relative automobile use by model year. The average automobile-fleet fuel efficiency in any given year is then determined by appropriately weighting the fuel efficiencies of each model year. The computation procedure used is outlined in Figure 2. National projections of new car sales and automobile ownership (which are used internally to project scrappage rates) are provided as input from the DRI economic forecasts.

Due to data limitations, the fuel-efficiency values for other types of vehicles could not be estimated in such a detailed manner. Therefore, these estimates were made simply by extrapolating recent national values (5).

Fuel-Consumption Projections

Fuel consumption has a direct impact on fuel tax revenue, which historically has been the largest single source of highway revenue. The approach most commonly used to project fuel consumption is to estimate (a) future vehicle travel (VT) and (b) future fleet fuel efficiencies. Once these two elements have been determined, total fuel consumption can be determined by dividing VT by fleet fuel efficiency. An outline of this approach is shown in Figure 3.

Due to problems of multicollinearity, it was not possible to develop a regression equation by which to forecast total VT. Consequently, the VT equation given by Poister, Larson, and Rao (6, Figure 1), in which estimates of VT are made by assuming a growth rate and a demand elasticity of VT with respect to fuel price, was used. The growth-rate and demand-elasticity assumptions were made from an analysis of existing data and relevant literature (5, 7). Future fuel prices were determined by using the gasoline-price-deflator forecasts provided by the three DRI macroeconomic models.

The separate estimation of commercial VT growth (composed primarily of combination truck VT) is essential because of the large contribution these ve-

Figure 1. Overview of simulation procedure.

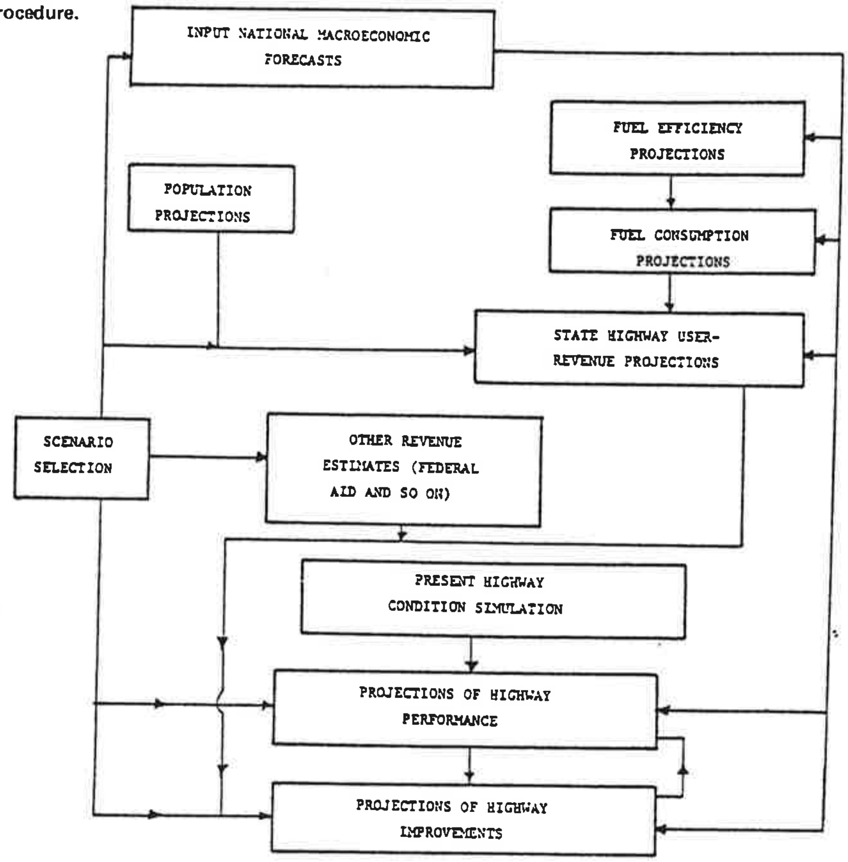


Table 1. Major assumptions underlying DRI macroeconomic forecasts.

Factor Forecast	TRENDLONG	CYCLELONG	PESSIMLONG
Fiscal policy	Federal expenditures increase at compound annual rate of 8.8 percent; federal budget is in balance after 1986	Federal expenditures increase at compound annual rate of 9.3 percent	Federal expenditures increase at compound annual rate of 10.6 percent
Monetary policy	Money supply is tightened in 1980 as inflation accelerates; stable credit is promoted	Fluctuations in policy contribute to severity of cyclic economic behavior	Same as under CYCLELONG
Consumer behavior	Low inflation rate and job security increase consumer confidence	Cyclic variations in sentiment result in large fluctuations in expenditures for durable goods	Same as under CYCLELONG
Business behavior	Decisions are made in a stable environment	Output fluctuations and uncertainty result in uncertainty and investor caution	Same as under CYCLELONG
Inflation rate	Capacity utilization and energy problems affect immediate future; steady improvement beginning in the early 1980s	Continual boom-bust pattern increases average rate	Aggressive wage and price behavior increases rates and also severity of economic slowdowns

hicles make to pavement deterioration. The estimation technique used calculates future changes in commercial VT by assuming that the change in total commercial VT is proportional to the change in motor truck intercity shipping. A regression equation was developed to project intercity shipping by using the national business index and Indiana steel production as independent variables. Provisions were also made for possible changes in truck capacities and truck capacity use, both of which will affect the proportionality assumption.

The total VT was segregated by vehicle type in the base year by using the national apportionments (5). The growth rate in combination truck VT was assumed to equal the growth rate in commercial VT, and projections of other vehicle VT values were made by extrapolating recent apportionment trends (5). Thus, fuel consumption can be determined simply by dividing the VT values by the appropriate vehicle fuel efficiencies.

State Highway-User Revenue Projections

Projections of state user revenue sources were made by categorizing such sources into four basic areas:

1. Revenues derived from motor vehicle registrations,
2. Revenues derived from license fees,
3. Revenues derived from state taxes on motor fuel, and
4. Revenues derived from miscellaneous user sources.

Automobile registration projections were made by assuming that an automobile saturation will be reached, at which time the number of vehicles per capita will stabilize. An appropriate saturation value was selected on the basis of findings in relevant literature (8, 9), and a power curve was fitted to the original data so that annual estimates of automobile ownership per capita could be calculated. Indiana population projections were made by the cohort survival method so that Indiana automobile ownership can be determined annually by simple multiplication.

Single-unit truck, bus, and motorcycle registrations were assumed to be proportional to automobile registrations. Combination truck registrations were projected by using an equation that uses the national business

Figure 2. Computation procedure for automobile fuel-efficiency model.

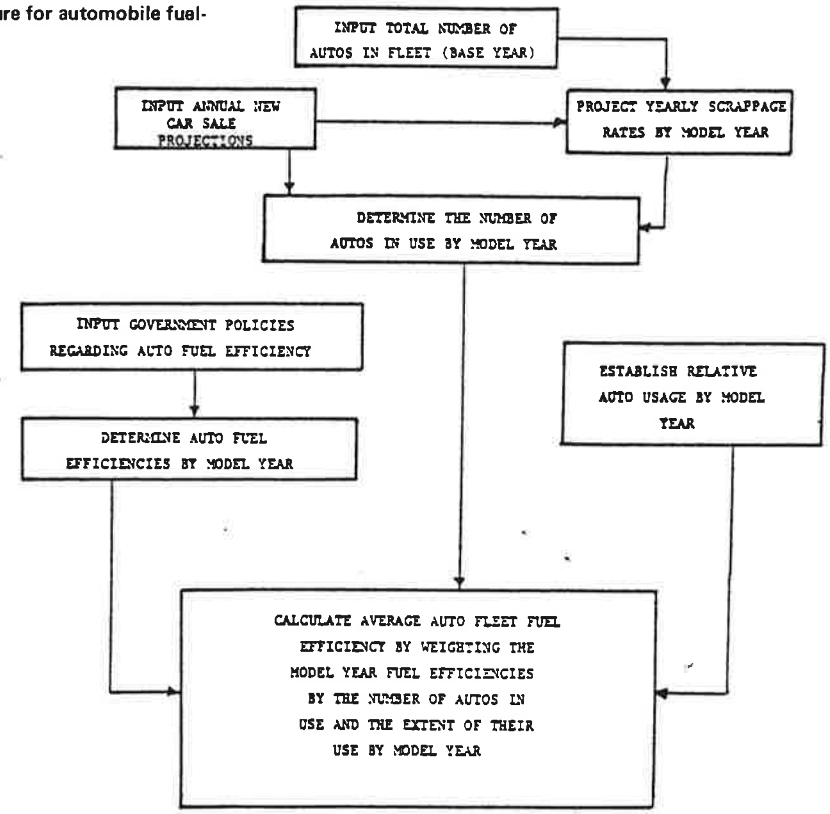
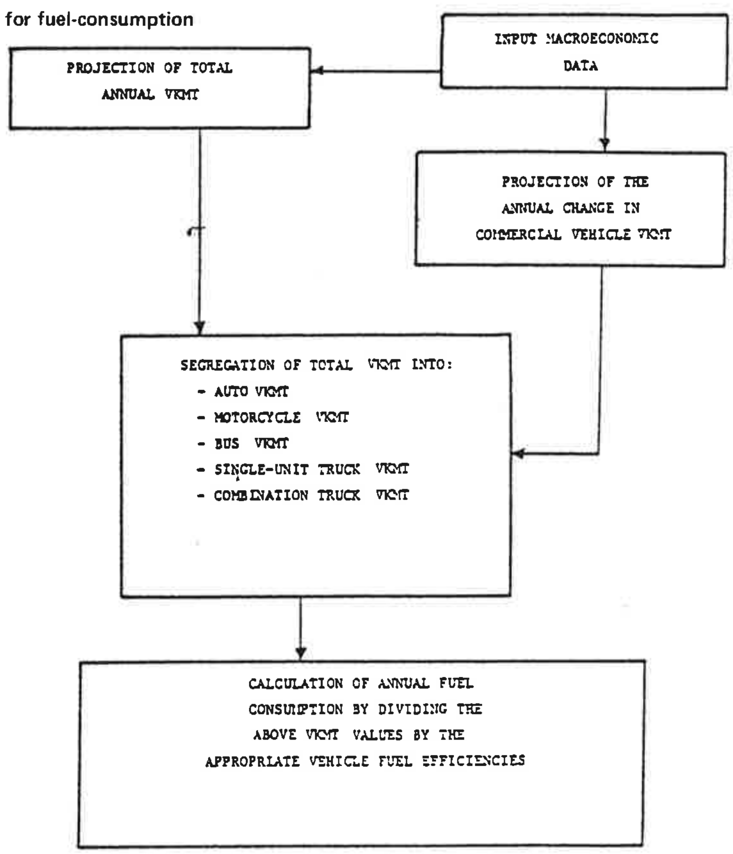


Figure 3. Simulation procedure for fuel-consumption model.



index and an assumed growth rate as independent variables. Provisions were also made for possible changes in truck weight distributions as such changes will directly affect the revenues collected from truck registrations.

Numbers of licensed drivers were estimated by extrapolating the ratios of licensed drivers per 1000 of driving age population by using historical data (5) and multiplying these projections by the driving age population (in thousands) determined from the cohort population projections.

Fuel consumption was estimated by using the techniques described above, and the revenues from this source were calculated by using the fuel tax rate. Revenues from miscellaneous user sources, such items as chauffeur licenses, distributor licenses, and a variety of motor fuel and vehicle sources, were assumed to be a constant percentage of the total projected state road-user revenue.

Highway Performance Projections

The relative performance of highway sections was considered by functional classification (e.g., Interstate, arterial, collector, and so on) and measured in terms of a condition index. The condition indices, which are scaled from 0 to 100, were derived by appropriately weighting relevant highway characteristics. The highway characteristics used were (a) pavement thickness, (b) pavement condition, (c) peak-hour volume-to-capacity ratio, and (d) lane width.

Because the base-year data needed to project highway performance were not readily available in detailed form, a simulation procedure was developed to provide the level of data aggregation necessary. The simulation used a Monte Carlo sampling technique to create a sample of roadway sections that were categoried by highway functional classification. The summary of statewide highway data presented in the 1976 NHIPS was used as a basis to assign a set of attributes to each roadway section that could then be used to project the four basic determinants of the condition index. These section attributes included (a) section length, (b) traffic volume, (c) number of lanes, (d) pavement thickness, (e) pavement condition, (f) peak-hour volume-to-capacity ratio, and (g) lane width. Each roadway section was aged by projecting traffic volume growth by vehicle type, axle-load accumulations, and so on. In addition, roadway sections were considered for seven major types of capital improvements: new location, reconstruction, isolated reconstruction, major widening, minor widening, resurfacing, and resurfacing and shoulder improvements. A priority-setting technique based on the cost-effectiveness of improvement types and the overall condition index of the section was developed and applied so that the limited funds available for capital improvements could be optimally allocated to roadway sections. After the assignment of a capital improvement type, the section attributes were appropriately redetermined and the condition index of the section was recalculated.

