TRANSPORTATION RESEARCH RECORD 680

Transportation Finance and Charges, Programming, and Costs

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The papers in this Record were treated according to the new standards.

Contents

Alternative Methods for Developing Transportation Improvement Programs for Urban Areas

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Three approaches for preparing a transportation improvement program (TIP) are examined. The first involves ratification by the metropolitan planning organization of programming decisions made by state and local transportation-implementing agencies. The second would rely on the collective judgment of an urban-area committee or forum to choose projects for implementation. The third would also use such a forum but would provide the committee with a formalized decision-making structure whereby programming decisions would be based on an expressed determination of priorities. Such a structure is described in detail: Projects are first submitted by implementing agencies. They are then reviewed for consistency with the transportation plan and those found to be consistent are placed on needs lists by type of project. The projects from the needs lists are placed in groups of similar relative priority. The groups are arrayed in priority order by funding source. The available money in each type of funding is then applied against the groups to be funded from that source arrayed in priority order. Projects in whole groups covered by available funds are inserted directly in the TIP. An analysis is made of the intermediate connective transportation system that will result. The results of this analysis are combined with other considerations, and projects from the unfunded groups are selected to use the remainder of the available funds.

On September 17, 1975, the Federal Highway Administration (FHWA) and the Urban Mass Transportation Administration (UMTA) published rules that require the preparation on an annual basis of a transportation improvement program (TIP) as a basis for federal financial assistance in support of highway and transit projects [40 Federal Register 42 976–42 984 (1975)]. It is intended by these agencies that the TIP list all transportation projects proposed for federal assistance and planned to be undertaken in the ensuing 3- to 5-year period. The TIP must also identify those projects proposed for implementation in the first year; this is identified as the annual element. The federal regulations indicate that the TIP is to be developed by local officials acting through the metropolitan planning organization (MPO).

There appear to be three distinct approaches possible for the preparation of a TIP. In the first, each individual implementing agency makes its own programming decisions based on its understanding of either an explicit or an implicit allocation of federal funds and then presents its list of projects to be programmed to the MPO. The MPO reviews the projects for consistency with the adopted-plan elements, submits the projects to an urban-area advisory committee composed of local officials or their representatives (who serve on a population-representative basis within the area), endorses the combined lists of all projects after receiving the advisory committee recommendations, and transmits a report thereon to the state and federal funding agencies. This method was used in the preparation of the first TIPs for the Kenosha, Milwaukee, and Racine urban areas in southeastern Wisconsin. In essence, this approach represents a ratification by advisory committees and the MPO of programming decisions made by state and local transportation-implementing agencies. The method has several advantages, including its workability as demonstrated over the past 3 years and its preservation of individual agency prerogatives in the programming of transportation-system development projects.

Another advantage is the relative ease with which the annual program can be updated through periodic amendments, because the method is unencumbered by an explicit process of determining areawide priorities. The major disadvantage of this approach is that the annual aggregation of individual agency-proposed projects does not necessarily result in the best program of transportation-system improvement for the area as a whole. The method, to be workable, depends on allocating the available federal aids such as Federal-Aid Urban (FAU) Highway System funds and formula-aid funds available under section 5 of the Urban Mass Transportation Administration Act of 1964 to the various local units of government on a formula basis. At the present time in Wisconsin, the state and federal governments have established allocation formulas for nearly all available aids, except for those such as the capital grants available under section 5 of the act, for which the competition is nationwide.

In the second approach, an attempt is made to lend a distinctive urban-area system perspective to the process. In this method, the implementing agencies submit lists of candidate projects to the area advisory committee, which acts as the MPO forum. Such lists are unconstrained by any preexisting formula-allocation process. The committee then, through one or more sessions, debates the merits of each project and, based on the results of the debate, formulates an annual TIP. This method relies almost entirely on the collective judgment of the committee members. For such a method to be effective, it is also necessary for the committee to have a significant amount of discretionary federal aid, such as FAU and section 5 funds, available to it for, in effect, distribution to those implementing agencies whose projects are placed in the TIP. At present, given the current federal-aid structure in southeastern Wisconsin, all federal-aid monies are allocated by formula, leaving no discretionary monies for the committee to distribute.

A possible third approach is to use the advisory committee as a forum for the preparation of the TIP (as in the second method) but provide that committee with a formal decision-making structure by which it can make programming recommendations based on an expressed reconciliation of competing and often conflicting needs and interests. The balance of this paper discusses in detail a possible decision-making structure that could be used to implement this method.

BASIC CONCEPTS AND PRINCIPLES

This alternative method for developing a comprehensive TIP involves five basic concepts or principles of improvement programming:

1. The programming of the implementation of transportation facilities should be consistent with and supportive of the orderly overall development of the area, including the development of essential public utilities and services and of a sound land-use pattern. Practically, it is also important that the transportation-system development program and the development programs in other functional areas affecting the urban area (such as sewers, water, other utilities, and municipal services) be coordinated to

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Figure 1. Flow of projects through TIP process.

Projects Submitted — Transit & Highway Implementing Agencies

TASK 2A — Proposed Projects

Proposed Highway & Transit Projects

TASK 2C — Non-Qualifying Projects Reviewed With Proposing Agency

STEP 2

Projects Checked Against Qualifying Criteria Including Conformance/Conflict With Transportation System Plan, Plan Staging, and Other Functional Plans and Programs

TASK 2B — Project Qualification (Project Qualifying Criteria Applied)

Result: Needs Lists

On-System Highway Preservation Needs | On-System Highway Improvement Needs | On-System Highway Expansion Needs | Transit Preservation Needs | Transit Improvement Needs | Transit Expansion Needs | Off-System Highway Construction Needs | Highway Safety Needs | Environmental Enhancement Needs

Grouping Criteria and Overriding Criteria Applied

Projects Gathered Into Categorical Priority Groups — TASK 4A

	On-System Highway Preservation	On-System Highway Improvement	On-System Highway Expansion	Transit Preservation	Transit Improvement	Transit Expansion	Off-System Highway Construction	Highway Safety	Environmental Enhancement
High Priority	HPHP	HPHI	HPHE	HPTP	HPTI	HPTE	HPOS	HPHS	HPEE
Medium Priority	MPHP	MPHI	MPHE	MPTP	MPTI	MPTE	MPOS	MPHS	MPEE
Low Priority	LPHP	LPHI	LPHE	LPTP	LPTI	LPTE	LPOS	LPHS	LPEE

Categorical Priority Groups Arrayed By Funding Type According To Priority — TASK 4B

Group Prioritization Criteria Applied

STEP 4

Funding Types:

Highway Construction	Transit Operating	Transit Capital	Off-System Highway Construction	Highway Safety	Environmental Enhancement
HPHP	HPTP	HPTE	HPOS	HPHS	HPEE
MPHP	HPTI	MPTE	MPOS	MPHS	MPEE
HPHI	MPTP	LPTE	LPOS	LPHS	LPEE
LPHP	MPTI				
MPHI	LPTP				
HPHE	LPTI				
LPHI					
MPHE					
LPHE					

Non-Discretionary Funded Projects Programmed By Implementing Agencies Removed From Groups (And Stapled Into TIP)

TASK 4C — Non-Discretionary Funded Project To TIP

Figure 1. Continued.

Available Funding
Constraint Applied In
Each Funding Type
Projects From Whole
Groups Covered By
Funds Included In TIP

TASK 5A

STEP 5

TASK 5B

Intermediate System
Resulting From Adding Non-Discretionary
Funded Projects and Projects From
Wholly-Funded Categorical Priority
Groups To Existing System Analyzed
For System Connectivity Problems
(Gaps, Bottlenecks, Etc.) Identified

TASK 5C

Projects
Selected From
Unfunded Groups
Sufficient To
Use Remaining Funds

Highway Construction

Funding Available

Funding Available

HPHP
MPHP
HPHI
LPHP
MPHI
HPHE
LPHI
MPHE
LPHE

Transit Operating

Funding Available

HPTP
HPTI
MPTP
MPTI
LPTP
LPTI

Transit Capital

Funding Available

HPTE
MPTE
LPTE

Off-System Highway Construction

Funding Available

HPOS
MPOS
LPOS

Highway Safety

Funding Available

HPHS
MPHS
LPHS

Environmental Enhancement

Funding Available

HPEE
MPEE
LPEE

Projects In Whole
Groups Covered By
Available Funds

To TIP

Intermediate System
(New Projects Dashed)

Project
Selection
Criteria
Applied

HPHE   LPTP   LPTE   MPOS   LPHS   PHEE
LPHI   LPTI   MPEE
HPHE   LPEE
LPHE

Selected
Projects
To TIP

TIP Consists of:

1. Non-Discretionary Funded Projects

2. Projects From Wholly-Funded Groups

3. Projects Selected From Remaining Groups
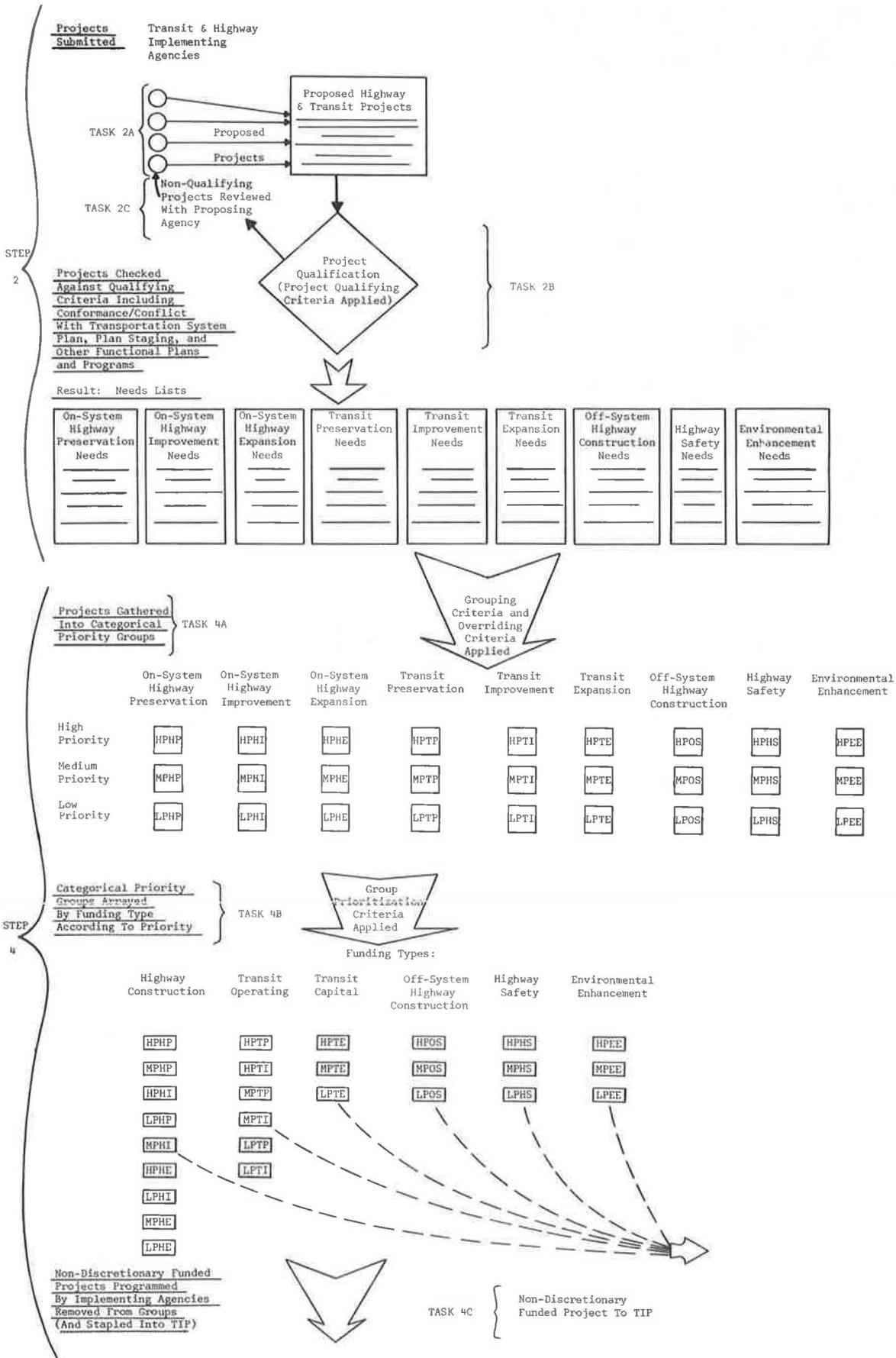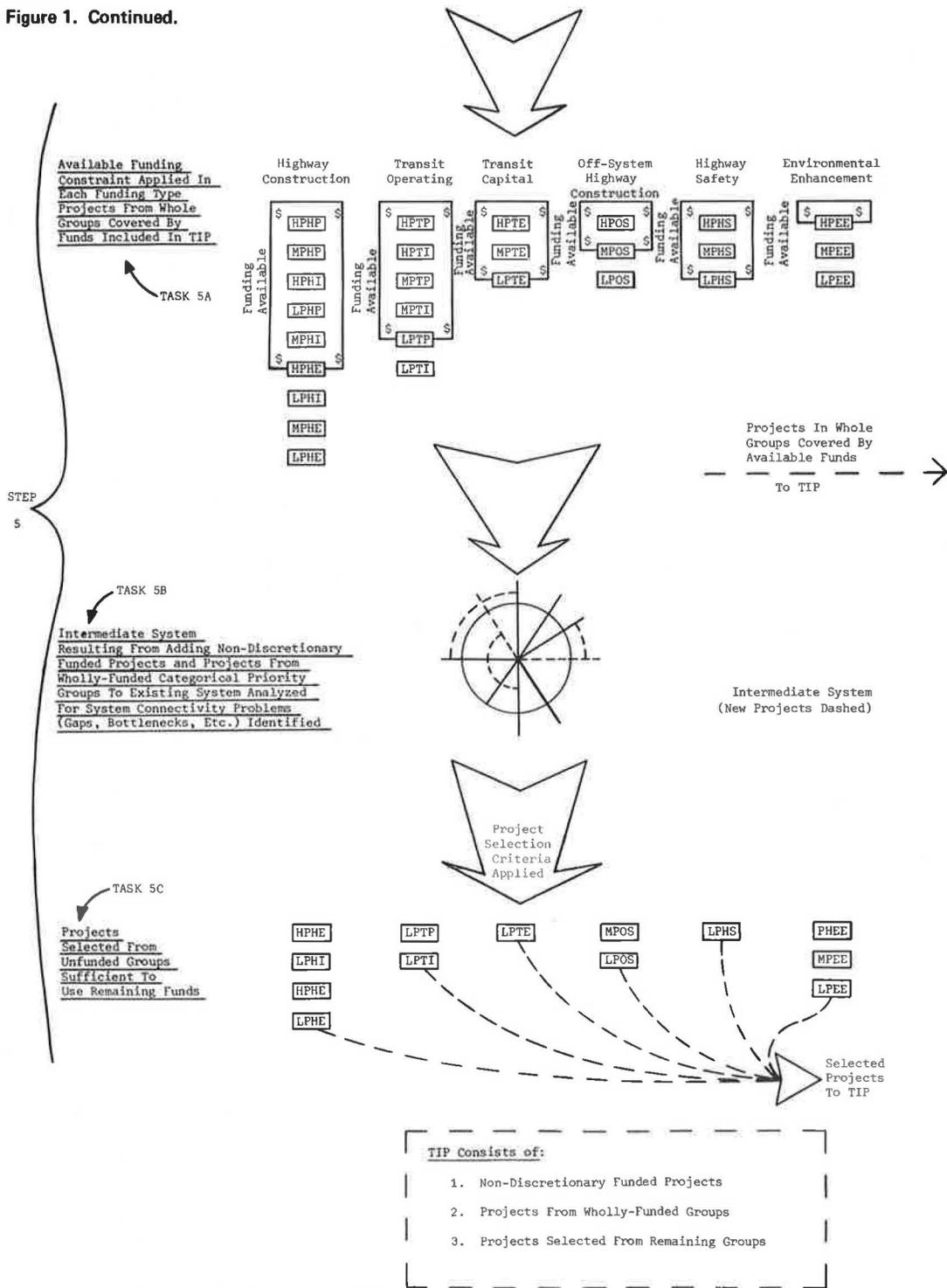
Note: Steps 1 and 3 are not explicitly shown in this figure.

the maximum extent possible in the interests of effectiveness and efficiency and the promotion of a sound regional development pattern.

2. The projects should be aggregated into categorical-priority groups of similar or related projects, which groups can then be rank ordered by priority. This enables those involved in the programming decision making to focus on the most important and difficult decisions required--i.e., grouping those projects that should obviously be included or excluded from any program and avoiding dealing in detail with each and every proposed project. The concept of the categorical-priority group not only facilitates the programming process but also allows local officials to preserve their implementation prerogatives by not explicitly listing local priorities on a project-by-project basis but rather gathering projects of similar priority into groups.

3. The programming should be based on a recognition and assessment of the relative worth of various projects. The relative worth of projects should be determined by some quantitative analysis.

4. The programming should acknowledge realistic funding constraints that will affect plan recommendations and only set forth for implementation those projects that can be reasonably expected to be accomplished during the program period and, taken together, do not require funding greater than that which can be reasonably expected to be available.

5. The workability and utility of the intermediate transportation system that will result from implementing the programmed projects should be considered as one stage to realization of the regional transportation-system plan that has been adopted.

In addition to these five basic principles, it is important to place the programming step in proper perspective relative to the overall planning and development process. Conceptually, the programming process presupposes that there is basic agreement on an adopted transportation-system plan. Accordingly, the programming procedure is not intended to determine whether or not a particular transportation project should be undertaken--that having been determined in the process of preparing and adopting a plan--but rather must be directed to the question of the timing of the particular project vis-à-vis the other projects included in the plan.

DESCRIPTION OF ALTERNATIVE METHODOLOGY

Based on these five concepts or principles, and the acknowledgment of the constraints on transportation system improvement due to current funding practices, and the interests of the jurisdictions represented within each urban area, this alternative methodology was developed for preparing TIPs for each of the urban areas in southeastern Wisconsin.

Figure 1 presents an overview of the alternative method from an orientation of the flow of proposed projects through the process. The projects are first submitted by the implementing agencies, then reviewed for plan consistency and project type and, finally, those passing review are placed on needs lists by type. The projects from each type of project needs list are placed in categorical-priority groups by relative priority--high, medium, or low. The categorical-priority groups are then arrayed in priority order by type of funding, because some funding programs fund more than one type of project. Non-discretionary-funded projects (those projects funded by money not allocated by the urban-area committee) identified by the responsible agencies are removed from the groups and inserted directly in the TIP. The amount of available money in each type of funding is then applied against the categorical-priority groups

of remaining projects under that type of funding arrayed in priority order. Projects from whole groups covered by available funds are inserted directly in the TIP. An analysis is then made of the intermediate connective transportation system that would result from adding the non-discretionary-funded projects and the projects from the wholly funded groups to the existing transportation system. This analysis is envisioned as being largely graphic in nature, whereby such problems as transit or highway system gaps and potential bottlenecks could be identified on a map, but could also extend to a quantitative analysis through traffic assignments to the proposed highway system or analysis of the resulting transit-equipment inventory.

The results of this analysis are combined with other considerations, and projects from unfunded groups are selected to use up the remainder of the available funds. These selected projects, the projects from the wholly funded groups, and the non-discretionary-funded projects then constitute the TIP. The methodology can also be used to identify either the annual element or the 3- to 5-year element of the TIP from appropriate lists of candidate projects.

This method would be implemented through 14 individual tasks under five main steps. Each of the steps and tasks is explained below, and steps 2, 4, and 5 are shown in Figure 1.

Step 1: Development of Criteria

Identification of the information that will be used to make the judgments about projects is required in the formulation of the TIP. This step is required at the very start because the items of information identified as important about each project must be included with the project description submitted by the agency proposing the project. The development of all three types of criteria is essentially a policy decision and, therefore, requires policy-level involvement by the committee.

Task 1A: Development of Project-Grouping Criteria

The second programming principle provides the reasoning for project grouping in the programming process. In task 1A, the criteria, or rules by which projects will be put into groups, are developed. At the present state of evolution of the methodology, the use of 27 categorical-priority groups is proposed: high-, medium-, and low-priority preservation, improvement, and expansion for both on-system highway and transit and for off-system, safety, and environmental enhancement for highways. The project categories are defined as

1. On-system highway preservation: projects that result in little or no increase in the traffic-carrying capacity of the existing highway system but are necessary to maintain existing capacity and structural adequacy of the facility for which the project is proposed;

2. On-system highway improvement: projects that significantly increase the capacity of existing streets or highways (by definition, the conversion of a road from rural to urban is an improvement--even though there might be only marginal capacity improvement);

3. On-system highway expansion: projects that significantly increase the capacity of the transportation system through development of new or extended streets or highways;

4. Transit preservation: projects that are necessary to maintain the current quality and level of service of the existing transit system;

Table 1. Example of criteria for determination of project priorities: transit-expansion projects.

Criterion	Weight (points)
Where project sponsor is not local unit of government, an ensurance that project implements local plans and has local support, as indicated by a letter from local government(s)	100
That a project directly provides or improves coordination between two or more transit systems as indicated by evaluation of the project submittal	50
Design provision for other modes	
Highway	25
Bicycle	25
Pedestrian	25
Service to special groups as indicated by evaluation of project submittal	
Elderly persons	75
Handicapped persons	100
Racial minorities	50
Functional criterion: type of service (total of 200 points available) as indicated by evaluation of the project submittal	
Primary	200
Secondary	150
Tertiary	100
Other	varies
Number of people served: proposed daily ridership	200
Surrogate for cost-effectiveness: passenger travel provided/cost of project	200

5. Transit improvement: projects that improve the quality and level of service of the existing transit system;

6. Transit expansion: projects that either expand the existing transit system or create new transit systems or subsystems;

7. Highway off-system: projects on streets or highways that are not on a currently designated federal-aid system;

8. Highway safety: projects that will improve or eliminate existing unsafe conditions on the federal-aid highway system as it currently exists; and

9. Environmental enhancement: projects that will materially reduce air, noise, or visual pollution, but not significantly affect system operations.

Once a proposed project is categorized, it is necessary to determine to which priority group it belongs. It is proposed to apply a set of weighted criteria to determine priorities for each category of projects. Table 1 is an example of possible project criteria for determining priorities for the transit-expansion-project category and possible associated criteria weights.

In brief, each project receives a rating under each criterion. This rating, which can be either zero or one for yes-no criteria or an actual number for such criteria as the average daily ridership on the proposed project, is then normalized (reduced to a scale of 0.0 to 1.0) and multiplied by the weight for that criterion to obtain the score under that criterion. For each project, the criteria scores are added to obtain the total project score.

For each criterion, two criterion-threshold values are identified: a high-priority criterion threshold and a medium-priority criterion threshold. Each criterion-threshold represents the minimum value of the criterion score required to identify the project as high or medium priority under that particular criterion. The high-priority criterion thresholds for all criteria are added to obtain the high-priority project-score threshold. Similarly, the medium-priority criterion thresholds are added to obtain the medium-priority project-score threshold. Projects that have total project scores greater than the high-priority project-score threshold are then categorized

as high priority. Projects that have total project scores less than the high-priority project-score threshold but greater than the medium-priority project-score threshold are categorized as medium priority. Projects that have total project scores less than the medium-priority project-score threshold are categorized as low priority. The table below gives possible criterion and project thresholds for the transit-expansion-project category.

Criterion	Threshold (points) Medium Priority	High Priority
Local support	0	100
Intersystem coordination	0	50
Design for other modes	25	50
Service to special groups	75	100
Type of service	100	150
Number of people served	50	125
Cost-effectiveness	50	125
Transit-expansion project threshold	300	700

(It is emphasized that the criteria and the values for criteria weights given in Table 1, and the threshold values given above are merely examples. The actual criteria and values to be used in the programming process for the transit-expansion category and all other project categories would be determined in task 1A.)

In addition to the development of project priority by the rating and weighting scheme discussed above, there are some other considerations that must enter into determining the project priorities. Special consideration must be given to a project that must be implemented because of a court order, to convert a situation of noncompliance with building or health codes, or to prevent an imminent catastrophe (e.g., the collapse of a bridge). Generally, a project sponsor must demonstrate, to the satisfaction of the committee, that his or her project should qualify under these so-called overriding criteria. If the committee agrees, the project must be given high priority within its project category, regardless of its project score.

The proposed methodology will work only if it is agreed at the beginning that there are such things as high, medium, and low priorities and that some projects should be placed in each group; i.e., not all projects are high priority. Although it is possible to identify additional criteria and not rely on an information-aggregation scheme (the rating and weighting technique illustrated), the process must be capable of dealing with a large number of projects (approximately 330 in the 1977 TIP for southeastern Wisconsin), and information must be gathered and processed about each project. The decisions about the type and amount of information to be gathered and used in judging the projects and about how that information is to be aggregated are made in this task.

Task 1B: Development of Criteria for Determining Group Priorities

After the categorical-priority groups are developed (by using the criteria developed in task 1A), they must be put in priority order by funding category. This involves, for example, making judgments about the relative importances of on-system highway preservation, improvement, and expansion projects that compete for the same funds. Task 1B involves the development of decision rules for making these judgments; e.g., are medium-priority highway-preservation projects more important than high-priority highway-improvement projects?

Table 2. Example of qualitying criteria.

Category	Example	Qualifying Criteria
On-system highway projects	On-system highway preservation On-system highway improvement On-system highway expansion On-system highway safety On-system highway environmental enhancement	Project must currently be on a federal-aid system; project must either be in conformance with and serve to implement or be not in conflict with adopted areawide development plans; project must be drawn from an adopted plan, either long-range or transportation system management
Transit projects	Transit preservation Transit improvement Transit expansion	Project must either be in conformance with and serve to implement or be not in conflict with adopted areawide development plans; project must be drawn from an adopted plan, either long-range or transportation system management; project sponsor must be designated recipient of federal financial assistance for transit or present written project sign-off from appropriate designated recipient
Off-system projects	Off-system highway projects	Project must not be a currently designated federal-aid system; project must not be in conflict with adopted areawide development plans; project must be drawn from an adopted plan, either long-range or transportation system management

Task 1C: Development of Project-Selection Criteria

When the projects have been arrayed according to priority by funding category and the constraints of available funds in each category applied, it is probable that the available funds will not cover exactly whole categorical-priority groups of projects and that some money will be available to fund some projects from unfunded priority groups. Task 1C requires the identification of the information to be used in selecting projects from the unfunded groups to use up the available money. The most important criterion is to select projects that, when added to (a) the existing transportation system, (b) those projects in the wholly funded categorical-priority groups, and (c) the non-discretionary-funded projects, provide for an intermediate connective transportation system for the urban area. Other possible criteria include (a) whether or not a project contributes to improved transportation for elderly or handicapped people or both; (b) whether a project is labor intensive; and (c) whether a project would, given the projects in the whole groups covered by funds and the non-discretionary-funded projects, contribute to a better geographic and jurisdictional dispersion of funds or projects throughout the urban area.

Once the three different sets of criteria (grouping, determination of group priorities, and selection) have been determined, information about the proposed projects can be gathered from the project sponsor at the time of initial project proposal.

Step 2: Identification of Needs

The purpose of this step is to develop a set of transportation needs by type of project for the urban area consistent with the regional transportation-system plan and other functional plans and programs in the urban area.

Task 2A: Project Submittal and Proposal by Implementating Agencies

This task requires that each transportation-implementing agency in the urban area examine the staging of the regional transportation-system plan, the county jurisdictional highway plans, the transit development program, and the elements of the transportation-system management plan and identify the projects for which it has implementation responsibility that it can implement within the 5-year programming period if funds are available. These projects are then submitted to the MPO, together with such project descriptive information as is necessary in light of the criteria developed in step 1.

Task 2B: Analysis of Conformance and Conflict of Projects With Regional Transportation System Plan

Before projects are admitted to the needs list, they should be reviewed by the MPO to determine consistency with the regional plan. Changes in UMTA and FHWA procedures make submission of the TIP by the MPO and metropolitan A-95 clearinghouse equivalent to positive A-95 review of each transit and highway project in the TIP. Therefore, an A-95-type review must be made on the TIP projects at some point in the process; it is proposed that this be done before they are admitted to the needs list. Formal A-95 endorsement, however, would be confined to those projects selected for inclusion in the annual element of the TIP. The projects would first be categorized into one of the nine project categories and then the appropriate qualifying criteria (such as those shown in Table 2) are applied. The projects that pass the review compose the nine categorized needs lists.

Task 2C: (If Needed) Review of Nonconforming or Conflicting Projects

As with any A-95-type review, there should be an opportunity for reconciliation of differences between the review agency and the implementing agency.

Step 3: Estimation of Funds

To formulate a realistic program of transportation improvements, it is necessary to estimate the availability of transportation funds.

Task 3A: Estimation of Availability of Nondiscretionary Funds by Mode and Funding Category

In the context of developing the TIP through an areawide forum structured by the MPO, "discretionary" funds are defined as those federal monies that can be allocated to projects to be set forth by the areawide forum (the committee) and "nondiscretionary" funds as those that are allocated to projects by some other mechanism. Nondiscretionary funds are estimated first because the units of state or local government that make the project fund-allocation decisions must make those decisions and inform the urban-area committee of those projects they wish to pursue and have included in the TIP. The availability of some funds can be estimated simply by examining the relevant allocation formula (such as urban system funds or section 5 funds), but others are much more difficult to estimate. The availability of federal-aid interstate and primary highway system and section 3 funds, for example, varies so widely from one year to another

for an area that even an analysis of historical trends may be of limited usefulness. Also, some, if not all, of these funds are the subject of delicate ongoing political negotiations; anything done by the committee in estimating fund availability must be extremely sensitive to these continuing deliberations.

Task 3B: Estimation of Availability of
Discretionary Funds by Mode and Funding
Category

In this task, the amount of money available for allocation is determined in each funding category with special emphasis placed on program restrictions (e.g., highway expansion only or transit operating only).

Step 4: Grouping and Determination of Priorities

Projects from each needs list are placed into categorical-priority groups that are then arranged in priority order by type of funding.

Task 4A: Categorization of Projects

In this task, all projects are assigned to one of the 27 categorical-priority groups by using the project-grouping criteria developed in task 1A.

Task 4B: Determination of Priorities
of Groups Eligible Under Each Funding
Category

For each type of funding (e.g., FAU, Transit Capital, Discretionary Transit Formula), the groups of projects eligible for funding under that category are placed in priority order by using the criteria for determining the group priorities developed in task 1B.

Task 4C: Removal From Groups of
Some Projects

Projects identified by the implementing agencies to be implemented with the nondiscretionary funds as estimated in task 3A are removed from further consideration for the discretionary funds allocated by the committee. These projects are placed directly into the TIP.