MODEL APPLICATION

A number of scenarios were considered to analyze the effects that legislative policy options, revised highway performance criteria, changes in future travel characteristics, and prevailing economic conditions may have on the performance of the Indiana highway system. [In discussing the results of these analyses, the scenarios are identified by an alphanumeric coding system in which the letter denotes the model used to provide the economic data (T = TRENDLONG, C = CYCLELONG, and P = PESSIMLONG) and the number refers to a specific option of possible legislative alternatives along with other attendant assumptions.]

In all scenarios tested, it was assumed that legislative policy options would have no effects on the macroeconomic data used as input. The only exception was that the gasoline price deflator would be influenced by changes in fuel tax rates. This assumption is reasonable; in a recent study, it was observed that a probable range of highway funding options have negligible impacts on economic conditions (2).

Revenue Assumptions

Revenues from federal agencies, state general-fund appropriations, and other nonstate road-user tax sources were estimated by assuming that such revenues would be proportional to the revenues collected from state road-user taxes. This assumption was based on historical data and current federal fund-allocation procedures.

Disbursement Assumptions

Highway disbursements were categorized into four broad classifications:

1. Local capital outlays, which includes all expenditures for capital improvements on the local road functional classification;
2. Nonlocal capital outlays, which includes all expenditures for capital improvements on nonlocal functional classifications (e.g., Interstates, arterials, and collectors);
3. Structure costs, which includes funds allocated for the rehabilitation of roadway structures; and
4. Routine maintenance, administration, and all others.

It was assumed that disbursement category 4 would increase at an annual rate that is proportional to the annual increase in the price deflator for highway capital improvements. Once this disbursement was calculated, an assumed fixed percentage of the remaining funds was allocated to structures, local, and nonlocal capital outlays. These percentages were estimated by using historical data and the values estimated by previous studies (2, 10).

Distribution of Nonlocal Capital Funds Among Functional Classifications

Two alternative funding distributions were developed by using, as a basis, the funding distributions given in the 1976 NHIPS (2) and the estimation of future Indiana capital improvement needs made for the 1972 National Highway Needs Study (10). The first funding distribution (series 1) was used for all scenarios that assume that the highway performance criteria and the travel characteristics will remain unchanged over the time period of the present study. The series 1 distribution allocates a relatively large percentage of capital improvement funds to high-volume facilities. This distribution reflects the state preference for maintaining the condition of high-volume facilities as opposed to low-volume facilities (which are given a lower priority, particularly when funding levels are not sufficient to meet highway needs).

The second funding distribution (series 2) was used for the scenarios that assumed changes in highway performance criteria or in travel characteristics. These assumed changes will result in a considerable reduction in the need for capital improvements on high-volume facilities. Consequently, the series 2 distribution allocates a greater amount of funding to low-volume facilities than does the series 1 distribution.

Discussion of Options

Table 2 summarizes the assumptions made for the five options presented in this paper.

Option 1

This option was designed to analyze the effects that continuing the current Indiana highway taxing policies will have on future Indiana highway performance. It was examined in terms of all three macroeconomic forecasting models so that the full impacts of varying national economic conditions could be assessed. The 1990 values of selected model parameters are summarized below (1 km = 0.62 mile and 1L = 0.26 gal).

	Scenario		
Parameter	T-1	C-1	P-1
Total VT (km 000 000s)	85 438	82 550	79 872
Combination VT (km 000 000s)	4 984	4 597	4 667
Total fleet efficiency (km/L)	7.82	7.78	7.76
Retail gasoline price ($/L)	0.35	0.39	0.44
Total revenues ($000s)	586 272	570 112	560 827
Nonlocal capital outlays ($000s)	182 056	167 843	153 113
Price deflator for capital outlays (1975 = 1.00)	2.75	2.92	3.38
Other noncapital disbursements ($000s)	314 546	319 599	332 299

As might be expected, when the results for the three models are compared, the high inflation rates and lower industrial productions of the CYCLELONG and PESSIMLONG models result in lower VT values, lower fleet fuel efficiencies, higher gasoline prices, and lower highway revenues (which will have less buying power per dollar).

The effects that economic conditions have on highway performance are shown in the table below, which summarizes the percentage changes in the condition indices of each functional classification between 1976 and 1990.

	Scenario		
Functional Classification	T-1	C-1	P-1
Rural			
Interstates	-11.2	-9.8	-8.9
Other principal arterials	-5.8	-4.1	-3.6
Minor arterials	-9.6	-7.6	-7.4
Major collectors	-22.5	-19.3	-18.7
Minor collectors	-29.6	-25.6	-25.4
Urban			
Interstates	-13.5	-12.5	-12.1
Other freeways and expressways	-14.4	-13.2	-10.9
Other principal arterials	-10.4	-10.3	-9.6
Minor arterials	-19.3	-19.1	-17.6
Collectors	-18.5	-18.5	-16.4

It is apparent that, if current highway taxing policies are continued, a considerable deterioration in Indiana highway performance, particularly on lower-volume facilities, can be expected. This loss in highway performance will arise from an overall degradation in system pavement conditions and increased congestion.

As for the impacts of economic conditions, in this option, the more pessimistic economic assumptions result in less deterioration of highway performance. This is due to the fact that pessimistic economic assumptions result in (a) less congestion because VT growth rates are lower and (b) less pavement degradation due to loading because the growth in intercity shipping is more moderate. For this option, these two factors offset the effects of decreasing highway revenues and reductions in per dollar buying power. The result is that the reduction in highway performance is lower.

It must be pointed out, however, that it should not be concluded that more-pessimistic economic assumptions will necessarily result in less deterioration in highway performance. In some cases, revised highway performance standards and travel characteristics will result, on certain functional classifications, in less reduction in highway performance, even under more-optimistic economic scenarios. This is due to the fact that highway performance is the result of the interaction of economic conditions, the performance criteria used, the travel characteristics assumed, and the physical attributes of each functional classification.

Option 2

Option 2 uses essentially the same assumptions as option 1, except for the implementation in 1980 of a 2.9 cents/L (11 cents/gal) gasoline tax [i.e., an increase over current gasoline tax rates of 0.8 cents/L (3 cents/gal)]. The increase in gasoline tax, which is also accompanied by increases in funds from other nonstate road-user revenue sources, results in a 27 percent increase in total highway revenues in calendar year 1980 (see Table 3) when the TRENDLONG data are used. The impact that the additional revenue has on Indiana highway performance is summarized below.

	Scenario		
Functional Classification	T-1	T-2	T-3
Rural			
Interstates	-11.2	-10.0	-4.2
Other principal arterials	-5.8	-3.1	+1.8
Minor arterials	-9.6	-5.8	-1.1
Major collectors	-22.5	-18.6	-8.4
Minor collectors	-29.6	-27.0	-17.7
Urban			
Interstates	-13.5	-10.7	-4.4
Other freeways and expressways	-14.4	-12.5	-9.5
Other principal arterials	-10.4	-9.7	-6.7
Minor arterials	-19.3	-18.8	-15.6
Collectors	-18.5	-15.6	-10.3

When the results of scenarios T-1 and T-2 are compared, it is evident that the increased revenue results in only moderate improvement in highway performance after a certain threshold level. This is due to the fact that the relationship between capital investment and performance is asymptotic [see Figure 4 (2)] and, therefore, a large increase in capital investment may result in only modest increases in the condition index.

Option 3

Option 3 assumes that a 20 percent ad valorem gasoline tax is implemented in 1980 in an attempt to keep pace with the inflationary pressures that, under the TRENDLONG assumptions, increase capital improvement costs by 275 percent between 1975 and 1990. Table 3 summarizes total highway revenues generated by the three options discussed thus far. The ad valorem tax obviously generates the most revenue. This is particularly evident for the mid-1980s, when decreasing fuel consumption actually reduces the total revenues collected under options 1 and 2.

Table 2. Summary of option assumptions.

Effect Analyzed	Option 1	Option 2	Option 3	Option 4	Option 5
Road-user tax rates	Same as 1979	Gasoline tax of 2.9 cents/L	20% ad valorem tax on gasoline	Gasoline tax of of 2.9 cents/L	Gasoline tax of 2.9 cents/L
Fraction of total revenues obtained from nonstate road-user tax sources	0.45	0.45	0.45	0.45	0.45
Distribution of capital funds to functional classifications	Series 1	Series 1	Series 1	Series 2	Series 2
Other	None	None	None	Revised improvement standards	Peaking reduced by 20 percent

Note: 1 L = 0.26 gal.

Table 3. Total Indiana highway revenues (thousands of constant 1978 dollars).

	Scenario				Scenario		
Year	T-1	T-2	T-3	Year	T-1	T-2	T-3
1976	549 267	549 267	549 267	1984	307 606	389 102	543 041
1977	516 278	516 278	516 278	1985	285 865	360 922	530 444
1978	486 056	486 056	486 056	1986	268 662	338 661	522 659
1979	450 232	450 232	450 232	1987	252 034	317 159	513 659
1980	418 227	532 702	618 414	1988	238 038	299 188	509 027
1981	385 005	489 594	594 247	1989	225 137	286 683	505 465
1982	355 249	450 992	573 138	1990	213 189	267 465	502 097
1983	330 153	418 414	554 076				

Although highway performance under scenario T-3 is noticeably better than that under scenario T-1 (see above), it is evident that, despite a considerable increase in revenues, it will still deteriorate on most functional classifications. This indicates that the generated revenue is still not sufficient to perform the capital improvements necessary to maintain 1975 conditions. There are essentially two reasons for this. First, the asymptotic relationship between investment and performance means less improvement than would be expected if a linear relationship existed. Second, the ad valorem tax is indexed to the price of fuel, which, in the TRENDLONG forecast, increases at a rate that is less than the rate of increase in the cost for capital improvements and, therefore, inflation continues to erode highway dollars (although to a lesser extent than under options 1 and 2).

Option 4

This option was designed to evaluate the effects that revised highway performance standards will have on future Indiana highway performance. This revision was achieved by attaching more importance to pavement conditions and less importance to volume-to-capacity ratios and lane widths. Such a revision in standards would permit the state to concentrate more of its capital funds on pavement rehabilitation and spend less on costly widening improvements.

This option also included the assumption of the 1980 implementation of 2.9 cents/L gasoline tax. It was further assumed that nonlocal capital funds would be distributed among functional classifications by the series 2 distribution, which allocates a greater share of capital funds to lower-volume facilities. The resulting impacts on Indiana highway performance are summarized below.

	Scenario		
Functional Classification	T-2	T-4	P-4
Rural			
Interstates	-10.0	-4.5	-2.5
Other principal arterials	-3.1	-5.7	-4.9
Minor arterials	-5.8	-6.5	-5.4
Major collectors	-18.6	-9.4	-8.1
Minor collectors	-27.0	-19.8	-21.2
Urban			
Interstates	-10.7	-11.3	-10.1
Other freeways and expressways	-12.5	-13.0	-9.8
Other principal arterials	-9.7	-9.9	-7.7
Minor arterials	-18.8	-16.6	-14.9
Collectors	-15.6	-6.5	-4.4

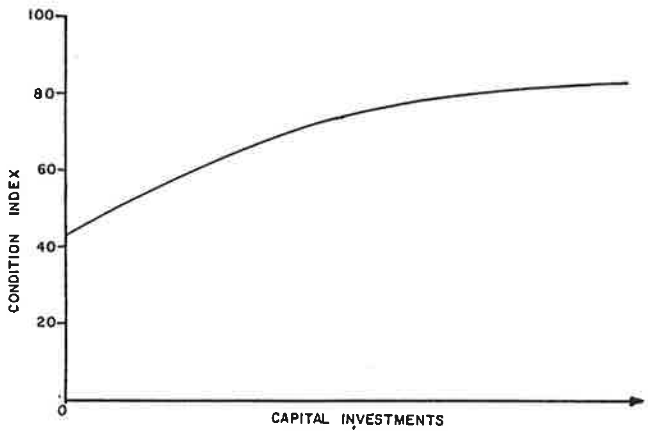
When scenarios T-2 and T-4 are compared, it is apparent that the latter generally results in less highway performance deterioration. This revision of standards means that the performance deterioration of the high-volume facilities under scenario T-4 will be comparable to that under scenario T-2 despite the fact that the funds allocated to these facilities under the series 2 distribution are less. Overall, the pavement conditions are improved considerably under this option, as expected. However, the volume-to-capacity ratios are generally higher, indicating a greater service loss.