Step 5: Project Group and Individual Project Selection

Groups of projects and individual projects are selected to the extent that the available funds allow in each funding category.

Task 5A: Application of Available
Discretionary Funds in Each Funding
Category

The constraint of available funds in each funding type is applied to the groups of projects listed in priority order under that category. Projects from wholly funded groups are included directly in the TIP.

Task 5B: Analysis of Intermediate
System That Will Result From
Adding Projects to Existing System

The system that would result from adding the non-discretionary-funded projects and projects from wholly funded groups to the existing transportation system is studied, and problems such as system connectivity are identified.

Task 5C: Selection of Projects From
Unfunded Groups to Use Remaining
Money

Projects to use up the remainder of the available funds in each category are selected from the unfunded groups. At the conclusion of this step, the projects to be set forth in the TIP are identified as consisting of the nondiscretionary elements identified in task 4C, the projects from whole groups covered by available discretionary funds identified in task 5A, and those projects selected from unfunded groups and covered by available discretionary funds as identified in this task.

CONCLUSIONS

One alternative method is outlined for preparing an areawide TIP that could be substituted for the method currently being used in southeastern Wisconsin and elsewhere. The implementation of such a method, however, requires two important changes:

1. At present in southeastern Wisconsin, all possible federal transportation funds that could be distributed through such a method are allocated by formula directly to the implementing agencies. The advisory committee has no control over the selection of projects for funding. It would be necessary to change the system so that at least some federal funds would be placed at the discretion of the committee in each urban area. Initially, it may be possible to include in the discretionary category the federal-aid urban highway funds and the section 5 transit funds. Ultimately, if the process proved beneficial, perhaps more categories of federal-aid funds could be placed at the discretion of the committee.

2. Transportation-system implementing agencies would have to change their approach to the preparation of the TIP. At present, such agencies submit final lists of projects directly from their capital budgets that they have scaled to anticipated available funds. Instead, it would be necessary for implementing agencies to identify likely candidate projects for consideration by the committee. Thus, such agencies should not be compelled to submit only those projects that might match available funds. If this process were to be implemented, it would also be necessary to closely coordinate the preparation of the TIP and the development of individual agency budgets so that any decisions made at the areawide level through the committee could be reflected in the local budget process.

ADDITIONAL RESEARCH

In 1978, the Southeastern Wisconsin Regional Planning Commission gathered the information about each proposed project in the 1978 TIP that would be necessary to apply the third alternative method. It is their intention to test the method and the associated criteria, weights, and threshold values through an application to the 1978 TIP projects. Some criteria may have to be discarded; others may have to be added; and the ratings, weights, and threshold values may have to be adjusted. Additional research to establish a technical basis for determining criteria weights may have to be pursued for some criteria. In addition, the possibility of developing a set of criteria, weights, and threshold values such that they could be used to compare projects from different categories will be explored, although that is anticipated to be a significant task. Nevertheless, such an application should help to determine the workability (or lack thereof) of this alternative method for preparing a TIP.

Evaluation and Application of a Priority Programming System in Maryland

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

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

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

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

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

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

EVALUATION OF PRIORITY PROGRAMMING TOOLS

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

teria selected by the Maryland Department of Transportation (MDOT) and the consultant team for evaluation, and the results of the evaluation.

Candidate Tools Examined

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

Criteria for Evaluation

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

Figure 1. Framework for identifying and resolving state-level transportation issues.
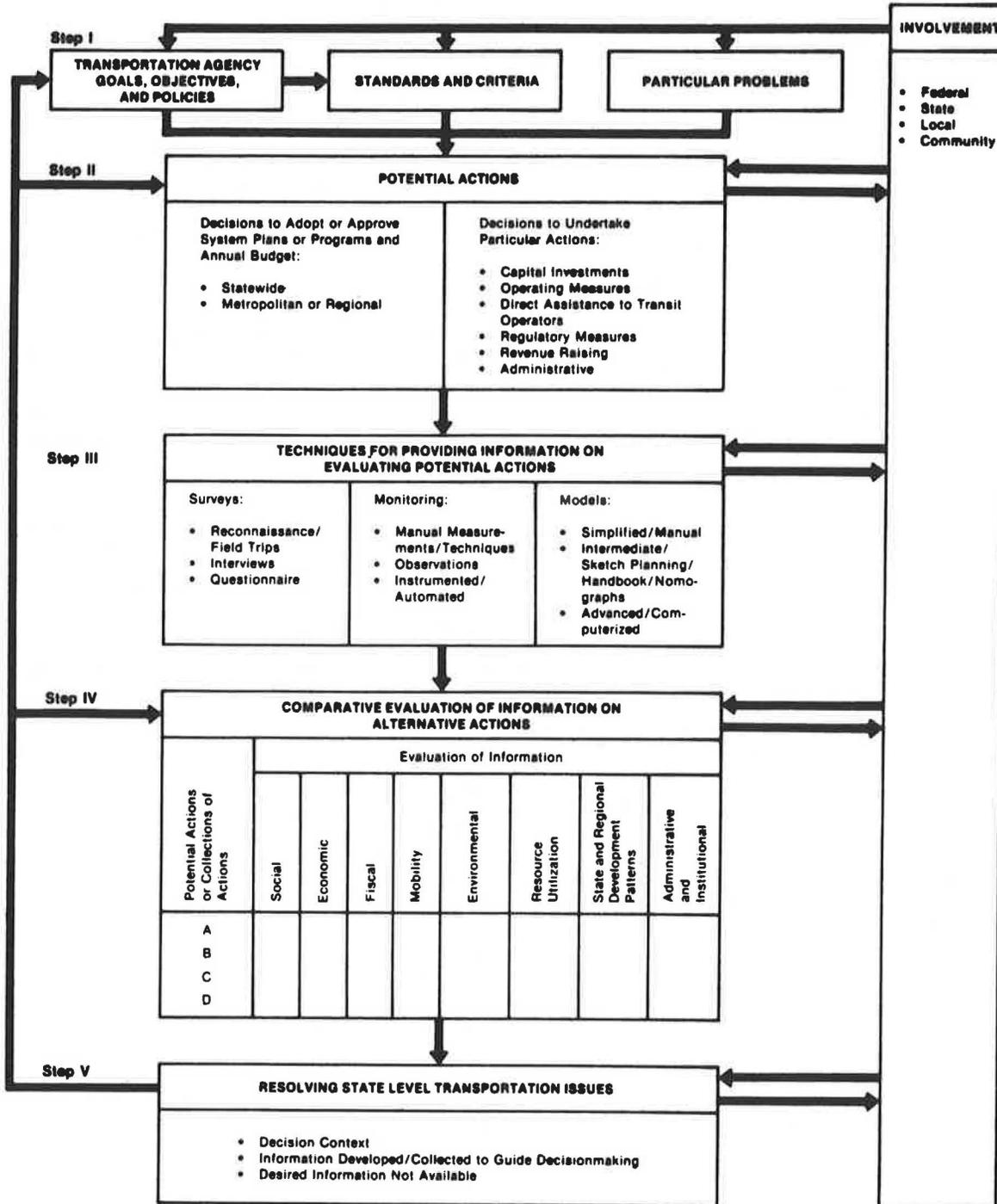
Table 1. Evaluation of alternative priority programming tools.

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

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

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

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

The NCHRP criteria were that the selected procedure should have

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

Evaluation Results

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

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

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

pability, and system relationships.

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

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

APPLICATION OF THE PRIORITY PROGRAMMING SYSTEM TO MARYLAND TEST CASE

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

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

These steps are described below. Caveats are noted.

Step 1: Development of Annotated Manual

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

Step 2: Development and Coding of Test Case

The input variables and project information were obtained from codification of 26 highway projects located in urban and rural areas throughout the state. This codification was critical to the analysis. Care was exercised to ensure that other highways related to the project were linked into the project description. This is the place where knowledge of the proj-
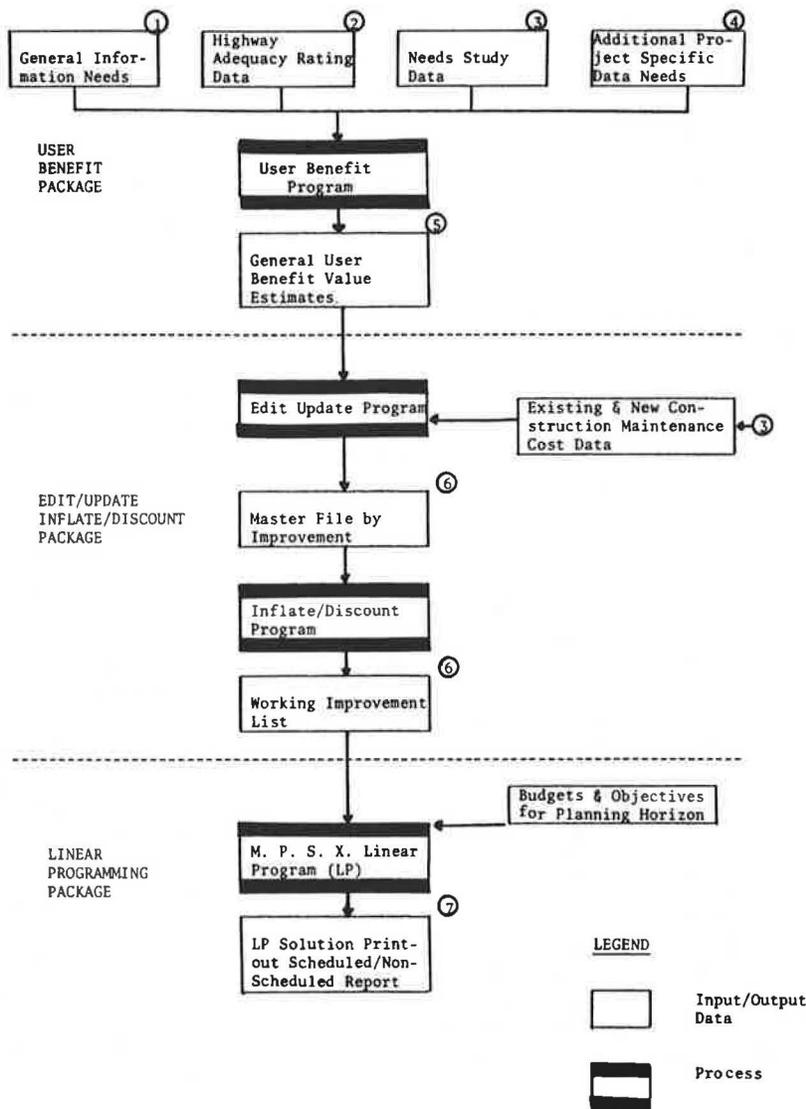
Figure 2. General information flow for PPS.

Table 2. PPS information requirements and output.

Inputs

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

[a]Needed only for urban projects.

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

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

The data related to each project set were avail-

able in urban areas through the continuing coordinated comprehensive (3C) process and in rural areas through sketch-planning-type processes.

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

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

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

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

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

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

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

Figure 3. Comparison of cumulative benefits and costs: Maryland test case.
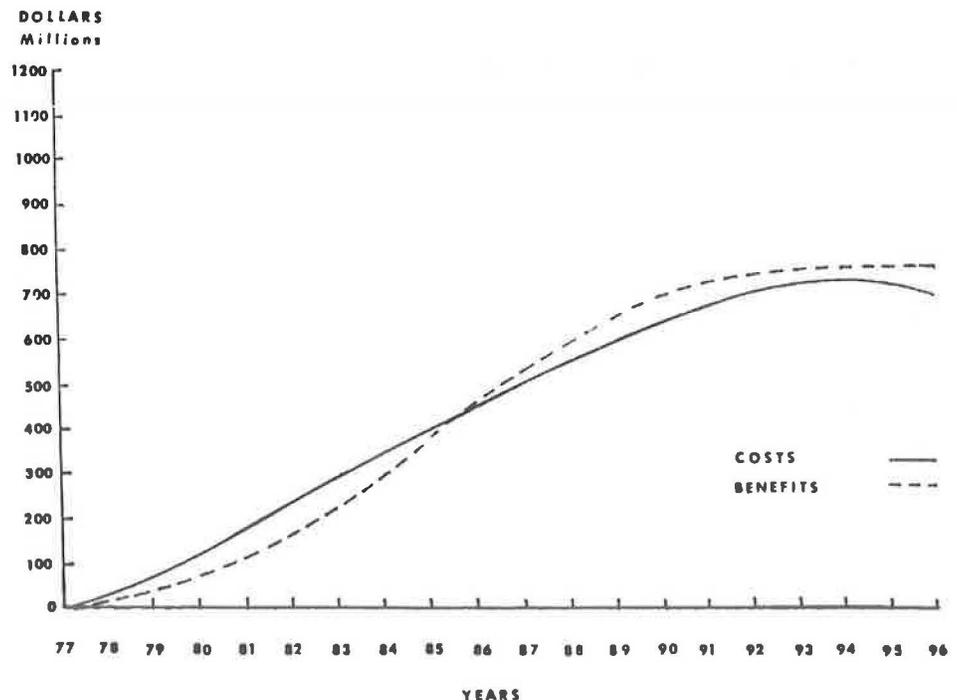
differently than environmental efforts in more urban areas where social and economic effects may be weighed higher than the physical environment. Therefore, projects entering the programming cycle were assumed to have already considered SEE effects to the point where costs to mitigate negative SEE impacts were determined.

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

differences in the determination of priorities. Because of this, the Ontario MTC has dropped SEE effects in their determination of priorities of highway projects.

Step 3: Installation of PPS on MDOT Computer

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

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

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

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

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

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

Step 4: Analysis and Interpretation of Results

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

Figure 3 illustrates the cumulative project benefits versus the project costs and shows that (a) the cumulative project costs are within the $0.8 billion budget constraint and (b) between 1985 and 1986, the benefits begin to exceed the cumulative costs. Table 4 shows the priority schedule for the projects and

how the PPS can be used to determine which of several projects should be started first to optimize the user benefits over time. This table also indicates a spending pattern that is at variance with the previously developed consolidated transportation program (CTP). The comparison indicates that, in light of budget constraints, the CTP 5-year program should be extended to a more realistic 10-year program.

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

IMPLICATIONS TO STATEWIDE DECISION MAKING

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

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

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

Table 5. Ranking of projects: Maryland test case.

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

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

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

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

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

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

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

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

SUGGESTIONS FOR FURTHER RESEARCH

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

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

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

many other possible applications of benefit-cost analysis and linear programming in transportation decision making.

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Financial Analysis Methodology for Regional Rapid Transit System Development

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In planning large-scale transportation improvement projects, local, state, and federal governments all insist that a major consideration be the establishment of the financial workability of the proposed project. The financial commitments involved in such projects extend over long periods of time and can potentially impose untenable financial burdens on a community. It is therefore imperative that the financial requirements be identified early in the planning process. This requires an analysis over time of capital costs, operating and maintenance costs, revenues, and funds from local, state, and federal sources. Through such an analysis, the financial impact of various design parameters and policies, such as fare structures and levels, can be identified and evaluated.

The computerized financial model described in this paper was developed for the metropolitan Dade County transportation improvement program--stage 1: rapid transit system. The costs presented here are for stage 1 (alternative), a 34.5-km (21.5-mile) conventional rail system. The financial model is being used in planning for the Dade County combined bus-rail transit system.

This financial (or cash-flow) model was developed and is being used to assist in the financial analysis of various design parameters and alternatives and in the evaluation of policy decisions. The model provides a yearly analysis of capital-cost and operating-cost expenditures, capital-funding and operating-funding sources, operating revenues, and other funding sources. It also calculates the annual net cash flow and determines the extent of additional funding required.