This option was also run by using the PESSIMLONG model to evaluate economic impacts under the revised performance standards. The economic impact results for high-volume facilities were much the same as those observed for option 1. This indicates that the reduced volume-to-capacity ratios and commercial VT values associated with the PESSIMLONG model offset the effects of decreases in capital investments. However, for the lower-volume facilities, which generally require more frequent resurfacing, the additional funds allocated to resurfacing improvements by the TRENDLONG model result in significantly improved pavement conditions. This, and the increased emphasis on pavement conditions in the revised performance criteria, offsets the lower volume-to-capacity ratios and commercial VT values observed for the PESSIMLONG model to a greater degree than was the case with the higher-volume facilities. Consequently, the difference in the performance impacts of the two economic models is less conclusive on lower-volume facilities. For the case of rural minor collectors, for example, scenario T-4 resulted in better overall pavement conditions than did scenario P-4 and, although the volume-to-capacity ratios were higher, the overall adverse effect on highway performance was less.

Option 5

This option was designed to evaluate the impacts that a reduction in the current peaking characteristics would have on Indiana highway performance. Such reductions can result from carpooling and vanpooling, staggered working hours, and so on. It was assumed that the 2.9

Figure 4. Generalized relationship between highway investment and highway performance (one curve for each functional classification).



cents/L gasoline tax would be implemented in 1980 and that the series 2 capital-outlay distribution would be used. In addition, it was assumed that there would be a 20 percent reduction in the percentage of the average daily travel occurring during peak periods by 1990.

This option resulted in an improved highway performance; the performance levels were considerably higher than those obtained under scenario T-2, which assumes a continuation of current peaking characteristics. This improvement results from the obvious reductions in volume-to-capacity ratios and the improvement in pavement conditions because more funds can be allocated to pavement rehabilitation as the need for widening diminishes:

	Scenario		
Functional Classification	T-2	T-5	P-5
Rural			
Interstates	-10.0	-2.8	-1.1
Other principal arterials	-3.1	-2.6	-1.0
Minor arterials	-5.8	-1.8	-0.6
Major collectors	-18.6	-6.5	-8.1
Minor collectors	-27.0	-14.9	-10.9
Urban			
Interstates	-10.7	-8.0	-6.2
Other freeways and expressways	-12.5	-6.0	-4.4
Other principal arterials	-9.7	-6.3	-3.8
Minor arterials	-18.8	-12.4	-9.3
Collectors	-15.6	-8.1	-2.7

The increased emphasis on pavement rehabilitation resulted in better pavement conditions under scenario T-5 than under scenario P-5, despite the lower loading conditions in the latter. However, the higher volume-to-capacity ratios under scenario T-5, and their relative importance in estimating highway performance, offset the improved pavement conditions and, consequently, highway performance deterioration was generally less under scenario P-5.

CONCLUSIONS

The options considered in this paper indicate that a general deterioration in Indiana highway performance can be expected in the future due to the enormous amount of revenue needed to sustain real highway investment levels. Alternatives other than generation of additional revenue, such as revision of performance standards and reductions in peaking characteristics, can minimize future highway performance deterioration but, realistically, a combination of increased taxes and additional non-revenue-generating alternatives will likely provide the most acceptable solution to the highway financing problem. The specific combination will depend on public willingness to accept additional taxation and public tolerance of additional highway performance deterioration.

REFERENCES

1. F. L. Mannering. Methodology for Evaluating the Impacts of Energy, National Economy, and Public Policies on Highway Financing and Performance. Purdue Univ., West Lafayette, IN, Rept. JHRP-79-6, July 1979.
2. 1976 National Highway Inventory and Performance Study. Federal Highway Administration, Rept. FHWA-PL-78-006, Sept. 1977.
3. 1974 National Highway Needs Report. Federal Highway Administration, 94th Congress, 1st Session, House Document 94-95, U.S. Government Printing Office, 1975.
4. U.S. Long-Term Review: The Economic Outlook—1978 to 1990. Data Resources Inc., Lexington, MA, Fall 1978.
5. Highway Statistics. Federal Highway Administration, 1960-1976.
6. J. Poister, T. Larson, and S. Rao. Fiscal Planning and Highway Programming: The Pennsylvania Response to a Changing Environment. TRB, Transportation Research Record 654, 1977, pp. 16-22.
7. N. Erlbaum, D. Hartgen, and G. Cohen. Automotive Energy Forecasts: Impact of Price, Availability, and Efficiency. Planning Research Unit, New York State Department of Transportation, Albany, Dec. 1977.
8. W. Bottiny. Trends in Automobile Ownership and Indicators of Saturation. HRB, Highway Research Record 106, 1965, pp. 1-21.
9. J. R. McCarthy. State Highway Finance and User Taxation in Indiana. Purdue Univ., West Lafayette, IN, Rept. JHRP-76-26, Oct. 1976.
10. 1972 National Highway Needs Report. Federal Highway Administration, 92nd Congress, 2nd Session, House Document 92-266, U.S. Government Printing Office, 1972.

Publication of this paper sponsored by Committee on Taxation, Finance, and Pricing.

Systems Approach to Increasing Preconstruction Engineering Productivity

Don C. Hoffeditz and Neal X. Jones

In the recent past, many highway and transportation agencies maintained large professional and technical staffs for preconstruction (postproject identification through letting) operations. Now, staffs have decreased and the scope of construction projects is changing. Projects are smaller but more numerous, which creates an enormous demand to increase individual productivity among preconstruction staffs. Improving productivity requires that management recognize the factors that affect it positively and create an environment that supports them. This paper discusses the human factors of a system for increased preconstruction engineering productivity. The total system is a set of attitudinal and motivational elements and includes necessary communication and information support.

The primary responsibility of all state highway and transportation departments—to operate effectively in providing services to the public—has become much more complex in the 1970s, and the prognostication for the future is that this trend is very likely to continue and accelerate. Complexities and multiple problems that are a reflection of many economic and cultural changes are operating not only in the United States but also in the world at large. Without overemphasizing the well-known problems of increased energy costs and shortages, a larger population base, increased public awareness and concern over environmental conditions and individual rights, it is obvious to everyone in the highway and transportation business that it is much more difficult to accomplish something than it used to be. Finally, added to the bewildering maze of outside and uncontrollable impedances to productivity are the problems of increased road capacity needs, reduced revenue from traditional sources, and greatly increased construction costs. It is, therefore, appropriate that management expend a major and continuing effort to increase productivity throughout their organizations.

This paper is specifically concerned with methods for increasing productivity in the preconstruction activities involved in highway development. (Preconstruction is defined here as the basic operations between planning and programming a project and letting it.) Although organizations vary across the country, the basic operations are as follows:

1. Design—roads, bridges, and hydraulics;
2. Engineering services—surveys, photogrammetry, environmental studies, and materials;
3. Right-of-way and utilities;
4. Traffic; and
5. Contract preparation.

The importance of managing productivity is a vital aspect of any agency's capital improvement plan in that the current staffing trends are downward, whereas the number of individual projects is upward; see Figures 1 and 2, which represent the specific experience of the Kansas Department of Transportation (KDOT). This phenomenon, coupled with the current public desire to reduce the cost of government, poses an interesting and complex dilemma.

During the 1960s and early 1970s, highway agencies grew at a tremendous rate, reaching a peak in 1974. At that time, staffing patterns in the preconstruction areas were generous. The philosophy was generally to maintain a professional staff capable of addressing any and all design and development problems the agency was likely to encounter. Dedicated motor-fuel tax funds were constantly increasing, and funding was at a high level. During this period, the use of trucks and, of course, the highway network to supply the urban centers of the nation increased dramatically. Meanwhile, through mismanagement, overregulation, and superior marketing ability on the part of truckers and the airlines, the railroad resources went into a rapid decline that is continuing today.

We have now, at the threshold of the 1980s, come to an era of limits—although the limits that highway and transportation agencies are experiencing are only those of resources; there is no reduction in the needs and demands of the public.

In the current environment, agencies are experiencing a doubling in the number of projects in their programs. Each project is, for the most part, smaller than in the past, but there are twice as many. They range from traditional new construction of various types to a variety of rehabilitation, resurfacing, and reconstruction (3R) and safety-type projects. As projects are smaller in size and scope, they each require less staff per project; however, the management and overhead requirement for each small project is not proportionately lower. This simply adds to the problem of smaller staffs and relatively lower budgets.

It would appear that a greater work load, coupled with a smaller staff and budget, is an impossible situation. Something must change—either the staff (budget) must be increased, consulting engineering aid must be engaged, or the work load must be decreased. There is, however, another possibility—productivity can be increased. This is currently a prime management challenge and will continue to be in the future.

A great deal of study, analysis, and writing has been done on increasing productivity. This is fundamental to a healthy economy. Many factors affect productivity, but they can be categorized into two groups: technical and human. This paper deals only with the human side of the productivity issue for preconstruction engineering.

The human side effects in the system described in this paper are limited to personnel skills and attitudes. It is assumed that an organization has a fixed number of personnel who have a defined level of the technical skills needed to accomplish the preconstruction engineering work of that organization. As to attitudes, the system is oriented to only the higher-order needs (such as self-esteem and self-actualization). That is, it is assumed that employees are not being requested to increase productivity under duress (which, however, will work effectively).

In the current environment, the following factors contribute significantly to improved personnel attitudes and thus result in productivity improvement:

Figure 1. Preconstruction engineering staffing levels: 1971-1978.

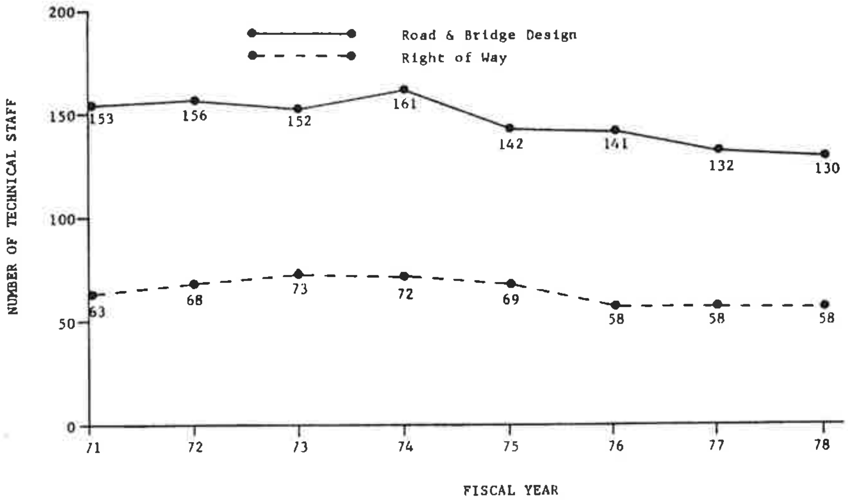
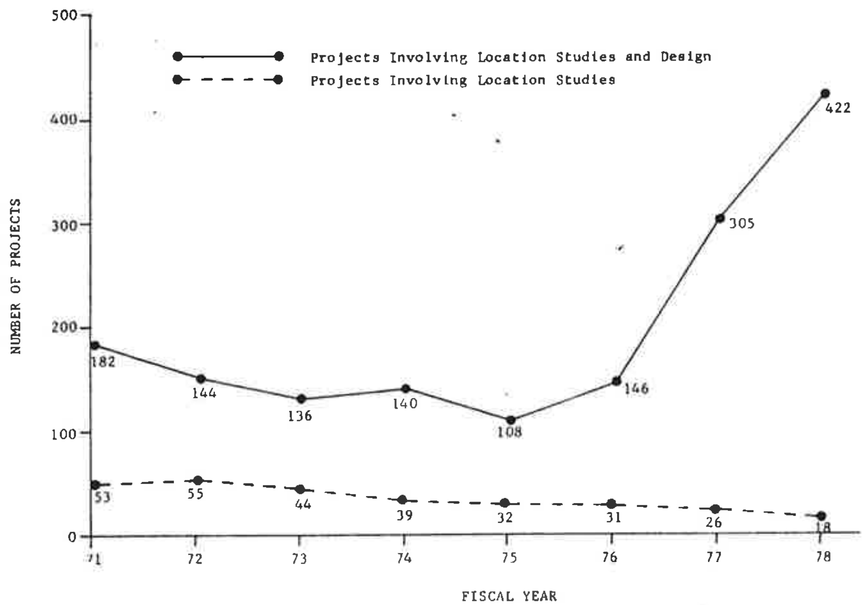


Figure 2. Preconstruction engineering projects: 1971-1978.