MODEL LOGIC

As currently implemented, the cash-flow (or financial-planning) model can be conveniently conceived as divided into six component parts:

1. Capital cost,
2. Operating cost,
3. Capital funding,
4. Operating revenue (especially fare-box revenue),
5. Operating funding, and
6. General funding.

First, consider the interrelationships among these component parts. Capital costs must be input to capital-funding computations because many capital funds are computed as a percentage of capital costs. Similarly, both operating costs and operating revenues should be input to operating-funding computations because, in particular, funds available under section 5 of the Urban Mass Transportation Administration (UMTA) Act of 1964 cannot exceed half the operating deficit. Finally, capital-funding computations and operating-funding computations must be input to general-funding computations. There, general funds (not specifically designated for capital or operating costs) are applied toward any remaining capital costs not met by capital funding plus any remaining oper-

ating costs not met by operating funding. These interrelationships are indicated in the flow chart of Figure 1.

Next, consider the sequence of actions within the capital-cost component. Data for the rail construction and procurement activities are input. For each activity, a class code, the duration of the activity, the escalation rate, and the base cost are input. The class code denotes the activity as belonging to one of several main classes that are output by the cash-flow model: right-of-way, rail fixed facilities, rail vehicles, or engineering and management costs.

The base cost of a rail activity is spread uniformly over its duration (in months) and escalated on a monthly basis. The monthly activity costs are then accumulated into yearly activity costs that are in turn accumulated into yearly costs for the output classes.

Data for bus capital costs are also input. These data include an initial schedule of purchases of new buses, a schedule of replacement purchases for existing buses, a growth rate for the bus fleet after the initial schedule, and the base cost of an individual bus. Additional data are the schedule of bus-garage construction costs in base-year dollars and escalation factors for bus costs. It is assumed that buses bought during the analysis time period will be replaced after 12 years. With this information, the base-year-dollar costs of buses can be computed and escalated on a yearly basis.

The rail and bus capital costs, as computed above, and the county expenses (a schedule of which is input) are output in a capital-cost table.

The operating-cost component is next considered. Initial schedules of base-year-dollar operating costs are input for both bus and rail systems. By using growth rates for the operating costs after the initial schedule, the schedule over the entire analysis time period can be completed. Appropriate factors are input to divide the total operating costs for bus and rail into the components of (a) transportation operations, (b) power, (c) maintenance, and (d) general and administration. These operating-cost components can then be escalated at possibly different rates.

Next, consider the capital-funding component. The total capital cost, bus capital costs, and any costs that are assumed will receive highway funds are introduced from the capital-cost computations. If there are highway-fundable costs, these will be met 70 percent from federal highway funds and 30 percent from state highway funds. The funds available under section 3 of the UMTA act are then computed as 80 percent of the total capital cost minus the highway-fundable costs. The state will contribute 10 percent of the amount of the total capital cost minus the highway-fundable costs. An attempt will be made to meet the remaining capital costs not covered by the federal and local contribution by the sale of general obligation bonds. If the remaining bond capacity is exceeded, the excess is labeled additional capital funding needed.

Next, consider the operating-revenue component.

Figure 1. Financial planning model.
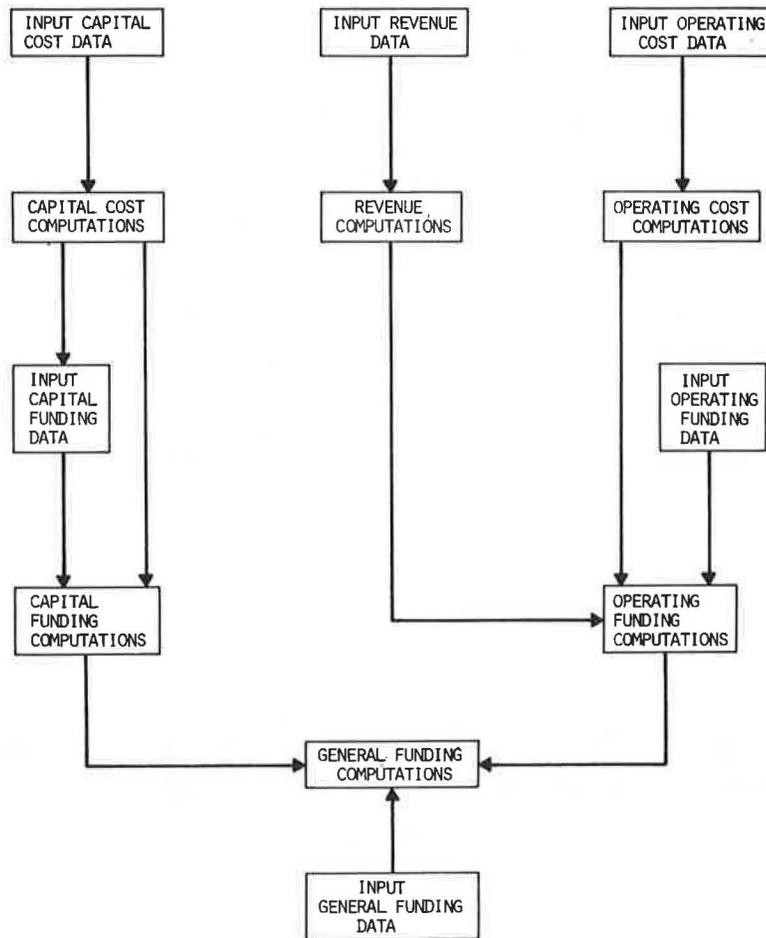
The inputs for this component include (a) nonstudent revenue patronage for the years 1977 and 1985, (b) initial student patronage and a growth factor for the time period after the initial schedule, (c) a revenue-distance schedule interpolated between 1977 and 1985 and projected by a growth factor thereafter, (d) a schedule of average regular fares (not reduced), (e) a schedule of perceived automobile cost per unit distance, (f) a schedule of elderly-fare riders as a percentage of total ridership, and (g) the Dade County population growth by year.

The 1985 revenue patronage is first factored to the same basis of fare and automobile cost as the 1977 patronage and then has the population growth from 1977 to 1985 factored out. A passenger-per-unit-distance factor to be applied between 1977 and 1985 is derived from the 1977 patronage, the twice-factored 1985 patronage, and the 1977 and 1985 revenue distances. An unadjusted patronage schedule is then projected from the revenue-distance schedule, the 1977-to-85 passenger-per-unit-distance factor, and a post-1985 passenger-per-unit-distance factor. This unadjusted patronage schedule is multiplied by appropriate yearly factors to adjust for fare, automobile cost, and population growth. The next step in the fare-box-revenue computation sequence is to compute the number of elderly-fare passengers as a percentage of the nonstudent passengers. The fare-box revenue is computed by using half-fare for students and elderly passengers and full average regular fare for the remaining passengers. The information from these computations is output in a fare-box-revenue table. Other operating revenues (e.g., station parking, value capture, and advertis-

ing) are introduced to be output in the operating-revenue table (a subtable of operating funding).

Now, attention is focused on the operating-funding component. A schedule of UMTA section 5 funds is input, and the total operating cost and operating revenues are introduced from the previous computations. Available section 5 funds are section 5 funds allocated for a given year plus any that were not used in the previous year. Used section 5 funds for the year are the smaller of the available section 5 funds and 50 percent of the operating deficit. The additional operating funding needed is then the part of the operating deficit not covered by used section 5 funds.

Finally, consider the last component, general funding. Here, schedules of transit-designated revenues, particularly taxes, that are not restricted either to capital or to operating costs are input. From the capital-funding computations, additional capital-funding requirements are introduced. From the operating-funding computations, additional operating-funding requirements are likewise introduced. The annual net cash flow is then computed for a given year as the total of the general revenues minus the additional capital-funding requirements. The actual financial situation for the year is obtained by adding to the annual net cash flow any cash remaining from the previous year and the interest accrued.

MODEL OUTPUT

The output format of the computer model consists of six tables corresponding to the six component parts

discussed above. For each year of the time span chosen, the cash flows corresponding to the column headings in each table are given.

USE OF RESULTS OF CASH-FLOW MODEL

The results of the cash-flow analyses are being used in the short-, intermediate-, and long-range budgeting processes of the Dade County Metropolitan Transit Agency (the present bus operator) and the Dade County Office of Transportation Administration. The operator is working interactively in the fiscal planning process and the development of the short-range operating budget. The transportation overview function in Dade County (the Office of Transportation Administration) is using the results in financial planning and programming and in the development of the county strategy for securing legislative support for bus and rail transit development. Based on these analy-

ses, a number of fiscal programming strategies have been considered and rejected and a course of action for the Dade County Board of Commissioners relative to deficit management has been and continues to be explored. The fiscal impact of delay and other construction staging decisions have been explored by using this planning tool.

Abridgment
Maryland's Primary Highway System: Criteria, Policies, and Financial Considerations

Robert P. Brodesky and Isaac Shafran, Maryland Department of Transportation

The state highway system in Maryland, like that in most states, has evolved over the years. Additions to the system are continually being proposed, but no specific criteria for additions or deletions have been developed.

In 1972, the state legislature required the designation of a state primary highway system and, in July 1972, the Maryland Department of Transportation (MDOT) adopted such a system, in accordance with this state law. However, the legislation does not define a primary highway and provides no substantive guidance.

In mid-1976, in preparing a statewide transportation plan, MDOT initiated an analysis of the primary highway system to develop departmental criteria and policies for system designation and development. This analysis included a review of the adopted primary system; the development of objective, consistent system guidelines; and a strategy for system development recognizing limited resources. This paper describes this analysis and its results to date.

ANALYSIS OF PRIMARY HIGHWAY CORRIDORS
AND DEVELOPMENT OF CRITERIA FOR
SYSTEM DESIGNATION

System Objectives

From the beginning, the study found that the objectives of the state primary highway system are similar to those of the national Interstate system. They were defined as

1. The provision of direct routes for major interstate and interregional traffic flows;
2. The connection of major urban areas and traffic generators;
3. The concentration of long-distance, high-volume travel on a limited high-level-of-service system;

4. The support of statewide developmental objectives; and
5. The concentration of funds on needed major highway facilities that serve interregional travel flows.

These objectives established the framework by which roadways and corridors of primary statewide importance could be identified.

Corridor Analysis

Based on these objectives, the primary highway corridor service to centers of economic activity, land use, population, and other major trip generators were analyzed. This resulted in overlays of areas that had population centers of more than 10 000 persons, employment centers of more than 2000 persons, major recreational centers, major transportation terminals, military installations, and national and state parks on maps showing the existing primary system. The series of overlays was an effective illustration of the number of times the links in the system connected activity centers of statewide interest. There were links that appeared to be nonessential and others that were identified as possible additions.

A similar analysis was conducted by using traffic-service information and developed overlays of average daily traffic, percentage of truck traffic, level of service, and access control. The traffic-service information was then used to identify those corridors serving high-volume, long-distance travel. This analysis led to the conclusion that several of the routes in the previously adopted primary highway system were lower volume routes (less than 5000 average daily traffic) and candidates for deletion from the system.

Table 1. Available funding for Interstate and primary highways.

| Nature of Revenue Estimate | Available Funding (millions of constant 1976 $) | | | | | | |
| | Interstate | | Primary | | Total | | |
	State	Federal	State	Federal	State	Federal	Total
Low or conservative	10	90	34	79	44	169	213
High or optimistic	60	540	1170	217	1230	757	1987
Constant purchasing power	60	540	1418	217	1478	757	2235

System Criteria

The analyses of traffic generators and traffic-service information were then compared to the Maryland functional classification system. (This classification system is based on the federal system although it also includes an intermediate-arterial category.) It was concluded that the state functional classification system is a good expression of the service provided by various facilities to land use and economic activity; thus, this system was used as the base from which to develop the criteria for primary highway system designation.

The use of the functional classification system had another benefit. County staff and elected officials in the state had already reviewed and concurred with the revised federal functional classification (approved July 1, 1976, as part of the federal-aid system realignment), which closely relates to the state network.

Thus, the following criteria for designation of the system were developed.

1. Limit the system to 5 percent of the total of state, county, and municipal highways and roads. This percentage is just slightly greater than the maximum allowance for principal arterials in the federal functional classification system.

2. Include all principal arterials (except Interstate highways) on the year 2000 state functional classification maps (legally, Interstate highways are not part of the primary highway system in Maryland, but the analysis described in this paper also included them): (a) connect population centers of 5000-25 000 persons, which are considered to be served when the highway passes within 8 km (5 miles) of the central business district; (b) emphasize direct through travel between population centers; and (c) serve long trips and the high-volume traffic typical of substantial interregional or interstate travel [that is, trip lengths greater than 40 km (25 miles) and traffic volumes greater than 17 000 vehicles/d in rural areas and 55 000 vehicles/d in urban areas].

3. Include those intermediate arterials of major importance: (a) connect population centers of 5000-25 000 persons, which are considered to be served when the highway passes within 8 km of the central business district; (b) connect the major highway corridors in adjacent states; and (c) provide connections between the Maryland portions of the main Northeast Corridor routes.

Revised System

A revised primary highway system that uses the above criteria was prepared. Generally, this system includes most of the elements of the 1972 adopted system, but it reflects a number of significant deletions. Roadways that parallel other primary system elements that carry more interregional traffic or represent more recent major investments in physical improvement (or both) were deleted. In addition, some elements of the original primary system were recommended for deletion from the revised system based on a determination that their traffic-carrying function was primarily local rather than of statewide importance.

The revised system was compared with the 1972 system on a regional level. The total length of the system was reduced by 298 km (186 miles), the percentage of the primary highways was reduced from 5.5 to 4.9, and the systemwide vehicle travel did not change appreciably. The proposed primary system carries about 57 percent of the vehicle travel of the entire state road system. This is only 4 percent less than the previous system. A comparison of the length of the primary system as a percentage of the length of the total system by region indicated that the system coverage is adequate and within a reasonable distance of all areas of the state.

FINANCIAL CONSIDERATIONS

The study also compared the cost of implementing the primary highway system with the anticipated revenues. There were several steps to this part of the analysis. First, a range of total state revenues available for transportation purposes over the next 20 years were estimated based on the present revenue structures and institutional arrangements. This gave three funding levels that are referred to as the conservative, optimistic, and constant-purchasing-power alternatives (see below).

Nature of Revenue Estimate	State Monies Available to Trust Fund (1976-1996) (1976 constant $)	State Revenue Available for Construction ($)
Low or conservative, low rate of growth in variables affecting MDOT revenues	3.5 billion	0.8 billion
High or optimistic, high rate of growth in variables affecting MDOT revenues, represents most optimistic estimate based on existing revenue structure and three or four tax increases over 20-year period	5.0 billion	2.3 billion
Constant purchasing power, revenue requirement based on maintaining MDOT's recent purchasing power over 20-year period, requires significant increases in revenue	6.0 billion	3.3 billion

Estimates of federal aid (assuming a continuation of present federal-aid formulas, policies, and funding levels) were then developed (see Table 1). Reasonable funding levels for primary highways were developed, based on the total state and federal revenue estimates. Finally, these funding estimates were compared to the MDOT 5-year program.

Comparing the total costs of the primary highway projects in the MDOT 5-year program with the state and federal revenue estimates available for primary highways led to the following conclusions:

1. Under the low or conservative estimate, MDOT cannot complete all the projects in its approved 5-year program within 20 years without additional revenues. By this estimate, only 24 percent of the needed funds to implement all the major capital projects in the 5-year program would be available over

the 20-year period, and only about 10 percent of the funds needed to complete the programmed primary highway projects would be available.