1. Stability of the work program,
2. A clear definition of work,
3. A role in accomplishment goal setting,
4. Timely decision making,
5. A role in decision making,
6. Reasonableness of the work load,
7. Performance evaluation, and
8. Communication.

These factors, in essence, constitute the system. The proper, supportive attitude of the organization toward all of these factors is paramount. The more supportive and committed higher levels of management are, the higher the potential productivity increases are through the system.

Another essential element of the total system is information. Without it, there is no system. And, all other factors being equal, the extent and quality of information being provided to support management decision making will have a direct effect on productivity.

When an integrated information system is available, individual managers and their staffs can plan for accomplishment of their responsibilities. They can agree on individual goals and objectives and rates of productivity. Their plans can then be used as information by other preconstruction functional managers and higher-level managers in planning the total preconstruction work program for the organization. Without valid and timely information, a manager can have no idea what level of productivity the staff is achieving or what level should be achieved. Without information, the staff has no way of measuring its accomplishments and rate of productivity.

If a manager of a preconstruction function such as road design is to improve productivity, he or she must develop a plan to successfully accomplish all the responsibilities of that function. To plan effectively, the manager must have information about the work to be accomplished and the capacity of the organization to perform and also about other operations involved in preconstruction. All information needed to plan, implement, control, and evaluate an operation does not usually reside in it; therefore, a good information system is a critical need. The same is true when an operation is faced with changes in its plans.

Let us begin by looking at the effects of this type of systems approach on an existing organization. The experience of KDOT, which embarked on the implemen-

Figure 3. Design department work load: August 1, each year 1971-1978.

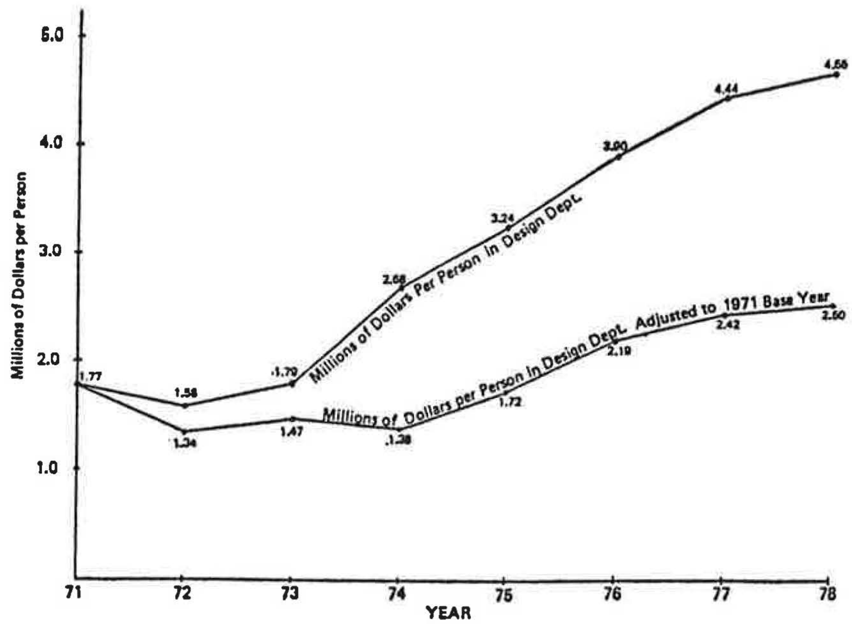
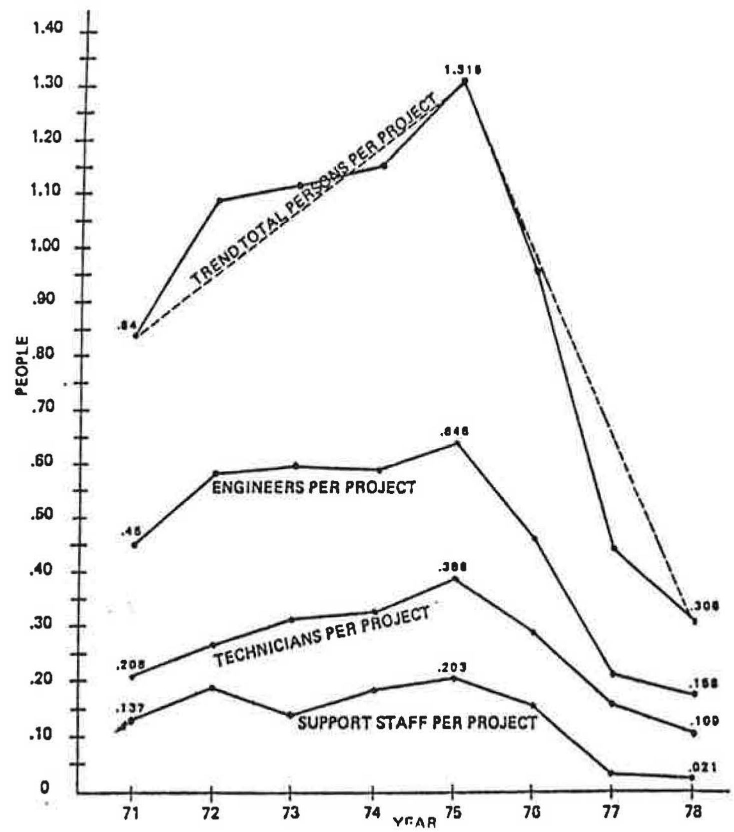


Figure 4. Design department persons per project: August 1, each year 1971-1978.



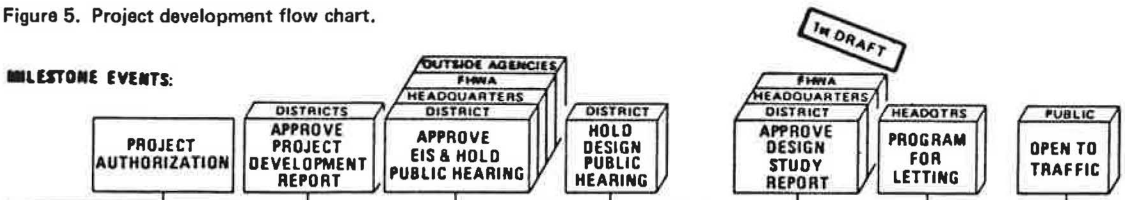
tation of a total systems approach for its entire organization, including preconstruction and construction engineering, in 1975, serves to provide some insight to the increases in productivity that can be achieved.

Figure 3 shows the increase in dollar volume of construction work produced by the design department. In constant dollars, the productivity of each staff member increased almost 50 percent over the period 1975-1978. Figure 4 shows that the ratio of the numbers of engineers and technicians employed to the number of preconstruction projects completed has decreased significantly. These are somewhat distorted by the shift in emphasis toward more 3R-type projects, but the results are still significant.

How can results such as these be achieved? Once an organization has adopted a total system approach for improving productivity, the information system necessary to support it must be developed.

The type of information system that has been implemented by KDOT is one that uses automated techniques to allow integration of the various preconstruction functions against an array of projects and to provide infor-

Figure 5. Project development flow chart.



FUNCTIONS / PHASE	PROJECT DEVELOPMENT PLAN	PRELIMINARY LOCATION AND EIS REPORT	PRELIMINARY LAYOUT DESIGN	FINAL DESIGN REPORT	DEVELOP CONSTRUCTION PLANS	CONSTRUCTION
PROJECT MANAGERS	PREPARE DEVELOPMENT PLANS	GATHER DATA PREPARE REPORTS AND COORDINATE ACTIVITIES	COORDINATE DATA COLLECTION PREPARE REPORT GET APPROVALS PREPARE FOR DESIGN PUBLIC HEARING	COORDINATE ACTIVITIES AND COMPLETE DESIGN AUTHORITY PACKAGE ON RECOMMENDED ALTERNATIVE	COORDINATE ACTIVITIES COMPLETE FINAL CONSTRUCTION PLANS	COORDINATE ACTIVITIES RESOURCES AND ADMINISTRATION REQUIREMENTS
PLANNING AND PROGRAMMING	PLAN SUPPORT	TRAFFIC FORECASTS	FINALIZE TRAFFIC FOR DESIGN FEATURES	TRAFFIC DATA FOR SURFACE TYPE	—	—
MATERIALS	—	GEOLOGY	SOILS TESTS	MATERIALS DESIGN FOR PAVEMENT SELECTIONS	MATERIAL CORRECTIONS	MATERIALS TESTS
ROAD DESIGN	PLAN SUPPORT	GEOMETRICS	ALIGNMENTS AND PICTORIAL PRESENTATIONS	PREPARE FINAL LAYOUT WITH GEOMETRIC DETAILS SURFACE TYPE COST ESTIMATES	FINAL PLAN PREPARATION QUANTITIES AND ESTIMATES	—
BRIDGE DESIGN	PLAN SUPPORT	BRIDGE TYPES	BRIDGE GEOMETRY	—	SITE LAYOUT STRUCTURAL DESIGN ESTIMATES	BRIDGE INSPECTION
RIGHT OF WAY	PLAN SUPPORT	RELOCATION IMPACTS UTILITY NEEDS	R/W LIAISON UTILITY LIAISON	CONDUCT RELOCATION STUDY SECURE UTILITY INFO OBTAIN RR AGREEMENTS	RELOCATE APPRAISE NEGOTIATE ACQUISITION CONDEMNATION	—
TRAFFIC ENGINEER	—	GEOMETRICS	GEOMETRIC REVIEW	GEOMETRY REVIEW	FINAL TRAFFIC PLANS	TRAFFIC CONTROL
SURVEY AND MAPPING	—	AERIAL PHOTOGRAPHS	CONTOUR MAPS	—	—	—
ENVIRONMENTAL SERVICES	PLAN SUPPORT	ECOLOGICAL & AESTHETICS	LANDSCAPE CONCEPT PLAN	ENVIRONMENTAL LIAISON	LIAISON	LIAISON
CONSTRUCTION	—	—	—	—	CONSTRUCTION REVIEW	CONSTRUCTION, STAKING INSPECTION, ADMIN

Table 1. Types of information provided to management.

Type of Information	Example
Program management	Project identification and description
	Project estimates (phase starts, costs, and funding)[a]
	Project financing (funding and expenditures by phase)[b]
	Project schedule (target and actual dates)[c]
	Project status (individual and activity)[d]
	Project contract status (any project contractual services)
	Project billing (FHWA billing status)
	Cross-reference to old project number
	Cross-reference to FHWA project number
	Cross-reference to county-route
	Proposed project changes (simulation scenarios)[e]
Financial management	Fund program status (individual FHWA, state, or other funds)
	Annual revenue and expenditure projections
Capacity management	Resources available (staff by functional unit)
	Work-load simulation[f]
	Fund program balance simulation

[a]See Figure 6a. [b]See Figure 6b. [c]See Figure 6c. [d]See Figure 6d. [e]See Figure 6e. [f]See Figure 6f.

mation when needed. This system is called a construction program management and funds control system; however, in general, it can be referred to as a program management system (PMS).

Simply stated, the goal of the automated PMS is to provide information and communications support to the various preconstruction managers in the areas of fund planning, project scheduling, project control, staff planning, and performance evaluation. The support must include information that can be used to analyze the effects of real and/or proposed changes to plans in order to assess impacts on current plans and resources. The information must be available and structured to multiple preconstruction management levels, including upper levels. That is, it must be available and structured to support a variety of decision-making levels.

The PMS provides information support for decision making at multiple preconstruction management levels:

1. Program development—resource planning, strategy development, and forecasting and simulation;
2. Work-plan management—project schedules, project status determination, and resource allocation;
3. Inventory control—fund accounting, personnel accounting, consumable and nonconsumable item control, and service (consultant, contractor, fee appraiser, and such) control; and
4. Feedback—of labor, equipment, and materials data; costs; and accomplishment.

Collectively, by integrating the information on the computer, the PMS provides the managers of the preconstruction functions with a broadly based and comprehensive information and communication resource. By providing access to information to managers and their staffs via terminals in their immediate work areas, there is a timely communication tool within and between preconstruction functions. The system also eliminates much of the clerical work previously performed by project staff, which frees their time for more productive work.

Thus, the PMS can be used by preconstruction managers to increase the effectiveness and efficiency of their operations in the following ways:

1. To identify various projects collectively as work programs that meet specific sets of objectives;
2. To determine, before commitment is made, resources (time, staff, funds) required to complete a project or accomplish an entire work program;

Figure 6. Types of information provided: (a) project estimates, (b) project financing, (c) project schedule, (d) project activity status, (e) simulation scenario for proposed project change, and (f) work-load simulation.