2. Under the most optimistic assumptions of revenues available to MDOT, which includes three or four revenue increases, all projects in the 5-year program can be completed over the 20-year period. However, MDOT would not have the financial capability to initiate any additional major port, aviation, rail, highway, or transit projects within the next 20 years without cutting back on operating services or currently programmed capital projects. Furthermore, because of an anticipated shortfall in federal primary highway funds, about 75 percent of the primary highway funding would have to be provided entirely by the state; i.e., there would be no federal matching funds available for many of the primary highway projects.

3. Under the constant-purchasing-power revenue estimate, MDOT could expect to complete all of the programmed projects plus about $250 million worth of nonprogrammed primary highway projects. Again, all of the new projects would have to be entirely state funded, because all of the estimated federal aid available would have been used on programmed projects.

Comparing the costs to implement the 1972 system and the system proposed here with the estimates of anticipated revenues led to the following conclusions:

1. The proposed revisions to the primary highway system reduce the total costs to complete the system by $500 million.

2. All the critical highway needs (i.e., those needs perceived necessary today) under the proposed system could be met by assuming the most optimistic revenue estimate but, under the adopted system, about $300 million worth of critical needs would remain unmet.

3. Under the constant-purchasing-power revenue estimate, the total costs to implement the proposed primary highway system exceed the revenues that are anticipated to be available. Even assuming that non-Interstate federal aid would double, approximately one-sixth of all primary needs would remain unmet at the end of the 20-year period. Because of this situation, MDOT is considering access-control policies to preserve the traffic-carrying capacities and functions of the existing primary facilities.

SUMMARY AND CONCLUSION

Criteria for system designation and policies for system development have been proposed that recognize that the funding necessary to bring the entire system to freeway standards will not be available in the foreseeable future. Several estimates of state and federal revenues were developed, and it was concluded that (a) MDOT cannot complete all the primary projects in its approved 5-year program within 20 years without additional revenues and (b) even under the most optimistic estimate of revenues, the total cost to implement the primary highway system exceeds the revenues that are anticipated to be available.

Emphasis, therefore, has been placed on making better use of existing facilities, for example, by adding access controls where practical. In addition, several major freeways that were part of the long-range planned freeway system in Maryland were deleted from the primary highway system.

The proposed criteria for system designation will provide, for the first time, an objective process by which to consider suggested additions to the system. Thus far, only the primary system has been analyzed. As a next step, it is proposed to conduct a similar analysis and develop criteria for inclusion of facilities in the secondary system so that the entire state highway system can be rationalized.

ACKNOWLEDGMENT

Transportation Programming in Today's Rapidly Changing Fiscal Environment

Marshall F. Reed, Jr., Highway Users Federation, Washington, D.C.

Because of decreasing rates of revenue growth, increasing inflation, and growing maintenance and operating costs, revenues for transportation are insufficient to satisfy public expectations. This paper summarizes a discussion of how several states are altering the programming process to meet changing financial conditions. Maryland is emphasizing smaller, less costly highway projects, designing for current rather than future service needs, and planning more projects than can currently be funded. Texas, on the other hand, has embarked on an $11.8 billion 20-year highway construction program. Pennsylvania, concerned over abandonment of railroad branch lines, is providing subsidies for commuter rail lines. To allocate limited resources for airport development, Illinois has instituted a systematic project-selection process. At the local level, the New York Metropolitan Transportation Authority is putting heavy reliance on federal-aid funds. Uncertainty in these funds causes a problem in programming. In an effort to hold local subsidies down, capital funds have been used for transit operations.

Almost every major industrial state in the nation is facing a cost-revenue squeeze. The problem is related to three basic factors:

1. Decreasing rates of revenue growth;
2. Diminishing buying power because of inflation; and
3. Increasing maintenance and operating costs because of the aging of physical facilities, a backlog of maintenance and repair work, and high traffic volumes.

The impacts of this situation can be stated simply: For almost all modes of transportation, revenues are not sufficient to satisfy public expectations for system and service expansion. Furthermore, this cost-revenue squeeze has reduced improvement projects sharply rather than gradually.

This report summarizes a conference session that discussed this topic. Two of the five speakers presented state highway department approaches. One

speaker indicated the problems of planning and programming statewide railroad improvements. Another speaker discussed the programming of airport improvements, and the last speaker discussed mass transportation programming in a large metropolitan area.

MARYLAND STATE HIGHWAY PROGRAMMING

Frederick J. Goettemoeller of the Maryland Highway Department traced the problems in Maryland of construction programming in the 1973-1977 period.

Highway-user tax revenues, which are related to automobile travel, had been increasing rapidly until 1974, when there was an abrupt downturn, which was followed by a leveling in 1975 and an upturn in 1976 and 1977. Programmers who were attempting to make forecasts based on annual revenues were consistently wrong in their projections, thereby creating a credibility gap between highway officials and both citizens and legislators about construction projects to be included in annual programs. Rapidly increasing construction costs during this period compounded the problem of establishing realistic programs.

As a result of the experience, the Maryland Highway Department is now emphasizing smaller, less costly projects. This change was made because cancellation of small projects has less impact on the total construction program than does cancellation of larger, more expensive projects.

Also, Maryland is now programming projects that are needed for current traffic and deferring facilities that will be needed to satisfy future traffic. For example, some projects that require only two lanes now but will require four lanes in the future are being designed and built with two lanes and enough right-of-way to accommodate four lanes.

Furthermore, more projects are now being included in the program than are likely to be funded to be prepared for the possibility of increased travel and therefore more revenue than anticipated. This requires that preconstruction activities be completed on many projects that are not likely to be built during the construction period and also requires special care in explanations to legislators and the driving public.

In summary, an important objective of the Maryland programming process is to keep options open as long as possible. At the same time, extra effort is being made to be candid with the public and elected officials on the need for this flexibility.

TEXAS STATE HIGHWAY PROGRAMMING

Robert L. Lewis of the Highway Design Division of the Texas Department of Highways and Public Transportation explained how they are meeting financial problems.

First, the workforce was reduced from a staff of 18 000 persons in 1974 to 14 000 in 1975. Second, a special task group was organized that led to changes in design standards and project specifications and other changes to improve economy and efficiency.

However, most important was a comprehensive study of the construction program and finances, which found an $11.8 billion backlog of committed projects and only $1.9 billion of available state funds to meet these commitments over a 20-year time period.

In January 1977, the results of the study were presented to the Texas legislature in the form of alternative lists of projects based on alternative funding levels. The legislators were given the choice between cutting back the program in line with available funds or increasing the resources to expand the number of projects that could be completed. With close to unanimity, the legislature and governor authorized an immediate $200 million in catch-up

funds and, at the same time, established $700 million as the annual statutory base for state highway funds and provided for increasing this annual level based on a highway cost index.

To estimate the highway cost index, a highway fund forecasting model, termed HIFUND, was developed that estimates both highway revenues from all sources and highway costs on an annual basis for a 25-year future period.

RAILROAD PROGRAMMING

Edson L. Tennyson of the Pennsylvania Department of Transportation (PennDOT) explained that the statewide railroad system is largely controlled by the private railroad companies and the federal government. PennDOT is, however, concerned, because abandonment of branch lines may adversely affect Pennsylvania industry and citizens. Federal subsidy for the continuation of service on branch lines is available to the railroads and is related to the benefits of the service.

Because of the popularity of the 15 commuter rail lines in Pennsylvania and because the cost of commuter rail service is more than passenger fares will cover, Pennsylvania uses available federal and state aid to subsidize the railroads for continuation of commuter service.

AIRPORT PROGRAMMING

Harry Wolf of the Illinois Department of Transportation (IDOT) described the three-stage process used to develop their airport capital-improvement program. The types of improvements are (a) airport resurfacing; (b) construction of runways, taxiways, and aprons; (c) land acquisition; (d) automobile parking lot expansion; and (e) new airport construction. The three-stage systematic project-selection process is needed because airport capital needs are three times greater than available improvement resources.

In the first stage, IDOT determines the program objectives and defines what is to be accomplished during the program period.

In the second stage, IDOT establishes the relative priorities of the program objectives. For example, IDOT may choose as its first priority to preserve essential airports by resurfacing and replacing worn-out facilities or equipment. However, program priorities are established to preclude a situation in which the entire program emphasizes either construction or rehabilitation.

The third stage in the process is the development of project-selection standards. These are established to ensure that only those projects that can be implemented and that make the best use of available funds are included in the program. Threshold standards, in terms of aircraft use and other items, are established and used to eliminate low-priority projects.

URBAN MASS TRANSPORTATION PROGRAMMING

John Kaiser of the New York Metropolitan Transportation Authority (MTA) outlined the role of his organization in funding mass transportation service in the New York City metropolitan area. To place the MTA in perspective, Kaiser indicated that the buses, rail transit system, and commuter railroads serving the area carry 31 percent of the nation's total transit riders.

Two issues are of special importance to the programming of mass transportation capital improvements in the New York City area: federal funding options and the mixing of social and mobility objectives.

Federal funding is important because approximately

$220 million is available for transit construction or rehabilitation and because state and local governments need provide only 20 percent in matching funds to gain the federal support. However, the problem in programming is the uncertainty of the federal funds because, under federal law, these funds can be, and are being, diverted to system operation.

In their attempts to hold down both local subsidy of transit operations and fares, state and local officials have opted to use much of the available capital funds for transit operations. Because New York City has an old rail transit system, this diversion of capital resources and the deferment of capital rehabilitation may cause future problems in the reliability of the subway system.

The other MTA programming problem surrounds the issue of mixing objectives. Mass transportation is evolving into a social benefit for elderly and handicapped persons without added financial resources to cover the additional costs.

An example of a social program that has no special funding is New York City's half-fare program for the elderly. This program was enacted in 1969 without careful establishment of need. Basic to the enactment of the program was the assumption that twice as many elderly persons would use the system, thereby making the program a break-even financial proposition. However, in reality, the elderly are making only 27 percent more person-trips and, therefore, this program substantially increases the deficit of the system.

Also, new federal regulations require that, in the future, transit vehicles must accommodate wheelchairs (although there has not been a careful study of the needs of handicapped persons). Unless substantial public resources are made available to the MTA to meet this new social role, transit service to New Yorkers will deteriorate.

State and Federal Issues in Financing Highway Programs

Len Sherman, Cambridge Systematics, Cambridge, Massachusetts

Current and emerging issues in highway finance are summarized from both a state and a federal perspective. The highway revenue outlook is presented and contrasted with recent historical experience. Inflationary forces, particularly in the highway construction and maintenance sectors, and the projected revenue impacts of the Energy Policy and Conservation Act of 1975 are having a severe effect on the ability of the states to maintain and improve existing highway systems. The increasing constraints on state highway budgets raise several questions concerning future highway finance alternatives and the proper roles of federal and state governments. The problem of the inability of the existing federal-aid highway program to adapt to changes in the highway finance environment and shifting investment priorities is growing. More attention should be given to the link between highway investment policy objectives and the programs designed to implement these objectives.

By past standards, the revenue outlook for state highway departments is austere at best. After nearly two decades of rapid growth in highway programs following the inception of the Interstate system, the states now face the prospect of sharply reduced revenues in the wake of the Energy Policy and Conservation Act (EPCA) of 1975. The recently mandated nationwide 88.5-km/h (55-mph) speed limit and other legislation pending before Congress may also serve to erode state highway revenue bases. Although various forecasts differ somewhat (1,2,3,4), it is generally conceded that recent legislative actions will result in gasoline consumption levels in 1985 that are little or no higher than current levels despite a significant projected growth in vehicle travel (VT). Because gasoline tax receipts have traditionally contributed approximately three-fourths of state and federal highway revenues, the revenue impact of projected automotive fuel-economy improvements is a significant concern of highway officials at all levels of government.

The potential problems associated with projected decreases in the growth of highway revenues are compounded by inflation and the recent sharp increase in highway maintenance requirements. Inflation in particular has had a severe effect on the costs of construction, maintenance, and highway administration. As one example, the California Highway Commission on Problems of Financing Transportation has reported that, during the 8-year period between 1967 and 1975, the state highway-construction cost index increased by nearly 140 percent in contrast with the increase in the state consumer price index over the same period of only 63 percent. Nationwide, the figures are, if anything, more striking. The 1975 composite federal-aid highway construction index was more than double its 1967 level, although the nationwide consumer price index increased by little more than 50 percent over the 8-year period (5). Inflationary forces have been especially severe since the 1973 oil embargo. Petroleum cutbacks and increased oil-import costs have led to dramatic increases in the prices of the bituminous and asphaltic materials used in construction and maintenance. In fact, since 1973, the yearly increase in highway material costs in many states has been as high as 45 percent (6).

HISTORICAL PERSPECTIVE

Historically, the increase in construction and maintenance costs has not been accompanied by a commensurate increase in highway revenues, and this trend is likely to be exacerbated as new, more fuel-efficient automobiles enter the nation's vehicle fleet. Over the past 8 years, state highway motor-fuel tax revenues have grown by an annual nationwide average rate of 6.6 percent. Federal highway grant authorizations, another major source of revenue to the states, have grown even more slowly, at an annualized rate of only 4.4 percent [see below (7)].

Item	1967 Level (current year $000 000 000)	1975 Level (current year $000 000 000)	Annual Growth Rate (%)
State gasoline tax receipts	5.01	8.35	6.6
Federal highway grant authorizations	4.00	5.45	4.4
Composite index for highway construction	100	203.8	9.3

In contrast, the federal-aid highway construction index over this period has increased at an annual rate of more than 9 percent. Simply stated, the consequence of these trends is that total state highway revenues have decreased significantly in constant dollars over the past decade, as have total expenditures and expenditures per vehicle kilometer.

Unless this trend is reversed, the nation's highway system will decline from its present level of service, at least on selected routes. In fact, there are already signs that the states have been deferring needed maintenance on major federal-aid-system roads, bridges, and bridge decks. The Interstate system and its supporting structures have placed a major strain on state highway maintenance budgets. A large portion of that system was built in the 1960s under conditions in which the states were spending "10-cent dollars" for construction. Although the system was heavily subsidized, state funds devoted to Interstate construction still represented a sizable fraction of total yearly state highway department budgets as shown in Figure 1. In the mid-1960s, in fact, the state expenditures on the Interstate system exceeded their expenditures on the primary and secondary systems combined, although the latter systems were federally subsidized only on an equal-matching basis (8).

Roads and bridges built during the mid-1960s are now more than 10 years old. Large sections of roadway constructed during that era of unprecedented highway route expansion are in need of resurfacing and other maintenance operations. In retrospect, it appears now that many highway departments overcapitalized during the past decade. The legacy of that era is the soaring maintenance requirements facing state highway departments. Highways built with 10-cent dollars now must be maintained with unsubsidized 1970s dollars whose purchasing power is only a fraction of their earlier value.