(a)
```
PMPEST/K -0436-01/                              PROGRAMMED PROJECT ESTIMATES

PMPEST/PP-PPPP-SS
                                                                          2000000
PROJECT ID:  K -0436-01 DESCRIPTION: I-35 OVER SL&SF  RR  NB  #14.34  &  SB  #14.35

WORK PHASES          PE        CE                  CONST                 TOTAL
TOT EST($1000)                          57           323                   380
PROG YR/PERCENT  1977       1980       100    1980   100

FUND   MATCH   PRORATA   PRORATA   PRORATA  PRORATA  PRORATA  FHWA R/S ARGMT
 I               40        40        40                       0035-3      269
 KM      I        4         4         4
 K
 IR              50        42        42                       0035-3      269
 KM     IR        6        14        14

KDOT APPROVAL DATA:  07/01/78   ANCESTOR PROJECT:
PROJECT STATUS:  ACTIV STATUS DATA:  07/01/78  REASON:
```

(b)
```
PMPJFN/K -0436-01/CONST/                         PROJECT FINANCING
PMPJFN/PP-PPPP-SS/WWWWW
                                                                          2000000
PROJECT ID:  K -0436-01  PHASE CONST DESC I-35 OVER SL&SF RR NB #14.34 & SB #14.3
ACTIVITY BEG:  TARGET        ACTUAL        ACTIVITY END:  TARGET      ACTUAL
               01/15/80      MM/DD/YY                     11/15/80    MM/DD/YY

FUND          ESTIMATE               AUTHORIZATION                    EXPENSE
SOURCE   M   ($1000)      PRO    ORIGINAL  LATEST  STATUS OBLIGATION  TO DATE

 I              129 040          MM/DD/YY MM/DD/YY  NONE
 KM      X       12 004          MM/DD/YY MM/DD/YY  NONE
 K                  000          MM/DD/YY MM/DD/YY  NONE
 IR             135 042          MM/DD/YY MM/DD/YY  NONE
 KM      X       45 014          MM/DD/YY MM/DD/YY  NONE

PART
TOTAL            321 COMP MM/DD/YY
```

(c)
```
PMPJSC/K -0436-01/00/                          PROJECT SCHEDULE       PG 01
PMPJSC/PP-PPPP-SS/PG
                                                                          2000000
PROJ ID K -0436-01

MILE    CHCKPT  TYPE    TARGET    ACTUAL     MILE   CHCKPT  TPE  TAR       ACTUAL
DAUTH            MI    08/01/77  MM/DD/YY   LETTG           MI   02/15/80  MM/DD/YY
WAUTH            MI    08/01/78  MM/DD/YY           CONAP   BD   03/01/80  MM/DD/YY
        BSURV    BD    08/15/78  MM/DD/YY           NOTPR   BD   05/01/80  MM/DD/YY
        SURCM    BD    11/15/78  MM/DD/YY   NOTAC           MI   10/01/80  MM/DD/YY
FLDCK            MI    06/15/79  MM/DD/YY   FINAL           MI   11/15/80  MM/DD/YY
        PLROW    BD    08/15/79  MM/DD/YY
        UTAGR    BD    11/15/79  MM/DD/YY
        UTCOM    BD    12/15/79  MM/DD/YY
        APPAP    BD    08/15/79  MM/DD/YY
        APCOM    BD    08/15/79  MM/DD/YY
        NGCOM    BD    08/15/79  MM/DD/YY
        PRPCL    BD    08/15/79  MM/DD/YY
        PLCOM    BD    12/15/79  MM/DD/YY
PRCOM            MI    12/15/79  MM/DD/YY
        BGPSE    BD    12/15/79  MM/DD/YY
        ADVER    BD    01/15/80  MM/DD/YY
DATE MODIFIED:                        REASON MODIFIED:
```

(d)
```
PMPJST/K -0436-01/PRDES/00/                    ACTIVITY STATUS          PG 01
PMPJST/PP-PPPP-SS/AAAAA/PG

PROJ ID K -0436-01 ACTIV PRDES   DESC I-35 OVER SL&SF RR NB #14.34 & SB #14.35
ACTIV START:  TAR 08/15/78 ACT MM/DD/YY COMPL  TAR 06/15/79 ACT MM/DD/YY
FUNC                        DOT  ACCOMP  PLAN  ACT   RESOURCE EST   ACT  AS OF
UNIT      RESPONSIBLE      ACCT   TYPE    QTY  QTY     TYPE   QTY   QTY COMP DAT
BRIDG                                          LB                       MM/DD
CONBR                                          LB              3        MM/DD
CONRD                                          LB             10        MM/DD
ENVIR                                          LB              1        MM/DD
ROAD                                           LB                       MM/DD
SPECL                                          LB             20        MM/DD
UBTRA                                          LB              1        MM/DD

                         INTERNAL CHECKPOINT STATUS
   CHECKPT                 TARGET     ACTUAL        CHECKPT              TAR & ACT
DRAFT EIS TO FHWA        MM/DD/YY  MM/DD/YY  DRAFT EIS APPROVAL       MM/DD/YY
DESIGN HEARNG OPPORT     MM/DD/YY  MM/DD/YY  DESIGN HEARNG ADVERT     MM/DD/YY
DESIGN HEARING           MM/DD/YY  MM/DD/YY  NOISE STUDY COMPLETE     MM/DD/YY
```

(e)
```
PMPJCG/K -0436-01/80001/C/                     PROPOSED PROJECT CHANGE
PMPJCG/PP-PPP-SS/IIII/C                        DATA REQUESTED NOT ON FILE
NEW RECORD MAY BE CREATED                                                2018100
PROJECT ID:  K -0436-01 PROJECT DESC:  I-35 OVER SL&SF RR NB #14.34 & SB #14.35
PROPOSAL ID:  80001
                              PROPOSED CHANGES
              WORK PROG YR:  1981   ESTIMATED INFLATION FACTOR:  24
       MILESTONE LETTG MOVED 15  MONTHS ---------PROJECT STATUS CHANGED TO

FUNDING SOURCE        WORK PHASES AND PERCENT PRORATA
         MATCH        CONST

I
F                      80
KM        I
KM        F            20
```

(f)
```
PMSIWL/ROAD /                               SIMULATION-WORKLOAD
PMSIWL/FFFFF                                UPDATES COMPLETED SUCCESSFULLY
MAKE NEW REQUEST AND/OR PRESS ENTER                      4015000
PROJECT ID       MILE       CHANGE           PROJECT ID   MILE    CHANGE
                STONE      DATE    MONS                  STONE  DATE  MONS
 K -0111-01     WAUTH               12        K -0572-01  WAUTH          12
 K -0101-01     KAUTH              -12

     NET CHANGE IN NUMBER OF PERSONS BY MONTH - FOR FUNCT UNIT ROAD
1***2***3***4***5***6***7***8***9***10***11***12***13***14***15***16***17***18***19***20
1-  2-  2-  2-  2-  2-  2-  2-  2-        1         1    2    2    2    2    2    2    2
```

Table 2. Types of reports available.

Type of Report	Example
On request	Planning-value feedback (schedule feedback)
	Work-phase payout (cash-forecasting feedback)
	Project event status
	Work program status
	Functional unit work plan (real and simulation)
	Fund program status (real and simulation)
	Project priorities
	Project activity status
	Project financing status
	Contract status
	Cash forecasting
	Proposed work program (real and simulation)
Automatic	Exception and notification

3. To determine availability of resources needed to complete work programs;
4. To monitor and report progress toward completion of defined projects and work programs;
5. To report status, both financial and physical, of projects in the work program;
6. To schedule and reschedule projects within the multiproject work environment;
7. To use planning values for developing schedules, planned accomplishment, and resource requirements;
8. To provide feedback as to actual results on accomplishment and to planning values;
9. To allow changes in a simulation mode to provide information to "what if" questions or alternatives;
10. To notify involved persons of upcoming events, project exceptions, or significant outstanding problems;
11. To identify amounts for which reimbursement from the Federal Highway Administration (FHWA) is available;
12. To identify funding programs associated with each project and maintain the current status and balance of each fund; and
13. To determine work status of all staff, including consultants, who are working on preconstruction activities.

Project scheduling is a key management support tool of a PMS. Because project development in a preconstruction environment can be a very fluid operation in which changes are constantly occurring (and are not necessarily positive), automated scheduling must not be structured to a more-detailed level than can be effectively used and efficiently maintained.

PMS scheduling concepts are keyed to the objectives of several levels of management responsibility. The major objectives responded to include project priority, target project-completion dates, and the maintenance of an effective total work program.

In a PMS, project scheduling is defined as the activities, time, and resources required and available by functional group to develop and complete the preconstruction elements of a project. Planning values are used to automatically develop initial schedules that can then be modified by preconstruction managers based on engineering judgment. Available for a variety of project classifications, planning values consist of the time and resources (labor, equipment, materials, and such) required for each project activity and each functional group involved in that activity (see Figure 5 as an example).

By using an automated information system of this sort and video computer terminals, all aspects of work programs, projects, and resources can be readily ascertained. The effect of adding, changing, or deleting a project or staff resource is easily available, and a manager can quickly react to optimize the production operations in light of the new information.

The PMS operates in two modes: (a) the on-line or "now" mode, in which video terminals are used for input and updating of data and for inquiring about specific information or requesting reports and (b) the batch mode, which is used for preparing requested hard copy management reports and exception reports and for collecting feedback data.

Both the on-line and batch modes use an integrated data base that reduces input requirements and maximizes the correlation of information to multiple levels of management.

The types of information provided to management via the video terminals by PMS are summarized in Table 1, and selected items are illustrated in Figure 6.

The system must also provide complete information for analysis and evaluation of preconstruction plans, status, and accomplishment. The types of reports available for this are summarized in Table 2.

The impact of using the automated PMS as a preconstruction productivity-management support tool is extensive. However, for the system to be effective, all managers and their staffs must actively use and support it. For some managers, particularly those in project control and coordination operations, the effort required of them and their staffs can be extensive but, in nearly every case and certainly for the organization as a whole, the information is needed and essential to the total system of management and productivity improvement.

Much of the productivity improvement experienced in Kansas has been achieved without a fully operational automated information system to support the total system. The automated system is now operational. This should lead to a total system for productivity improvement that is supported by timely decision-making information available at multiple preconstruction management levels. Future years should reflect even greater productivity improvement.

Publication of this paper sponsored by Committee on Manpower Management and Productivity.

Abridgment

Preconstruction Engineering Management in Washington: Manpower Management Information System

Donald L. Lund

The Washington Department of Transportation has been involved in preconstruction staffing management in a formal sense since 1972; FY 1978, however, was the first fully operational year for the manpower management information system. Staffing standards, which are based on identified, quantifiable objects for data input, have worked out well. Project schedules have been found to be reasonably accurate, due in part to previous experience in the use of a critical-path method for scheduling engineering activities. Labor reporting has remained constant since 1973 with no major changes in the activities, titles, or coding numbers. Operational problems of the system have resulted from the programming, budgeting, and authorization processes of the department, where a close match does not exist between financial management systems and staffing management. Because there was no common data base, several coordination systems were developed to tie the financial and staffing systems together. Matching financial and staffing planning to expenditure systems has caused cross-referencing problems and some dilution of historical data. Data-processing differences between the financial and the staffing-resource management systems have delayed preparation of reports involving both. Monitoring and control of project progress and resource utilization has not been stressed greatly because of an initial lack of credibility in the system for resource estimating and project scheduling.

The manpower management information system (MMIS) of the Washington Department of Transportation is an automated, performance-standards-based, resource-estimating and scheduling tool. It provides detailed performance measuring and project schedule monitoring at numerous critical development points. The scope of MMIS runs from project inception through route location, facilities design, right-of-way purchase, and contract plan preparation to completion of construction. MMIS covers almost 1700 of the department's 2000 engineers, technicians, and right-of-way staff, ranging from entry-level technicians to project managers.

BACKGROUND

Work on MMIS was initiated in 1972. At that time, all project engineers were requested to prepare organization tables showing name, class title, and particular expertise used. Information on recently completed projects was used to provide historical data for analysis, and engineering-activities categories, previously established for labor reporting, were used to provide additional history by engineer and technician classes, project, and activity. These preliminary engineering-activities categories were based on the existing Washington automated control system, a critical-path project-scheduling tool. Having these familiar engineering activities to work with and an existing activity diagram was an advantage in creating a standards-based preconstruction-management system. Even so, considerable effort was spent in verifying the historical labor charging and in questioning the manner in which work was performed and the efficiency of the various operations. Random sampling techniques were used during field observation of all aspects of preliminary engineering. Many interviews with those working on or responsible for engineering projects were held. These interviews suggested ways to do things and estimates of the time required. These findings were then presented to a technical committee for review and final establishment of an engineering-activity staffing standard.