A sampling of recent public statements by state highway officials reported in the weekly newsletter "From the State Capitals" in the spring of 1978 testifies to the severity of the fiscal dilemmas faced by the states and the resulting shifts in program emphases:

1. The Alabama Highway Department is in "serious trouble in the maintenance" of highways, according to a department engineer. At a meeting with the Birmingham Regional Planning Commission's Transportation Citizens Committee, the state highway official said that his department receives federal funds to build highways, but must rely on state and local funds to keep them up. "There is no maintenance picture at all except for state and local funds, and we can't

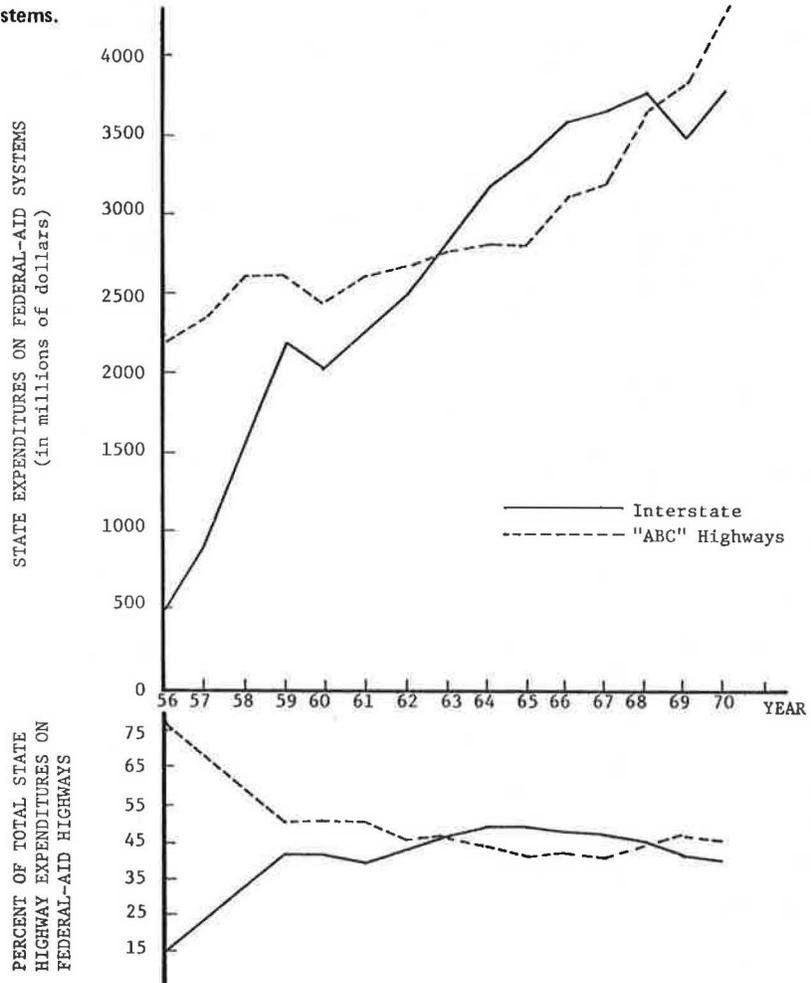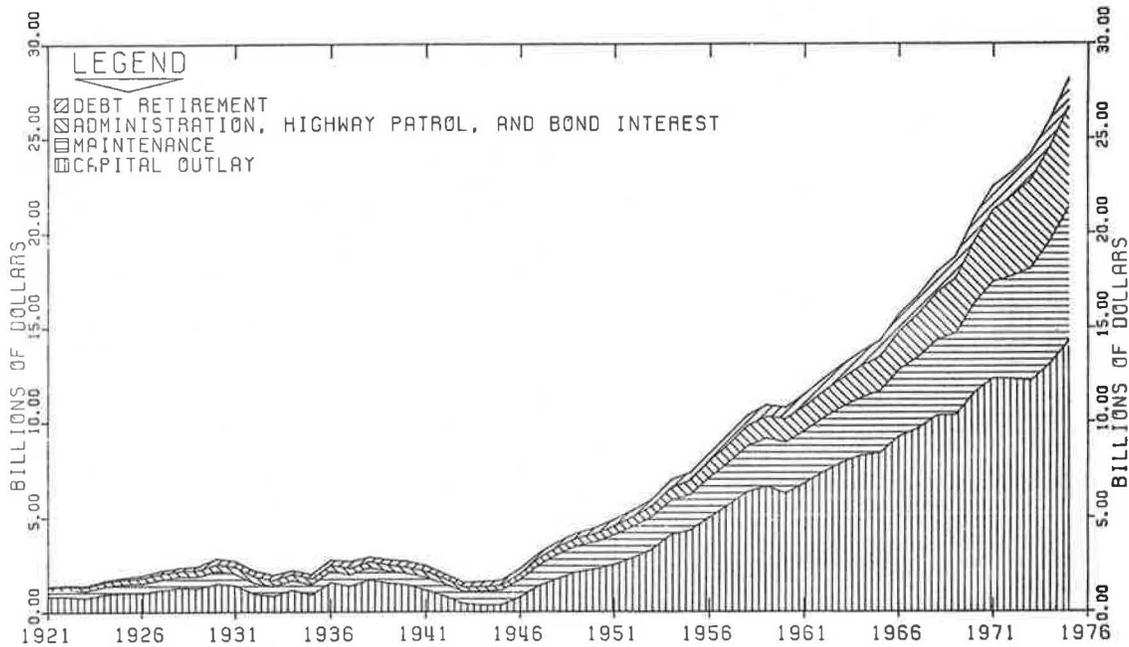**Figure 1. State expenditures on federal-aid systems.**

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Figure 2. Total disbursements for highways by function: 1921-1975.

do what we want to with that," he said, adding that the situation could be solved only by a tax increase. At present, the highway department can mow grass and clean up litter along roadsides only once a year because of the lack of funds.

2. More than $1.35 billion will be spent on highway and bridge construction in Minnesota between 1979 and 1985 under a plan proposed by the Minnesota Department of Transportation. The director of the transportation development division has said that the plan would shift the department priorities from building new highways to "fixing up the ones we have."

3. A Pennsylvania state legislative proposal for a $2 billion road and bridge program that could cost motorists $25/year more in gasoline taxes for the next 12 years was announced by the Southwestern Pennsylvania Regional Planning Commission at a press conference in Pittsburgh. The commission chairman declared, "I know people are sick and tired of taxes and hearing about our roads and bridges. But if we don't do something now, we might as well close up southwestern Pennsylvania and suffer the consequences."

4. Arizona state transportation officials have predicted that there will be a $2.4 billion deficit in the state highway users trust fund in 20 years, based on current revenue sources. The transportation officials presented to state legislative leaders a report that said, "It is obvious that, without an increase in revenue, Arizona's state, county, and city highways and streets will further deteriorate due to lack of maintenance and pavement preservation."

5. The Delaware Secretary of Transportation has said that gasoline tax revenues for highway improvements are needed to help keep the state from falling further behind on making road repairs estimated to cost $211 million. Attempting to have 2 cents of the gasoline tax designated for highway use, the secretary said that his office "is filled every week with requests from citizens, legislators, and personnel in the Delaware Department of Transportation for funds to repair and reconstruct roads."

6. More than $29 million worth of Rhode Island highway improvement projects will go or already have gone out to contract this year in a burst of construc-

tion that state officials say rivals the "boom times of freeway building" in the 1960s. The major difference, however, is that the money now is primarily for road maintenance and improvement, not for new construction. "The whole direction of road construction now is toward improving the existing highways," according to an assistant to the Rhode Island Transportation Director.

Despite continued heavy subsidization for capital expenditures, 1976 marked the first postwar year of the federal-aid highway program (FAHP) in which capital outlays for highways were less than half of total disbursements by all units of government (Figure 2). With the impending leveling off or decrease in state highway revenues (at least given the current tax structure) and the continued inflationary pressures on state highway department budgets, increasing attention is being given to realigning the provisions of the federal role in highway finance. Calls for relaxing the strictures on federal aid for maintenance have become more frequent, as have proposals for merging the highway trust fund with other transportation funds and general appropriations.

In fact, the Interstate highway trust fund is scheduled to end in 1979, and its renewal has been a major focus of the Carter Administration and the second session of the 95th U.S. Congress. Complicating the choices facing the Congress are the changing emphases of state highway programs, a series of administration and congressional proposals toward some form of a unified transportation trust fund, components of the administration's proposed energy bill affecting highway finance, and the projected leveling off of gasoline consumption that will significantly affect the principal source of income for the Interstate highway trust fund.

The shifts that will probably impact highway finance in the next few years at both the state and federal level point to the need to reconsider highway revenue forecasts. Although few planners could have foreseen the large increases in crude oil prices and the resulting reorientation of national priorities that led to EPCA and the administration's proposed national energy plan (NEP), it is by now obvious that

the previously used revenue-trend extrapolations are no longer relevant for current highway planning.

POLICIES AFFECTING FUTURE HIGHWAY REVENUES

Because the primary source of federal and state highway revenues is from taxes on motor fuel, any policy affecting highway fuel consumption will directly impact highway revenues. The federal government has taken several actions in the past few years that will significantly affect future highway revenue availability at both the state and federal levels.

By far the most significant of these is the passenger and light-truck fuel-economy standards mandated by EPCA. This act stipulates incremental improvements in automotive fuel economy through the 1985 model year, when each major automobile manufacturer will be required to meet a fleet sales-weighted average of 11.7 km/L (27.5 miles/gal). Light-truck and van fuel-economy standards have also been promulgated under rule-making authority granted by EPCA to the U.S. Secretary of Transportation. The latest published standards require 1981-model-year light trucks and vans of less than 3860 kg (8500 lb) gross vehicle mass rating (GVMR) to achieve an average of 7.7 km/L (18 miles/gal) for two-wheel drive models and 6.6 km/L (15.5 miles/gal) for vehicles that have four-wheel drive. To underscore the significance of these standards, it should be noted that the fuel economy of new domestic automobiles steadily declined in postwar years, to a low of 5.5 km/L (12.9 miles/gal) in 1974. Thus, the standards now in effect are requiring manufacturers to improve average automotive fuel economy by more than 110 percent in little more than a decade. The revenue impacts of these standards are significant and will be assessed below.

Although of lesser significance, there are several other energy conservation policies recently implemented by the federal government that will also reduce motor-vehicle fuel consumption. These policies include the national 88.5-km/h (55-mph) speed limit, the right-turn-on-red rule, and the voluntary truck and bus fuel-economy program.

The national 88.5-km/h speed limit was permanently enacted in early 1975. In the year following enactment, the Federal Highway Administration (FHWA) monitoring program determined that, although as many as three out of four vehicles violated the new speed limit in some states, nationwide, average highway speeds decreased by about 8 km/h (5 mph). The reduction in highway fuel consumption that can be attributed to the new speed limit has been estimated to be as high as 2.9 percent (3).

Adoption of the right-turn-on-red rule was urged by EPCA. Most states had already enacted this traffic regulation at the time of the passage of the act and, by mid-1978, the new law was in effect in all but one of the states. Allowing drivers to make right turns after coming to a complete stop at red lights reduces unnecessary idling time. However, the fuel savings (and hence the highway revenue impacts) that can be attributed to this regulation are extremely small, approximately 0.1 percent.

The third recent federal government action designed to reduce highway fuel consumption involves the voluntary truck and bus fuel-economy program initiated in 1975 by the U.S. Department of Transportation (DOT), the Federal Energy Administration, now part of the U.S. Department of Energy, and the Environmental Protection Agency. This program is designed to encourage manufacturers and users of commercial vehicles to voluntarily improve fuel economy through such actions as developing and offering more fuel-efficient products, conducting and reporting on fuel-economy tests, providing fuel-economy product information, advertising and training programs, and purchasing fuel-efficient new vehicles and add-on or replacement components. The program is concerned with trucks and buses that have a GVMR of 4550 kg (10 000 lb) or more and complements the EPCA provisions applicable to light trucks. An informal survey conducted by DOT indicates that fuel savings attributable to this program could be as high as 5 percent of total highway fuel consumption (3).

All of these measures are designed to reduce automobile and truck fuel-consumption rates. Unless there are compensating tax-rate increases, the net effect of these policies will be to reduce motor-fuel tax revenues. In the short run, consumers are direct beneficiaries. New automobile prices have traditionally increased more slowly than the consumer price index, and there is little evidence to suggest a significant shift in this price trend. Thus, in the years to come, consumers may be purchasing vehicles whose real acquisition and absolute operating costs are steadily declining.

In addition to legislation already in force, the administration has proposed a series of automobile-related proposals aimed at reducing 1985 gasoline consumption 10 percent below 1977 levels. Under the umbrella NEP published in April 1977, three specific proposals would have direct impacts on the size and composition of automobile and truck sales, vehicle use, fuel consumption, and (ultimately) highway revenues:

1. Graduated excise taxes on fuel-inefficient vehicles and rebates imposed on new automobiles and light trucks on the basis of their fuel economy: Although this policy would have no direct impact on federal revenues—it is designed so that tax revenues are wholly distributed as rebates—it provides a strong incentive for consumers to buy fuel-efficient vehicles. Its imposition would undoubtedly increase the sales-weighted fuel economy of new automobiles and light trucks and thus indirectly affect highway revenues.

2. Crude oil equalization taxes (COET) intended to bring world and domestic oil prices into parity by 1980: It has been estimated that imposition of this policy would cause a yearly 4 percent increase in the real price of gasoline at the pump through 1980, although tax adjustments thereafter would hold it constant. In the short term, this policy would reduce vehicle use somewhat as consumers responded to transient fuel-price increases.

3. Standby gasoline taxes of 1.1 cents/L (5 cents/gal) that accumulate for each year fuel consumption exceeds predetermined target levels: The administration's proposed consumption targets allow for slight increases through 1980, to be followed by relatively sharp decreases through 1985. Estimates vary somewhat, but it is generally conceded that these taxes would be triggered in 1982 at the earliest. As with COET, any revenues derived from the standby gasoline tax would be rebated to consumers. Thus, the major impact of this policy on highway finance would be its effect on vehicle use. Reductions in fuel consumption in response to higher gasoline prices would reduce the taxable base for revenue-generating state and federal gasoline taxes.

REVENUE IMPACTS: NATIONAL PERSPECTIVE

Although the consumer may be the short-term beneficiary of improved automotive fuel economy and other related measures, the longer term implications of the energy conservation policies described above concern the revenue impacts on federal and state governments and the resulting effects on highway construction and maintenance activity. A recent FHWA study (1)

Table 1. State gasoline tax revenues.

| | Revenue ($ millions) | | | | | |
| | High VT Forecast | | | Low VT Forecast | | |
Year	Neither EPCA nor NEP	EPCA but not NEP[a]	Both EPCA and NEP	Neither EPCA nor NEP	EPCA but not NEP[a]	Both EPCA and NEP
1977	8 408.0	8 183.2	8 183.2	8 286.3	8 065.2	8 065.2
1978	8 735.3	8 287.2	8 220.9	8 485.4	8 050.0	7 985.6
1979	9 077.1	8 356.0	8 202.3	8 690.3	8 000.0	7 852.8
1980	9 432.7	8 401.0	8 149.0	8 900.6	7 927.1	7 689.3
1981	9 803.3	8 412.0	8 129.4	9 117.1	7 823.2	7 560.3
1982	10 188.6	8 405.5	8 113.0	9 338.8	7 704.4	7 436.3
1983	10 589.1	8 435.1	8 141.6	9 566.1	7 620.2	7 355.0
1984	10 944.3	8 462.2	8 053.4	9 799.1	7 534.7	7 272.3
1985	11 438.8	8 488.4	7 939.0	10 038.1	7 449.0	7 189.8
Total	88 617.2	75 430.6	73 131.8	82 221.8	70 173.6	68 406.6

Note: Assumes no change in present state gasoline tax rates.
[a] Base case.

estimates that the revenue impacts may be extremely significant. The results of these analyses will be summarized below.

As a basis for comparing the impacts of the various proposals and existing legislation, the FHWA study simply assumed a baseline range of VT growth rates. Uncertainties about the future growth of travel and varying concepts of state reactions to offset the revenue effects of decreasing gasoline consumption make it difficult to decide on the most probable VT forecast. Thus, scenarios and options were developed to bracket the range of reasonable estimates of future fuel consumption, gasoline tax receipts, state revenue shortfalls, and the time at which the standby tax would be triggered.