Once activities or groups of activities were defined and labor reported against them in sufficient quantity for analysis, work establishing appropriate units of measure was begun. These units had to be quantifiable, readily identifiable, and usually descriptive of some product delivered. Considerable effort was required to define the staffing requirements resulting from different units of measure or modifiers to the basic units of measure. The final product was a mixture of basic units and modifiers and included

1. Type—eight basic units and their lengths;
2. Feature—numerous modifiers of the project types, e.g., bridge sites;
3. Major construction additives—which modify only the major construction projects, e.g., diamond interchange;
4. General project additives—which can apply to all project types, e.g., channel change;
5. Bridge project additives—which apply to structure-only projects, e.g., railroad bridge; and
6. Network generators—which consist of all the activities available for the particular phase.

Even with the extensive listing of engineering-activities categories (more than 160), it was recognized that some percentage of the engineering labor charged to a project would consist of overhead. Overhead, in this sense, means support functions directly relatable to the project but not product related, such as on-job conferences and instructions or training. Examination of historical records provided quantities and percentages used on previous projects.

ORIGINAL DESIGN

The initial MMIS design was based on the basic functions of (a) plan and schedule, (b) measure and compare, and (c) act and react. Capabilities were built into MMIS to provide information necessary for each. In detail, the plan function consists of a project definition for each phase of a project and uses project type, features, additives, and network generators (activities). This gives a quantity of resources (staff) needed to accomplish the work. Summarizing the plan then gives a critical-path diagram that is displayed in bar-chart format and shows critical activities, float times, and durations in days. The resultant of this planning process is not calendar dependent and requires another action to establish start and complete dates. From a summation of all projects defined (planned) and put on the calendar (scheduled), a staffing requirement by skill levels is available for the project manager, the district, or the entire department. Some balancing is done to stay within staff allocations. Staffing requirements are defined by the features of the project, so that only by changing starting dates can resource balancing be accomplished. By slipping and sliding projects on a time scale, the districts attempt to balance available staff against needs. It was originally planned to balance staffing at the project manager level, but that proved to be unworkable. Each district now attempts to balance staffing requirements at a districtwide level and then provide seasonal or temporary personnel to project managers who need extra help.

To date, MMIS has provided resource information only and has not been used to dictate whether a project can proceed or not because of resources. Any work load in excess of existing staff resources is done by consultants. This practice, and a statewide staff pool in the land management office, has been very helpful in meeting schedules while maintaining a relatively fixed work force.

Project Numbering

Washington has a unique numbering scheme for its capital-improvement projects. Each project has a number that is carried in some form, either as a basic or as a secondary identifier, throughout the life of the project. Critical to this numbering scheme is the planning unit, a particular stretch of highway that has homogeneous qualities. Each state highway in each district has its own series of planning-unit numbers; for example, a project on a hypothetical highway could be identified as 53031B—Lofall to Keller Ferry—as shown below:

Position	Example	Description
First numeric	5	District number (1 through 6)
Second numeric	3	Functional class number (1, 2, 3, 5, or 6, where 1 = principal arterial, 2 = minor arterial, 3 = major collector, 5 = Interstate, and 6 = other)
Third, fourth, and fifth numeric	0, 3, and 1	Planning-unit number, unique to the particular highway
First alpha	B	Unique project within the planning unit

The project numbering system allows the department to sort, group, and arrange project estimates in numerous ways. Other data are attached to the project number, including project type, benefit codes, and estimates of costs for engineering, right-of-way, and construction.

One problem with the project-number concept is that a project can consist of almost anything and can range from the entire scope of work in a given geographic area to a series of related activities that result in a product. Because of this problem of defining a project, MMIS uses the term "phase", e.g., design, to identify the parts of the total project. The sum of all MMIS phases will result in something that behaves like a project. The MMIS project matches the financial project number by using the project number and adding three digits to the end to signify the particular phase. For example, the design phase of the project example described above would be identified as 53031B-203—Lofall to Keller Ferry: bridge design.

Authorizations

The accounting system in Washington assigns work orders for design; plans, specifications, and estimates; and right-of-way portions of a project. This authorization provides clearance to begin work on a particular project by the assignment of still another six-digit number, e.g., 0L4163 or RW2364. This number may encompass part, all, or more than one project. When more than one project number is incorporated into a work-order authorization, dollar prorations are made to the included projects; hence, the match of planned dollars and actual labor expenditure dollars will never be good at the project level. This pro rata of dollars to projects has caused some problems in matching staffing requirements to the financial system.

Measure and Compare

MMIS currently provides eight reports that show relationships between planned quantities and expenditures. Their range of detail runs from that of the individual project or phase status report through those of headquarters-organizational- and district-level summaries. These reports more than cover the demand for expenditure comparison information. Project performance was intended to be a primary responsibility of the project manager in the field but, because labor reporting occurs only once a month, it is several weeks before the results of all labor charges are known. The comparison process is used extensively by MMIS staff during standards validation. Many cuts of historical data (completed phases and projects) are made by organization and activity. These are matched against new planned quantities generated by completed project features and additives. Measurement is made by MMIS staff, on a statewide or district level, to compare known performance with that projected by the standards. This gives a check on a proposed program and whether it can be delivered by the staff on hand. Emphasis is being placed on this level of comparison because it can identify areas of future problems.

Design Shortcomings

As originally designed, MMIS was to provide information on staff planning, scheduling, and expenditures for project managers to use in laying out work. It was also to provide project-monitoring capabilities by using development points for checks on progress. All support organizations would receive scheduling and resource information for their use in staffing to the work flow. Project managers do not have the autonomy they once had, because most of the program control is exercised at the district level. Washington now has a strong, decentralized organization that schedules projects to fit available staffing levels and does not tolerate large fluctuations in staff.

IMPROVED DESIGN

Right-of-Way

During the data-collection and work-analysis period (1972-1974), the scope of MMIS was limited to engineering aspects of project development in both preliminary and construction engineering. Right-of-way acquisition was not made part of the MMIS effort because the department already had a right-of-way staff-estimating system. In 1976, this system was eliminated and a separate phase was created in MMIS to cover right-of-way acquisition. The MMIS right-of-way phase normally runs parallel with the plans, specifications, and estimates phase. The staffing standards for all right-of-way functions were recently reviewed and updated, and some major cuts in the support functions, recognizing changes in review procedures, were made. Because right-of-way acquisition can be a major factor in project completion, bringing the right-of-way-acquisition function into MMIS now provides a better picture of project development.

Preconstruction versus Construction Engineering

Preliminary engineering and construction engineering followed separate paths during detailed MMIS design. Although both paths are well designed for their separate purposes, points of dissimilarity have caused some problems. The preliminary engineering phases have eight project types, whereas the construction phases have only six. Another difference between preliminary and construction engineering is the manner in which staff-time standards are applied. All preliminary engineering standards are individually planned at the activity level, while construction engineering staff time is planned by activity groups that summarize 1-20 activities.

Modifications to MMIS

MMIS has been modified as a result of changes in emphasis by the department, the necessity to provide information in slightly different formats, a desire for coverage that would better match the financial system, and addition of project information for budgeting purposes. One of the earliest requests was for the addition of a subprogram designator.

The capital construction program in Washington is divided into various subprograms; for example, A1 = rehabilitation work on non-Interstate highways and B1 = Interstate construction. Unfortunately, because new subprograms are added each biennium, historical records by subprogram are difficult to maintain.

An offshoot of the subprogram request was the development of a new format for an existing report so as to mesh with budgeting formats. The new format is by subprogram within each district, condenses the staffing detail into quarters to match the financial system, and prints both the staff and dollar information in the same report. This report is used extensively by the districts during budget development.

One of the control reports, District Milestone Status and Exception Report, has been extensively modified to provide more information at the project level. The tardiness by the districts in updating status reports caused many to exceed the exception limit, which made the original report very cumbersome. By revising the report format, all planned stages on a given project are now shown with the status of each. The new title, Project Status Report, is indicative of the shift in emphasis to the project itself. This should become the key informant for a scheduling, monitoring, and control function.

Systems changes involving the data-handling package purchased by the department are complex but require some explanation. The data-base system purchased was a state-of-the-art system, and the vendor was not intimately familiar with it. Thus, considerable time was needed for the systems development staff to learn to use the data-base system and costs to develop MMIS were higher than normal.

Some of the MMIS reporting requirements did not use the data-base capability efficiently. The particular data-base system is very good for ready access of all types of single- or small-group information needs but is not adequate for large summaries and reports. Much reprogramming was done to remove production summaries and expenditure reports from the data base. Once the extracts were made, processing costs decreased appreciably. Systems support has improved over time and the MMIS data base is no longer a novelty, but it is still used as the department training ground for new programmers. It would, however, be impossible to process the data contained in MMIS by using older methods of data processing.

Even after several years of experience and an effort to simplify the basic system, MMIS is still complex and not well understood. It is also expensive to update because of the large amounts of data maintained.

Thus, MMIS is not cheap to maintain. A major portion of the costs are for computer processing and systems support. MMIS staff consists of four people in headquarters who handle the operational aspects and standards validation and provide training and troubleshooting expertise. These four are supported by a systems analyst and a design programmer who are familiar with the data-base system. The six districts collectively have approximately 4.8 staff years of support with which to keep the MMIS data base current.

The costs for FY 1980 break down as follows:

Item	Cost ($) Districts	Headquarters	Total
Labor	120 000	90 000	210 000
Data processing	5 000	165 000	170 000
Travel		5 000	5 000
Printing		3 000	3 000
Systems support		90 000	90 000
Total	125 000	353 000	478 000

MMIS development costs, from the beginning in 1972 to the point when the system was declared operational in 1977, exceeded $1 million. In addition, much of the current effort on modifications should also be called developmental, as it is attempted to fit MMIS to a different environment than originally anticipated.

MMIS IN THE FUTURE

After a couple of years of operational status and a full biennium of project history, the questions are, Was it worth it? And is it still necessary to plan staffing requirements to the nth detail? The answer is that we still think so! It was a formidable task to try to provide staffing planning for both preliminary engineering and construction engineering at the same time, establish a new data-base system, and base staffing standards on individual project details. It may have taken several years longer than originally planned, but the results are now coming in. The extensive work done in establishing standards is resulting in good performance overall. The system may be more complex than needed for its current use, but times have changed since the early 1970s when gasoline was cheap, construction was booming, and many large projects were on the drawing boards. It is much easier to trim back than to add on to a system of this size.

Now that major new construction projects (on which the MMIS was primarily based) are almost extinct, rehabilitation is the commonest operation, and both gasoline and money are scarce, the department must consider its efficiency and do a good job of utilizing scarce resources. MMIS as a management tool is being changed to fit that new task. Eliminating excess paperwork, processing fewer reports, working more quickly, and broadening the audience for the system are under way now. Joining forces with the financial system is a necessity. Staffing needs cannot be estimated separately and managed without some relationship to the programming and expenditure of funds. Commonality of data in resource management systems seems the way to go.

Publication of this paper sponsored by Committee on Manpower Management and Productivity.

Abridgment

Preconstruction Engineering Management in Virginia

Frank E. Tracy

The Virginia Department of Highways and Transportation has implemented a project-monitoring system and a limited staffing planning system. These systems are automated to the extent that computer files have been developed that output a large number of specially formatted listings designed to assist middle- and high-level management in the administration of the annual construction program. All technical areas of the department were involved in defining the specifications for the project-monitoring system and are involved in its daily operation. A single large operating division was selected as the pilot area for the staffing planning system. A task force approach was used in each case to define the system details. In the future, the systems will be combined and expanded to other engineering areas of the department. On-line capabilities and statistical techniques will be used in this expansion. The staffing planning programs are written in COBOL, and the project-monitoring system is written in COBOL and FORTRAN.

The present-day Virginia Department of Highways and Transportation has major responsibilities in each of several modes of public transportation. For many years, however, the agency's basic responsibilities were confined to highway systems and, even today, the 88 000-km (55 000-mile) highway network and its attendant planning, design, construction, and maintenance remains as the largest area of concentration for the engineering staff. The scheduling and monitoring of the preconstruction stages of the thousands of highway development projects and the assignment of staff, as needed, to the hundreds of engineering and other tasks involved in each of these is a continuing voluminous undertaking that involves almost every unit and every technical discipline in the organization.

PROJECT MONITORING

Several years ago, the department began the development of a methodology designed to outline the steps involved in a construction project and to monitor the progress of a project in relation to meeting a realistic bid-advertisement date. An internal task force representing all affected divisions of the department was appointed and assigned the task of specifying the system requirements. The system, as defined and as developed, is best described as semiautomated. Computer-maintained files have been built and can be accessed to produce reports and to indicate schedule variances, but the scheduling itself remains largely manual. The system, therefore, can be considered a project-monitoring-and-status system but not a project-scheduling system.

The first action consisted of manually defining the identifiable activities involved in two theoretical most-complex projects. These projects included each known step in a project having one public hearing (combined location and design) and in a project having two public hearings (separate location and design hearings).

Basic data consisting of such information as route, county, project number, description, and length are collected for each construction project and entered into the system. These data, grouped by projects that are expected to be advertised in one contract, are entered into a computer file. A tentative date for advertisement-for-construction bidding, which has previously been determined, is used as the control by which target dates for other steps in the development of the project are based.

The dates are furnished individually by division or district representatives in lieu of a computer calculation. It was found that this approach was more accurate and more flexible for the initial period (although automated calculation is being considered for the future). A project turnaround sheet, which includes the proposed advertisement date, is circulated among the affected divisions. Each division representative determines the activities within his or her area of responsibility and produces one or more target dates. This information is entered into the computer system and a resultant target-date report is produced for each project. This report shows the bid-advertisement date together with dates for other critical phases of work as required to keep a project on schedule. The computer system evaluates the effectiveness of each date when compared with an actual date and produces other reports to alert the affected divisions and management area(s) of critical steps, deadlines, and such.

A number of critical points in the development cycle for a project, such as environmental-impact-statement approvals, holding of public hearing(s), and such, are identified as permanent checkpoints. Other critical stages of various preconstruction operations are isolated, and specially formatted listings are produced, by district and by advertisement date, of the critical dates involving road design, bridge design, right-of-way acquisition, district operations, and other factors. Figure 1 illustrates the type of data reported for bridges in a particular construction district.

Many other computer-output formats have been developed for specific use by a particular division or district. One of these is an output that indicates the chronological sequence in which various work elements must be performed to allow projects in a construction district to remain on schedule. This type of advance information is of extreme importance in scheduling staffing requirements. Other specially formatted listings are prepared for the various units of the department involved in preconstruction activities.

When a project fails to advance on schedule, reports produced by the automated system alert the affected administrative areas. This allows corrective action, if possible, within the remaining time frame or, alternatively, setting the project aside to apply concentrated attention to other projects.

When it is necessary to significantly revise a portion of a project, a listing by district is produced showing descriptive data, a statement concerning the revision, and the next step in the anticipated development of the project. This alerts the affected unit(s) and allows them to make proper adjustments, if necessary, in the dates of subsequent operations.

A district project file is produced on a regular basis showing in summary, by district, the status of all projects in the system. This basic information is of particular benefit in scheduling the individual demands on the staff of the department and gives a concise overall look at all projects in the system.

Figure 1. Critical stage report: bridges.

VIRGINIA DEPARTMENT OF HIGHWAYS AND TRANSPORTATION

M25-1805-01 PROJECT DEVELOPMENT MONITORING SYSTEM 11/09/79
BRIDGE DIVISION
CRITICAL STAGES IN PROJECT DEVELOPMENT PAGE 8

XXX DISTRICT

PROJECT	DSG	<- - - - - - - DESCRIPTION - - - - - - ->	BRIDGE DESIGN REQUESTED TAR	ACT	FOUNDATION DATA RECEIVED TAR	ACT	PRELIM BRIDGE PLANS APP TAR	ACT	COAST GUARD PERMIT RECEIVED TAR	ACT	FINAL BRIDGE PLANS TAR	ACT
		ADVERTISEMENT DATE 0180										
0081-080-105.8647		BRIDGE - NBL OVER RTE 311	0	676	0	0	778	778	0	0	1179	1079
0081-080-105.8648		BRIDGE - SBL OVER RTE 311	0	676	0	0	778	778	0	0	1179	1079
		ADVERTISEMENT DATE 0280										
U000-126-103.8601		BRIDGE - N & W RAILWAY	0	978	0	0	0	1278	0	0	1279	0
0697-033-160.8628		BRIDGE OVER MILL CREEK	0	678	0	0	379	379	0	0	1279	0
		ADVERTISEMENT DATE 0480										
0081-962-101.8609		WIDEN BRIDGE RTE 100 INTERCHANGE	0	0	0	0	1079	0	0	0	280	0
0081-962-101.8610		WIDEN BRIDGE RTE 100 INTERCHANGE	0	0	0	0	1079	0	0	0	280	0
		ADVERTISEMENT DATE 0580										
0501-009-103.8604		BRIDGE CABIN CREEK	0	0	0	0	0	0	0	0	380	0
0501-009-103.8605		BRIDGE LONG BRANCH	0	0	0	0	0	0	0	0	380	0
		ADVERTISEMENT DATE 0680										
0614-011-158.8639		ROUTE 614 OVER MIDDLE CREEK	0	776	0	0	479	479	0	0	480	0
0614-011-158.8640		ROUTE 614 OVER JENNINGS CREEK	0	776	0	0	479	479	0	0	480	0
0614-011-158.8641		ROUTE 614 OVER JENNINGS CREEK	0	776	0	0	479	479	0	0	480	0
		ADVERTISEMENT DATE 0780										
0081-962-102.8627		BRIDGE REPAIRS RTE 608 OVER RTE 81	0	0	0	0	0	0	0	0	0	0
0639-080-143.8628		BRIDGE ROANOKE RIVER	0	474	0	0	1179	0	580	0	580	0
0646-033-153.8622		BRIDGE PIGG RIVER	0	1177	0	0	0	179	0	0	580	0

A listing showing those projects scheduled for advertisement on a statewide basis for a particular future month can be produced. The successful meeting of such a schedule is the end product of the entire preconstruction effort. The successful operation of a highway construction program is tied to the ability of the many units within the department to maintain a scheduled rate of progress. The overall system continues to monitor this progress and contributes significantly to the department's ability to efficiently obligate construction funds and to maintain an effective program.

Summary sheets for the entire system are produced quarterly. These show the number of projects by year of bid advertisement and by road system and indicate their status in the project-development monitoring system.

Project monitoring is currently being used throughout the agency by all affected central and field offices. More than 20 individual reports, some with many variations, are being produced and distributed on a monthly basis. The system is an effective and useful tool for following the progress of the hundreds of individual projects under way at any time and thus measurably increases productivity at every level.

STAFFING PLANNING

Project scheduling and monitoring is a major portion of any highway and transportation agency's administrative work that to be of practical use must be fully coordinated with staffing planning efforts. The department has not, as yet, combined the project-monitoring and the staffing planning programs into a single interactive system. This will be done in the future. Staffing planning programs were relatively new concepts when the Virginia Department of Highways and Transportation began to investigate their use. Other highway and transportation agencies had taken steps in the field but most were still modifying and adjusting their systems to fit their needs and requirements. In Virginia, it was administratively determined that a detailed, but limited, study would be made to determine the effectiveness and anticipated advantages of such a system. It was also determined that the study would center about the demands and requirements of a single division and that the location and design division, with its broad involvement in almost every preconstruction phase of a project and its large personnel complement, would provide the best test.

The study was undertaken by another internal task force. The basic intent of the group was to outline a plan for

1. Budgeting staffing programs and costs for individual projects per unit of work,
2. Comparing the budgeted values with actual performance on actual projects, and
3. Developing a workable set of procedures that would allow the various design units to take advantage of the benefits of the system without letting input to the system become too time-consuming.

This required the development of procedures for forecasting work efforts and, at a subsequent date, determining the actual efforts and comparing them with the estimated or budgeted values. It was necessary to first break down each item of work into its basic ele-

Figure 2. Monthly project report.

VIRGINIA DEPARTMENT OF HIGHWAYS AND TRANSPORTATION
LOCATION & DESIGN PROJECT REPORT
PRIMARY SYSTEM - URBAN

INITIAL BUDGET 6/07/77
LATEST REVISION 7/01/79

PROJECT XXXX-XXX
ENGINEER NO. 03 DIST. XXX
NOV. 30, 1979

	EL. NO.	MILES	MANHOURS BUDGETED	MANHOURS EXPENDED	DOLLARS BUDGETED	DOLLARS EXPENDED	PERCENT USED HOURS	PERCENT USED DOLLARS	FISCAL YEAR EXPEND. MANHOURS	FISCAL YEAR EXPEND. DOLLARS	% PART	% TOTAL
1. PRELIMINARY ENGINEERING FIRST EXPENDITURE 06/77												
PRELIM SURVEY	02	P	195	195	1,057	1,057	100%	100%				1%
RECON-PROJECTIONS	03	P	90	90	488	488	100%	100%			7%	2%
PRELIM DEVELOP	04	6:00 AM	780	780	5,226	5,226	100%	100%			66%	8%
REVIEW-RECOMM	05	P	150	150	1,125	1,125	100%	100%			77%	9%
LOCATION HEARING	06	P	85	85	595	595	100%	100%			84%	10%
LOCATION SURVEY	07	6:00 AM	7,800	7,800	49,920	49,920	100%	100%	1,250	8,010		69%
PLAN BASE PREP	08	6:00 AM	3,768	3,500	22,796	21,850	93%	96%	2,570	1,560		98%
IN-DEPTH REVIEW	09	P	213	200	1,420	1,650	94%	116%	200	1,650	100%	100%
TOTALS W/O ELS 02,07,08			1,318	1,305	8,854	9,084	99%	103%	200	1,650		
TOTALS			13,081	12,800	82,627	81,911	98%	99%	4,020	11,220		
2. PRELIMINARY DESIGN FIRST EXPENDITURE - 09/78												
PRELIM DESIGN	32	6.00 AM	540	540	2,662	2,662	100%	100%	225	1,110	11%	9%
HYDRAULIC DESIGN	33	6.00 AM	1,080	1,080	6,221	6,221	100%	100%	550	3,170		26%
COMPL PRELIM DES	34	6.00 AM	1,290	1,290	6,360	6,360	100%	100%	1,290	6,360	36%	47%
FIELD INSPECTION	35	P	85	85	419	419	100%	100%			37%	48%
RW PLANS	36	6.00 AM	1,440	725	7,099	3,445	50%	48%	725	3,445	65%	71%
PUBLIC HEARING	37		60		296		0%	0%			67%	72%
TOTALS			4,495	3,720	23,057	19,107	83%	83%	2,790	14,085		
3. FINAL DESIGN												
FINAL DESIGN	62	6.00 AM	1,110		5,472		0%	0%			88%	90%
SUMMARIZE	63	P	250		1,233		0%	0%			93%	94%
CHECK-DISTRIB	64	6.00 AM	360		1,775		0%	0%			100%	100%
TOTALS II & III W/O EL 33			5,135	2,640	25,316	12,886	51%	51%				
TOTALS			6,215	3,720	31,537	19,107	60%	61%	2,790	14,085		
4. CONSTRUCTION												
CONSTR SURVEY	82	6.00 AM	6,240		26,650		0%	0%				
FINAL SURVEY	83	6.00 AM	960		4,100		0%	0%				
TOTALS			7,200		30,750			0%				
5. FINALS												
FINAL ESTIMATE	92	6.00 AM	265		1,185		0%	0%				
TOTAL			265		1,185		0%	0%				
PROJECT TOTALS			26,761	16,520	146,099	101,018	62%	69%	6,310	25,305		

ments. The task force developed a series of element person-hour norms. Basically, a proposed construction project was broken into five general categories or phases: location, preliminary design, final design, construction preparation, and final estimate. The last step (final estimate) is a postconstruction operation in lieu of preconstruction. It is, however, a distinct phase that requires significant field and office engineering personnel involvement and is an integral part of the staffing planning programs.

Within the five categories, elements of work were identified and person hours per project or per unit length of highway were determined for rural and urban locations within each type of road system. These values or norms were determined by the task force members based on their considerable experience in this field. Employee time-sheet records, when available, were studied to determine person-hour expenditures on various work elements. After implementation and testing, certain of the values were adjusted and their review and detailed calibration will be continued.

The person-hour norms were established for alignment length, i.e., the length that will require the basic engineering functions of alignment and gradient calculations. Thus, dual-lane facilities having independently designed lanes for opposing traffic will have double alignment lengths. Interchange ramps, intersections, and such will also increase the alignment length.

The person-hour norms per project are for tasks that must be accomplished for a particular construction project but are not a function of its length. An example of this would be the efforts involved in the scheduling of, preparation for, and conducting of a public hearing.