The FHWA analysis was limited to changes in gasoline tax revenues even though the various policies may also affect the other highway revenue sources. Gasoline tax revenues were singled out because they are the focus of the energy conservation measures and because they are the predominant source of state and federal highway revenues. Also, it is not clear that EPCA and NEP will have a significant effect on nongasoline revenue sources (e.g., vehicle registration fees, drivers' licenses, and title fees).

The baseline travel forecasts were the basis for the projections of all other items. Two VT projections were made. The high forecast projects VT to maintain the same 4.1 percent annual growth rate experienced in the 1965-1975 period. The low forecast assumes a 2.6 percent annual growth rate that is more consistent with recent demographic trends and the approaching saturation of high-income automobile-ownership levels and driver licensing rates.

Table 1 summarizes the results of the FHWA analysis for three policy scenarios that represent revenue forecasts in the absence of both EPCA and NEP, in the presence of EPCA standards but not NEP, and in the presence of both. The first scenario assumes that average automotive fuel economy would remain at its 1976 level for the model years 1977-1985.

The most striking finding from the FHWA analysis is that, unless there are compensating tax increases, state highway revenues from motor-fuel taxation will decline significantly from historical levels, i.e., what could have been expected in the absence of the EPCA provisions. The cumulative change over the 9-year period 1977-1985 in state gasoline tax revenues that can be attributed to the EPCA standards is more than $12 billion under the low-growth scenario and $13 billion in the high-growth scenario. The addition of the NEP provisions would further reduce 9-year cumulative state revenues by $2.3 billion to

$3.1 billion, depending on VT growth.

Federal revenues show a corresponding decline under the provisions of EPCA and NEP. FHWA estimates that the EPCA provisions alone will reduce cumulative federal revenues over the period 1977-1985 by $6.3 billion in the low-growth scenario and nearly $7 billion in the high-growth scenario. The NEP provisions would add an additional $0.9 billion to $1.2 billion shortfall to cumulative federal revenues. For these projections, only revenues from the 0.9 cents/km (4 cents/gal) federal tax are considered. Although FHWA predicts that the standby gasoline tax would be triggered in 1984 and 1985 under the high-growth scenario and that COET would yield 1.8 cents/L (7.9 cents/gal) when fully implemented in 1980, NEP provisions call for full rebates of these tax revenues.

The impact of EPCA and the proposed NEP on the overall level of highway construction stems primarily from their effects on highway revenues, although the programs may also have an indirect inflationary impact on highway costs. The analyses described above found that the reduction in total state and federal gasoline revenues attributable to EPCA and NEP would be in the range of $21.0 billion to $23.6 billion in current dollars for the period 1977 through 1985.

Unless countervailing actions are taken, the revenue decrease may reduce cumulative highway capital expenditures by all levels of government by $10.2 billion to $11.4 billion in current dollars (or by about 14.5 to 16.7 percent), assuming that revenue reductions give rise to equal spending reductions and current capital-expenditure allocation trends continue. The exact amount of reduction is difficult to predict because it would depend on, among other things, the extent of state borrowings and the rate of obligation of available federal-aid funds.

Even if the states were to increase their gasoline tax rates at the same annual rate as in the 1970-1975 period, a prospect that appears dubious politically, total state highway revenues would still decrease substantially from historical growth rates. Specifically, if extrapolated state tax increases are assumed, state revenues under the EPCA provisions alone over the period 1977 to 1985 would decrease by an annual rate of approximately 1 percent. This is in contrast to a 6.6 percent annual increase in current dollar state gasoline tax receipts over the period 1967 to 1975. In fact, for the states to fully offset the effects of the EPCA standards, state gasoline tax rates would have to increase at twice the annual rate that took place in the 5 years preceding the passage of EPCA.

POLICY IMPLICATIONS

The increasing constraints on state highway budgets raise several questions concerning future highway-finance alternatives and the proper roles of federal and state governments. In one sense, the most important issue raised by recent and pending legislation involves a strictly political problem. The tax base of state highway departments is shrinking. To compensate for this, tax rates should be raised. Whether tax rate increases are imposed by individual states or by the federal government (and revenue transfers made to the states) at first glance seems to have more immediate political ramifications than economic.

For either federal or state governments, the justifications for a tax increase appear compelling. It has been argued that rates should be adjusted to maintain the same tax per vehicle kilometer of travel because, to a great extent, capital and maintenance cost requirements depend on road use. As vehicle fuel economy increases, tax rates must be adjusted upward to keep the rate per vehicle kilometer constant. Politically, this concept has proved hard to sell as

evidenced by the defeat in the U.S. House of Representatives of the proposal by Representative James Howard that the federal gasoline tax be increased 1.1 cents/L (5 cents/gal) and the inability of numerous states to pass gasoline-tax-increase legislation in the past few years. The problem, of course, is one of short-run perception. Although it may be true that, over several years (and presumably one or more changes in vehicle ownership), an individual may pay no more tax per vehicle kilometer of travel, at a given time when legislation is proposed, it is perceived simply as an unwanted tax increase affecting existing cars.

RESTRUCTURING FEDERAL-AID PROGRAM

Beyond the political issue of how the highway tax burden should be shared between federal and state governments, there are economic implications of the recent energy legislation that concern the effect of the federal-aid highway program on state highway expenditure behavior. Federal funding policies have their greatest effect when they are in a position to force state actions, i.e., in times of fiscal scarcity when states are highly dependent on federal aid. Given the realities of the current fiscal environment, it is becoming more and more likely that the states, in stretching their dwindling resources over various federal-aid programs, will undertake additional construction while current roads are undermaintained or initiate route reconstruction under the subsidized rehabilitation, reconstruction, and resurfacing program available under section 108 of the Federal-Aid Highway Act of 1976 rather than following a more economical, but unsubsidized, program of scheduled minor maintenance.

Until now, state fiscal resources have been sufficient for most of the categorical highway grants to have been allocationally equivalent to block grants. For example, consider the ABC program of subsidizing primary (A), secondary (B), and urban extension (C) roads that has been in existence for decades and had steadily growing federal authorization levels. In the decade between 1964 and 1973, federal ABC authorizations, available on a 50 percent matching basis, grew from $950 million to $1.225 billion. Over that same period, the states' own capital expenditures on the ABC systems grew from $2.063 billion to $3.578 billion. In other words, the states spent far more of their own funds on the ABC systems than the amount minimally required to secure the federal grants. A 1975 report analyzing these data (8) suggested that the categorical restrictions and matching provisions of the ABC program did not have a significant impact on the allocation of state funds and as such, speculated that the 1974 increase in the federal ABC share payable would not alter the state highway expenditure behavior. A more recent analysis of the FAHP (9) seem to bear these findings out. The state obligations of federal ABC funds actually declined relative to Interstate obligations over the period 1973-1975. This suggests that, even at the higher federal matching ratio, ABC grants still acted as a substitute for state funds rather than as a stimulation to greater state expenditures.

In light of these findings, it appears that past arguments for realigning matching ratios or consolidating categorical grant programs have, for the most part, been moot. By and large, we have had, except for the Interstate program, a block grant program of highway funding. These block grants have been disguised as categorical grants that have nonbinding provisions. Allocationally, there is no difference between a noncategorical $50 million block grant and a $50 million categorical grant for construction that a state would have undertaken in any event. In the

latter case, the categorical grant merely frees $50 million in state funds for other uses.

The emerging fiscal environment has changed this situation dramatically. Because of the onset of fiscal scarcity in the aftermath of the oil embargo and the increasing fuel economy of new automobile fleets, state officials have indicated that nonfederal programs are becoming the first casualty and state resources are increasingly being channeled to federal-aid systems to maximize capital activities (9). The FAHP, which in many respects has been operating as a block grant program, is now beginning to behave as a categorical grant program and have all the attendant allocational implications. Therefore, this is the time to reassess its structure with respect to its impact on highway expenditure activity.

CONCLUSIONS

Categorical programs have been a primary means of encouraging state and local governments to invest according to perceived national priorities. The appropriate degree of categorization is of current concern in considering the rebate of federal funds to the states. By assuming that the federal government accepts some obligation to compensate the states for EPCA-induced revenue reductions, Porter and others note that there appear to be two distinct strategies (9).

On the one hand, additional funds could be placed in the present or new categorical programs. On the other, funds could be made available in the form of block transportation grants (with or without changes in present categorical programs and revenue arrangements). Preliminary experience in opening the urban system and Interstate highway programs for transit use has not led to excessive transfer from highways. The extent to which one can generalize from this is unclear, but it suggests that block grant programs might be workable.

Ironically, at a time when maintenance requirements are at their highest level since the inception of the FAHP, categorical restrictions excluding maintenance subsidization are for the first time becoming binding. State highway officials have consistently argued against federal aid for maintenance, fearing excessive red tape and unwanted maintenance standards. However, federal aid for maintenance need not inherently have these faults. For example, if administered properly, an unconditional block grant applied toward maintenance could tend to equalize interstate fiscal strengths without interfering with state preferences among investment alternatives.

Federal objectives must be clear if effective programs are to be formulated in the new fiscal environment. As has been shown by Sherman (8) and Porter and others (9), for programs whose objective is to stimulate expenditures in new areas or expand expenditures under existing programs, categorical grants are most appropriate. Categorical restrictions ensure that funds are spent for the desired activities, and associated matching ratios ensure that localities who share in the national benefits of a highway system also share in its costs. If, on the other hand, the goal of a particular federal program is not to stimulate expenditures, it is presumably to assist a state or municipality in maintaining its transportation system by substituting federal funds for some portion of state or local funds (e.g., the operating assistance available under section 5 of the Urban Mass Transportation Act of 1964). Programs of this type involve issues primarily related to equity and distribution. Who pays for and who receives the benefits of transportation service? In this sense, choices among increased state taxes, increased federal aid, and federal rebates to the states are inherently

political in nature but, as has been noted, the choices made may have significant economic consequences as well.

What is urgently needed is a clearer definition of federal and state transportation investment goals. This paper has documented the change in the highway finance environment and the shift in highway program emphasis from route expansion to route maintenance. A growing problem arises from the inability of the existing federal-aid highway program to adapt to the changing highway investment environment.

Although the potential of FAHP to influence highway investment decisions has always been present, it has taken shrinking highway revenues to dramatize the issue. Now, because the important link between federal transportation policy and the characteristics of grant programs to implement that policy, a renewed effort is required to realign the provisions of FAHP.

The Interstate system is now largely in place, and the role of the federal government in highway finance is changing. For the past 2 decades, the federal government has played a dominant role in influencing highway capital investment, leaving route maintenance as a strictly state and local issue. However, it is problematic whether the growing inability of localities to maintain highways financed with federal funds can continue to be viewed as strictly a local issue.

Perhaps the most fundamental requirement for planning changes in FAHP is to explicitly address the link between policy and programs. Highway investment policies must be redefined in light of the current energy-conscious environment, and programs must be designed accordingly. Simplistic statements aimed directly at programs (e.g., equalizing matching ratios) are certain to continue the ad hoc development of FAHP. Certainly, matching ratios can be different for highway grant programs, but there must be a rational explicit reason related to the trade-offs between local and national investment benefits. Tradition notwithstanding, highway block grants do make sense if the main purpose of the grant program is distributive rather than allocative. Future debate in this area should recognize the critical link between policy objectives and the programs that implement policy.

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Review of Road Expenditures and Payments by Vehicle Class: 1956 to 1975

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The question of whether, over the past 20 years, the payments made by road users have been sufficient to match the expenditures made on their behalf for road systems is addressed. The results suggest that, in aggregate, payments by road users have not been sufficient to meet expenditures for roads. For urban roads, payments have more than met expenditures but, on rural roads, payments have been well below expenditures. An analysis of time trends suggests that these discrepancies have grown progressively. This analysis further suggests that, if different road users are considered separately, payments by light vehicles (automobiles and light trucks) and by medium vehicles (medium trucks and buses) have been much greater than the expenditures occasioned by each. It is shown that,

for heavy vehicles (heavy trucks), payments over the 20 years were significantly greater than occasioned expenditures only for urban roads. In recent years, however, payments by heavy vehicles on both rural and urban roads (and hence on all roads) have been greater than occasioned expenditures.

Highway financing and the relations between expenditures for and receipts from roads have long been important policy issues. Legislative history since 1950 suggests that the primary concern of the U.S. Congress has been to establish an equitable way of charging road users so as to generate the revenue needed to pay for the road program. The worth of road investments has always been taken for granted, but Congress has repeatedly implied that those who benefit from roads should pay their fair share in relation to the benefits derived from and the costs occasioned by them.

This paper summarizes a study (1) of the question of whether the expenditures for the road system and the different parts of it have been matched by the payments made by users of the roads. It thus addresses the issue of whether road users as a whole or different groups of users have paid their fair shares of the expenditures as intended by Congress. We concentrate on the costs occasioned, not the benefits received, thus implicitly accepting that the congressional judgment of the worth of road investments was correct. In a companion paper (2), we have addressed the question of what, if anything, should now be done to change the basis of road charges, assuming possibly different congressional intentions in the future.

The study on which this paper is based treats the problem of equitable treatment for road users in two ways. First, we make year-by-year comparisons, over the 1956-1975 period, of expenditures made on behalf of all road users with the payments made by them, for the system as a whole, for different types of roads, and for classes of road users. This type of analysis is not new (3,4); our intention is to make more careful, comprehensive, and up-to-date evaluations. Second, and as an alternative view, we discuss the question of whether road users as a whole and classes of users have received more favorable treatment than have other industries at large. This involves regarding road users as customers of an integrated industry that includes the provision and maintenance of roads. We investigate the accounting of expenditures for and payments made by users as if the industry comprised ordinary firms, using appropriate accounting conventions. The principal difference between this approach and the pay-as-you-go approach is that differences between payments and expenditures, if positive, yield returns to the suppliers of roads or, if negative, raise the need to finance deficits. This will be referred to as the roads-as-an-industry approach.

Consideration of different classes of users raises two kinds of problems--the definition of the vehicle classes and the identification of the expenditures and payments (or outlays and receipts in the case of the industry approach) with the classes. Because of the nature of road costs, these two problems are connected. As argued in the larger study (1), it proves impossible to uniquely identify expenditures with the particular vehicle classes we would like to distinguish. Accordingly, we analyze for alternative groupings. Our interest is in three vehicle classes that seem to be relevant in terms of congressional intent:

Class	Includes	Called
1	All automobiles and light trucks that have two axles and four tires (chiefly pickups and vans)	Light vehicles
2	Buses, single-unit trucks that have more than	Medium
	four tires, and truck combinations that have registered gross masses less than 23.6 Mg (50 000 lb)	vehicles
3	All heavy truck combinations that have registered gross masses of 23.6 Mg or more	Heavy vehicles

ANALYSIS PROCEDURES

Expenditures

All expenditures (capital outlays, maintenance, operation, and administration) on behalf of road users made by the federal, state, and local levels of government are included. The earlier studies account for only those so-called direct expenditures that are clearly earmarked for roads and for the operating costs of activities directly related to motor vehicle use. They exclude expenditures such as the proportion of state and local court system costs that are attributable to road users (e.g., traffic cases, and juvenile, civil, and criminal cases involving vehicle-related crimes such as automobile theft and drunken driving), local police department costs over and above those for the traffic police (e.g., the costs of general patrolmen, detectives, and other personnel who are not part of the traffic department, but spend some of their time enforcing traffic violations and road-related crimes such as automobile thefts and drunken driving), and a proportion of the state and local correctional institution costs of the state and local prosecution bureaucracy (e.g., district attorneys' offices). We have included estimates of these items in our expenditures.