The sum of the total person hours for each of the five phases is the total overall staff time estimated for the entire project. A pass against a person-hour cost file is made by the automated system to produce dollar budget values.

Figure 2 is an example of a monthly project report of budgeted versus expended costs. This report allows the design units and their management to monitor both the progress of an individual project and the cost and effectiveness of their staffing expenditures. These are available on a monthly basis and on a year-to-date basis. The percentage of available funds and the percentage of available person hours are calculated and furnished on the project report. This allows close review and control of projects by all management levels.

The accurate preparation of staffing-requirement projections is the backbone of the system. It is necessary to determine nonproductive time and nonproject time, and considerable study was expended by the task force in defining these elements. The basic time distribution consists of 2080 hours/year (52 weeks × 40 hours/week) from which is subtracted holiday, vacation, and average anticipated sick-leave time. This available time is further adjusted by design unit supervisors in preparing their person-hour budgets by separating productive time from nonproductive and nonproject time.

The monthly summary sheets produced by the system show monthly person-hour expenditures by design unit and by road system. As is the case throughout the system, the purpose of this report is to allow management to be fully advised of the status of one or more preconstruction activities—in this case, the expenditures of the actual person hours and funding compared with the budgeted values.

The staffing planning system is currently under detailed study as to its place and utilization within the department. It is designed so that certain segments of the organization may use it permanently without others using it at all. Its future lies in its practicality. In some areas of the department, it will be implemented and fully utilized and, in others, it will not be used at all. A management study of the department's organization and reporting procedures is now under way. It is anticipated that this study will have a direct bearing on the expanded use of the staffing planning system.

This approach by the Virginia Department of Highways and Transportation to the overall areas of preconstruction engineering management is still in an early stage. A significant degree of automation is included in the system as now developed, but additional methods and procedures will be included in the future as the system is further developed. Particular future attention is required in the scheduling areas of project development and in the person-hour projection areas of the staffing planning portion. The obvious next major step will involve combining the two systems into a single system. Greater use of statistical concepts will be evident as the system is expanded. On-line capabilities, particularly for the project-monitoring portion, are being reviewed and studied and will be incorporated into future versions of the system. Critical-path methods and program evaluation and review techniques are being evaluated as to their practicality for inclusion in the system. The expansion of the staffing planning concept into other engineering disciplines is another obvious step (although different units may have different requirements).

The advantages of even a limited approach as currently used in Virginia are that management has a much closer grasp of the overall system, can recognize problem areas at a much earlier date, and can make necessary administrative adjustments at a stage that will not disturb construction schedules. These are substantial and immediate benefits.

In these times of restricted budgets and uncertain levels of transportation income, approaches such as these for project monitoring and staffing planning are of both intermediate- and long-range importance. All areas of government must take advantage of every possible means of accurately forecasting money and staffing requirements in order to provide the public with expected services efficiently, on time, and within funding restrictions.

The automated portions of the systems described in this paper consist of approximately 35 computer programs. The project-monitoring programs are written partly in FORTRAN and partly in COBOL. The staffing planning programs are written entirely in COBOL.

Publication of this paper sponsored by Committee on Manpower Management and Productivity.

Abridgment

Changing Criteria for Project Evaluation and Priority Setting

Kumares C. Sinha

Five topics relevant to changing criteria for transportation project evaluation and priority setting were discussed in a conference session. Types of criteria were defined, their limitations were identified, and a list of guidelines that can be used to deal with changing criteria was presented. The relationships between national goals and state and local planning and the various mechanisms that can be pursued at the federal level to ensure that national goals are addressed in transportation programming were described. Some of the analytical and graphical methods used in transportation priority setting were reviewed. The unique problems of transportation programming in metropolitan areas—particularly the mismatch caused by the fact that, although historically most of the programming function has occurred at the state level, this function is assigned by the 1975 joint Federal Highway Administration-Urban Mass Transportation Administration guidelines to the metropolitan planning organization—were considered. The role of minimum standards (threshold criteria) was examined, and it was suggested that potential improvements to the transportation system should be reviewed from a complete perspective of the condition of the existing service and the utility and feasibility of the proposed services.

In recent years, the task of programming transportation projects has become increasingly complex. Caught in the crunch between decreasing revenues and increasing costs, it has become necessary for transportation agencies to defer many needed improvements and to attempt to select only those projects that are optimally cost-effective. The need for a multimodal approach to transportation programming has steadily become more important. At the same time, the forms of federal, state, and local government responsibilities in transportation financing are in a state of change. In addition, public concerns about energy conservation, environmental preservation, social equity, and economic feasibility have added a new dimension to the transportation programming process, particularly in metropolitan areas. This paper describes a conference session in which the changing criteria for the evaluation of transportation projects and for the determination of priorities for their implementation were identified.

PROBLEM OF DEFINITION AND MEASUREMENT

Before one can discuss the changing criteria for project evaluation and priority setting, it is important to define the types of criteria commonly used and to identify their limitations due to changes in the transportation decision-making environment. Bruce Campbell of Fay, Spofford, and Thorndike, Inc., presented an overview of the programming process, including project evaluation and priority setting.

An important element in the programming process is the uncertainty involved in changing administrations at both state and federal levels. Campbell proposed that, if a process for planning, priority-setting, programming, design, and construction activities can be established and accepted in at least a broad overview perspective, then impacts of changes of administrations, and thus changes of priorities, could be greatly minimized.

A detailed review was made of the criteria that have been traditionally used for project evaluation and priority setting. However, no magic number that combines all criteria can be developed, because many of the factors—whether social, economic, environmental, or ecological—cannot be adequately quantified. Consequently, Campbell suggested a matrix approach of levels of achievement for given criteria. Examples of the various forms of the matrix approach used in Massachusetts, Wisconsin, Maryland, and Minnesota were included.

Campbell concluded his presentation with a list of guidelines that can be used to deal with the changing criteria for project evaluation and priority setting. He stressed the need of citizen input, improved communication among agencies involved, and the use of flexible options on the level of projects. He felt that, to date, project evaluation and priority setting in a multimodal context have not been successful and that efforts in this direction should continue beyond the current practice of indirect priority setting through categorical funding.

NATIONAL GOALS AND STATE AND LOCAL PLANNING

Many of the changes in the environment for transportation decision making are due to changing national goals. Kevin Heanue of the Federal Highway Administration reviewed the evolution of national goals relevant to transportation and how these goals are integrated with state and local planning and programming. He noted that an early transportation-related national goal was to provide aid to commerce by opening up undeveloped territories and resources. In recent years, however, there have been many goals and some of these conflict with each other (e.g., environmental protection versus economic development). However, the provisions of Title 23 of the U.S. Code allow local decision makers to determine trade-offs between conflicting goals.

Heanue then examined the sets of goals at different levels; generally, the goals are the same but the priorities are different. For example, although the control of inflation and energy conservation currently have the highest priorities at the federal level, the top priorities at the state level are generally economic development and the maintenance of highways and rail and intercity bus systems and at the local level are urban development and the maintenance of municipal services.

There are several mechanisms that can be pursued at the federal level to ensure that national goals are addressed in transportation programming. These mechanisms include program authorization and appropriation levels, matching ratios, funding categories, planning certification review, and environmental impact statement approvals. Heanue felt that the integration of national, state, and local goals is most effectively achieved at the state and local levels as local officials are mainly responsible for programming decisions. The approval processes of various programs by the Urban Mass Transportation Administration (UMTA) and by the Federal Highway Administration (FHWA) attempt to ensure that transportation-related national goals are appropriately addressed. At the regional level, federal agencies have developed mechanisms (intermodal planning groups) to coordinate approval and certification procedures of the various planning work programs. Heanue indicated that these groups should be expanded to include the U. S. Departments of Energy and of Housing and Urban Development as full participants.

It was pointed out that several of the legislative proposals that have arisen due to the national concern for energy conservation will have significant impacts on state and local transportation programming. Examples of these legislative initiatives include (a) automobile-use management in which the federal matching ratio for energy-efficient projects would be increased and (b) automobile fuel-efficiency improvements. The present funding mechanisms are such that improvements in fuel efficiency may mean decreases in highway-user revenue, which will cause subsequent decreases in highway program funds at all levels of government.

EFFECTIVENESS OF PRIORITY SETTING

Some of the analytical and graphical methods used in transportation priority setting were reviewed by Salvatore J. Bellomo of BKI Associates. This included a detailed discussion of the implications of priority setting for professionals and planners, engineers, and policy analysts; an examination of the effectiveness of priority setting in political and technical perspective; and an outline of a set of associated guidelines.

It was pointed out that the traditional approach of merely preparing a long list of priorities is no longer satisfactory. In the present environment of transportation decision making, objective analytical approaches are necessary for making multimodal trade-offs and priority determinations. Such approaches are particularly relevant in the context of revenue shortfalls, energy constraints, and the changing emphases of transportation in society.

The criteria used to evaluate the effectiveness of the available priority-setting methods were discussed, and a detailed presentation was made of the priority programming system. Bellomo felt that many of the technical approaches to priority setting can run into serious problems when challenged by politicians, and he suggested a strong federal role in the further development and demonstration of multimodal priority-programming techniques at all levels of government. It was felt that the private sector should be involved in transportation programming, particularly for public transportation; projects that reduce costs through private initiatives should be explicitly incorporated in the priority-setting process.

PROGRAMMING IN METROPOLITAN AREAS

The unique problems of transportation programming in metropolitan areas were discussed by John J. Roark of PAWA, Inc. He felt that there is a mismatch between what was conceived and what actually exists in the programming process at the urban level. Most of the programming function has historically occurred at the state level, but the 1975 joint FHWA-UMTA guidelines assigned the function in urban areas to local elected officials through the metropolitan planning organization (MPO). Although it can be argued that programming is inappropriate at the urban level, Roark felt that there is no inherent conflict between the programming concept and having the MPO do the programming and gave two reasons: (a) programming by the MPO would allow better integration of planning and programming and (b) such programming would ensure early involvement of local elected officials and citizens in the programming process.

Although the concept of programming at the MPO level is valid, there are several factors that make the process difficult, if not impossible. First, there are the problems of conflicting local goals and of project identification and project evaluation. However, the primary problem of transportation programming in metropolitan areas is the difficulty of establishing the amount of available funds.

The existence of the various categorical fundings at the federal and state levels and of their specific requirements make the programming process at the metropolitan level almost redundant. It is necessary to search for a procedure that could resolve the conflict between categorical funding and sound programming based on stated community goals and objectives.

ROLE OF MINIMUM STANDARDS

The role of minimum standards in project evaluation and programming was discussed by Melvin R. Lehr of the New Jersey Department of Transportation. First, the threshold criteria for improvement projects were examined, and examples from various sources were presented. A detailed review was made of the recent criteria used by the New Jersey Department of Transportation, along with the priority-setting methodology used in project selection. It was pointed out that the threshold criteria must be related to the locational, economic, modal, and energy factors of the particular area under consideration, not just to absolute factors of the transportation system such as capacity, demand, condition, and cost. A general framework was then defined for the development of threshold criteria for New England and the Middle Atlantic states. Lehr suggested that improvements to the transportation system be reviewed from a complete perspective: the condition of the existing transportation services and the utility and feasibility of proposed services. The list of existing and proposed facilities can be subdivided into four major groups and then separately treated for each mode: (a) existing services to be maintained, (b) proposed services to be forwarded, (c) existing services to be abandoned, and (d) proposed services to be tabled or abandoned. A set of relevant criteria based on stated policy objectives can then be established to examine the proposed projects in terms of these decision categories.

The realities of the programming process were stressed by Lehr. Although detailed technical criteria can be developed for use in programming, such factors as the effects of time, the political process, and the mandated public-involvement process can greatly affect the outcome of a programming and project selection process.

CONCLUSIONS

Decisions on when and where to make improvements and of the type to be made are among the most important tasks faced by transportation agencies at all levels of government. Traditionally, decisions have been made independently for each mode of transportation and the processes used have varied significantly among modes. Now, intermodal planning and programming needs have created a new challenge, particularly in view of current funding practices. Categorical funding and government bureaucracy work against sound programming.

An effective process of project selection and priority setting is necessary to ensure optimal allocation of limited funds for transportation facilities. The criteria for this process cannot be restricted to the specific systems under consideration; the broad goals of energy conservation, environmental protection, improved quality of life, and economic growth must also be considered, as well as specific community and areawide objectives. Furthermore, the criteria for project evaluation and priority setting cannot be limited to technical aspects only; the political perspective of the process must also be recognized.

Publication of this paper sponsored by Committee on Transportation Programming, Planning, and Evaluation.