Payments

All user payments are included--such as receipts from federal, state, and local road-user taxes that are conventionally earmarked as such. The earlier analyses included the following:

1. Federal excise taxes on the purchase of trucks and buses, gasoline and diesel fuels, tires, tubes, and tread rubber, lubricating oil, and parts and accessories and use taxes on trucks and buses;
2. State excise taxes on gasoline and diesel fuels, user taxes on heavy vehicles, vehicle registration, and miscellaneous charges; and
3. Local (municipal and county) parking fees, local fuel and other user charges, and miscellaneous imposts including fines.

In addition to these, we include the revenue from the federal excise tax on new automobile purchases (repealed in the fall of 1971), which was not earmarked for the highway trust fund, but nevertheless was a payment associated with the purchase of an automobile.

Certain payments are excluded because they give rise to an equal and offsetting expenditure and thus balance out of the accounts. Private parking and toll receipts are excluded because the expenditures on parking facilities and toll roads, which are assumed to offset these receipts, are excluded. Also excluded are private inputs to trip making such as time spent driving or truck drivers' wages.

Because we wish to follow the conventions for accounts in other industries as far as possible, two main sources of tax receipts--state and local sales taxes on motor vehicles and related purchases and local personal property taxes on motor vehicles--are excluded. Most inputs for other industries would not be subject to what are intended to be taxes on consumption. We, therefore, ignore these considerations in this analysis.

The operations of each year involving expenditures for maintenance, capital investment, and other items are regarded as being set alongside the payments by road users and representing receipts to the industry. A positive difference attracts a credit interest, and a negative difference requires an interest charge to finance the operations. We assume that both outlays and receipts are evenly spread over any year and the charge or credit is the interest on the annual balance.

The rate of interest we have selected is 5 percent. This could be argued. What is required for the industry analogy is the rate (net of inflation, already allowed for in the calculations) at which a comparable industry could borrow. The degree of risk should be similar. The road industry was, over the period, an obviously expanding industry of very low risk indeed. During most of the period, the prime rate for government bonds was a little less than 5 percent. If we allow for low but increasing inflation during the period and some premium for the assumed nongovernment, but low-risk, industry, 5 percent seems a reasonable approximation.

Expenditures Occasioned by Vehicle Classes

In attempting to identify expenditures associated with particular vehicle classes, we found that the smaller the class, the less it is possible to make an unequivocal statement on the issue. Even dividing users into only three classes, it is necessary to make alternative calculations. Thus, we present results for the following combinations of classes:

1. Light versus medium plus heavy vehicles and
2. Light and medium versus heavy vehicles.

We call expenditures identified with these classes occasioned expenditures. Expenditures that cannot be identified are called common.

Occasioned expenditures are based on an incremental approach. We begin with the idea of the provision of road services for a given vehicle class and then ask what is added to or subtracted from expenditures if other classes are permitted to use the roads or, alternatively, withdrawn. In principle, one can begin with any given class, which has its own demand for items such as route length, number of lanes, and structural strength, and consider the addition of another class that has different demands. We have, of course, no very good evidence to identify these demands, and so we have taken a rather arbitrary position. Our assumptions are given below.

We begin with the incremental expenditures associated with adding heavier vehicles to lighter ones. The latter, which are smaller and more maneuverable, can be provided with an adequately designed road for a relatively low cost per unit served. We first consider, given that a road system of the actual extent experienced was provided, the expenditures occasioned solely to serve heavier, wider, and higher and lower performance vehicle classes. This leads us to calculate

1. Structural-strength requirements,
2. Climbing-lane requirements,
3. Vertical-clearance requirements, and
4. Lane- and shoulder-width requirements.

This gives us an estimate of the savings possible if medium and heavy vehicles are excluded from the system. We assume that 3.05-m (10-ft) rather than 3.7-m (12-ft) lanes would have sufficed and 3.05-m rather than 4.3-m (14-ft) clearances. No attempt is made to estimate how extensive a system would have been de-

manded by the different classes of users.

It can also be argued (and will be below) that different vehicle classes cause different levels of pavement and shoulder damage. The relationship used to estimate pavement and shoulder maintenance and resurfacing expenditures by vehicle class makes these expenditures a function of axle loads and vehicle kilometers of travel by vehicle class. It is assumed that there are no common costs in this category of expenditures--that all relevant expenditures can be attributed to the respective vehicle classes.

An important element of uncertainty in calculating occasioned expenditures arises from the fact that, in the period under review, decisions about original capital construction and subsequent maintenance were taken in a rather arbitrary way. There was no attempt to optimize expenditures with respect to the factors involved. Indeed, essential elements providing the basis for such calculations only began to be available during the period--for example, the AASHO tests were not reported until the early 1960s. We cannot satisfactorily answer the question of what expenditures would have been avoided by prohibiting, for example, heavy vehicles from using the roads. It would have been possible to have selected weaker pavements and thus save capital costs. On the other hand, had an attempt been made to minimize full lifetime pavement costs, the conclusion might well have been that thicker pavements are preferable for all traffic because maintenance expenditures will be lower. This would have raised the proportion of common costs above what we have computed. We thus cannot settle the issues as to what would have been the appropriate occasioned capital and maintenance costs. The adjustments to the expenditures we have identified might have gone either way with respect to excluding a given vehicle class.

Other maintenance, administrative, safety, and law enforcement expenditures are regarded as overheads. Although there is some relationship between these costs and the extent and the use of the system (particularly items such as the costs of the equipment and bureaucracy required to enforce commercial vehicle weight laws), current data do not permit us to determine this relationship; thus, no parts of these expenditures can be shown to be occasioned by a particular vehicle class. This is not a severe problem, because these costs are a relatively small fraction of total program costs and any occasioned costs are smaller still.

In summary, the approach we use is to try to answer the question, For each of the industries (rural roads and urban roads) concerned, what was involved in expenditure terms in providing service for different kinds of customers? The service is not considered to be the best that could have been provided or the most desired; it simply happened to be how the industries were run over the time considered. As in accounting for past experiences in most industries, difficulties are encountered in assigning all expenditures to customer classes but some useful comparisons can nevertheless be made.

Structural-Strength Requirements

The structural-strength calculations for structures are based on those described in section 210 of the highway cost-allocation study (3), which developed structural cost increments for vehicles of different gross masses. That study found small differences between cost increments for different types of roads. Our three vehicle classes can be identified with corresponding mass limits, which enables us to identify the portion of total structural expenditures occasioned by heavy vehicles alone and by heavy plus medium vehicles. Current information does not enable

us to relate bridge maintenance costs with vehicle characteristics; thus, these were not assigned.

Climbing-Lane Requirements

We think that, to maintain service levels when vehicles with inferior performance are admitted to the roads, an industry would provide extra capacity. This applies to medium and heavy vehicles; they have poor maneuverability and are unable to sustain speeds on heavy grades. Had all vehicles been designed to perform as well as light vehicles, climbing lanes could have been avoided. Reductions in the number of lanes would, in principle, lead to savings in maintenance. However, we regard this latter item as negligibly small; there is no reflection of it when assessing maintenance.

Vertical-Clearance Requirements

So far as vertical clearance is concerned, the cost of grade separations and interchanges is governed by vertical height. Heights vary widely among types of vehicles, and the problem in assigning cost responsibility is one of judging sensible distinctions. We seem to be on reasonably safe ground only in distinguishing between our light vehicle class and the others. Thus, for example, buses, which are classified as medium, have more in common on this dimension with heavy vehicles than light. By using this distinction, the savings for 3.05-m rather than 4.3-m clearances was calculated, and this cost was assigned jointly to medium and heavy vehicles. This involved the following items:

1. Certain grading and drainage costs associated with construction of approaches to grade separation and of depressed road segments (because gentle approaches and smaller cross sections requiring less earthwork would have sufficed for light vehicles),
2. Certain right-of-way costs associated with depressed road segments (because a smaller cross section would have been required, resulting in a narrower right-of-way), and
3. Certain costs associated with grade separation and interchange structures (because shorter spans would have sufficed).

The significant expenditures associated with vertical clearance requirements, then, are those for constructing interchanges and grade separations because higher clearances necessitate longer and higher structures of these types.

Lane- and Shoulder-Width Requirements

If narrower lanes and shoulders had been built, some expenditures would have been avoided. Again, it is possible to distinguish only the impact of light vehicles and the others. This results in a modification of the actual 3.7-m lanes to the 3.05-m width that can accommodate vehicles of width 2.0 m (6.5 ft) as opposed to the 2.4-2.6 m (8-8.5 ft) of large trucks and buses. On parkways built exclusively for use by automobiles and other light vehicles, 3.05-m widths and shoulders 0.61 m (2 ft) narrower than elsewhere are common. These two differences occasion savings in the following capital expenditures:

1. Pavement and shoulder construction;
2. Grading and drainage;
3. Acquisition of right-of-way; and
4. Construction of structures, because all structures would have been narrower and grade separations and interchanges could have been built with shorter spans over the roadway.

The narrower lanes would have resulted in savings of about 16 percent in width, which implies a 16 percent reduction in structures, about 9 percent reduction in roadway width, and 5 percent in right-of-way width. The corresponding savings in costs are 16 percent of construction costs (because bids for construction are made in proportion to the surface area), 9 percent of grading and drainage costs, and 0 percent of right-of-way costs (because for rights-of-way, no significant impact would have been expected). On most of the rural and urban segments, the right-of-way widths are so large compared with the roadway width that there would be no savings at all. In dense parts of urban areas, up to 5 percent reduction in width might, in principle, be realized, but it is doubtful whether significant reductions in costs would have accrued.

When putting these estimates together to describe occasioned expenditures, two kinds of problems emerge: Each of the components has been estimated separately, which causes danger of double counting, and the smaller systems postulated imply differences in maintenance costs from those actually experienced. On the first issue, the procedure used is first to subtract the expenditures occasioned by climbing lanes (and resurfacing) from total capital outlay. The remaining expenditures can be identified as right-of-way, pavements and shoulders, grading and drainage, and structures. The differences in expenditures implied by each further element of saving (strength, vertical clearance, and width) are then expressed as percentages of these four categories. To estimate overall savings for each expenditure category, the three sets of individual percentages are multiplied together to form the final estimates. On the second, we were able to make no adjustments although, in principle, some small savings could have been realized, especially in maintenance attributed to heavy vehicles, because of the postulated smaller system they required. On the other hand, the narrower lanes and other reductions would have implied a smaller maintenance figure for light vehicles as well. The net effect of these omissions is to slightly bias the total occasioned costs against the heavier vehicles because, as shown below, maintenance is attributed primarily to them.

Maintenance and Resurfacing Expenditures

These are a considerably more important component of noncommon expenditures than are the capital costs. Our estimates are based on the AASHO tests of the early 1960s, subsequent laboratory studies, and reported field observations. These have generally indicated that heavier axle loads are responsible for a much more than proportionate amount of pavement damage. We measured the expenditures associated with maintaining serviceability over the period in question, identified with the maintenance and resurfacing expenditures defined above. The masses and distances run by the vehicle classes provide the basis for estimating the proportion of these expenditures to be assigned to each vehicle class. Pavement damage can be shown to be a function (greater than the fourth power, according to AASHO) of axle-load applications. This suggests that a causal and quantitative relationship exists between axle-load applications (axle kilometers of travel by various operating axle loads) and pavement damage or loss of serviceability. Thus, in principle, a function relating costs to pavement damage and axle kilometers of travel by different axle loadings can be established, and costs occasioned by vehicles that have various axle loads can be derived. [A more satisfactory way than this, in principle, to have answered the question of what maintenance expenditures were in fact occasioned by vehicle

classes would have been to sample actual experience--perhaps, for example, by relating expenditures for a cross section of roads to different vehicle mixes in a regression model. However, our inquiries showed no convincing empirical work of this kind and little prospect of satisfactorily fitting a current model without great expense (1).]

Maintenance accounted for $76 billion over the 20 years, or 27 percent of highway expenditures. It covered many kinds of operations--the repair of roadside drainage, of surfaces and bases, and of shoulders and structures, as well as traffic services and snow control. Pavement maintenance, the most important item, accounted for 40 percent of maintenance expenditures and varied considerably by road type. The heterogeneity of types of operations and their incidence argued in favor of separate treatments of the subcategories.

Examination of these activities shows that a number of them cannot be related to use of the roadway except insofar as the presence of the first vehicle on the road makes them all necessary. These include

1. Roadside and drainage--this consists primarily of mowing, seeding, and repair of the effects of erosion;
2. Snow control--this consists of plowing and salting;
3. Maintenance of structures--this consists primarily of painting and repair of the effects of weather and is not affected by use of structures by vehicles; and
4. Traffic services--this consists of signing, striping, and related operations.

To a very slight extent, ignored here, the cost of traffic services is affected by vehicle use in that use of the roadway by trucks requires the marking of truck routes, announcement of weighing stations, and so forth. No portion of these four cost items can be shown to have been occasioned uniquely by any particular vehicle class because they are equally necessary for all road users. This was, in fact, the approach adopted by the section 210 study.

Pavement and shoulder maintenance (including resurfacing) expenditures present more complex problems. Here, the indications are that different types of vehicles do cause different expenditures. In calculating them, we have to consider (a) the relationship between traffic, weather, and other forces and the physical deterioration of the pavement and (b) the relationship between the state of the pavement and the expenditures required for keeping up the road. The first has been the focus of most work to date.

The AASHO Road Test involved the construction of six test roadways and their subjection to repeated applications of six different types of vehicles. Careful measurement of pavement conditions was made, and all but the simplest maintenance activities were deferred until the pavement reached terminal serviceability and began to break up. Four important results emerged from analyses of these data:

1. The physical quality and structural soundness of a pavement decreases in proportion to the number of load applications to which it is subjected--each type of pavement can absorb some fixed number of load applications before failure;
2. For any given type of pavement, the number of load applications contained in its effective service life is inversely proportional to the mass of the load--service life decreases rapidly as vehicle masses increase;
3. The strength of a pavement, measured in terms of the number of load applications before failure,

increases rapidly as pavement thicknesses increase; and
4. For different types of pavements, the rate of deterioration is, of course, different, but the general shapes of the deterioration function and the relative amounts of damage done by different load applications are the same.

Thus, for any given type of vehicle, the trend of pavement deterioration can be predicted with considerable accuracy solely on the basis of the volume of traffic that the road has carried over its lifetime. Furthermore, pavement damage increases very rapidly as vehicle masses increase.

The implication of the stability of the shape of the deterioration curves derived from the AASHO test data is that the equivalent damage factors, as shown below (1 kN = 225 lbf), will remain approximately constant over a range of types and thicknesses of pavements that includes essentially all those in service today (5).

Axle Load (kN)	No. of 80-kN Loads That Cause Equivalent Amounts of Damage
8.9 (passenger automobile)	0.0002
8.9-35.6	0.006
35.6-71.0	0.18
71.0-89.0	1.00
89.0-107.0	2.35
107.0-133.5	5.80
133.5-151.5	12.00
151.5-169.0	20.00
169.0-196.0	33.00

In other words, regardless of the strength or weakness of the roadway, most of the pavement deterioration will be the responsibility of the heaviest vehicles. The values are such that this will be true even if these vehicles represent only a very small fraction of the traffic stream.

No piece of research conducted since the AASHO Road Test has directly addressed the same question on anything like the same scale. The test results have been adopted around the world and have stood up well under the test of time. But, although the empirical work relating road use to pavement damage has yielded clear, definitive results, the relationship between damage and maintenance expenditures is much more difficult to establish. Apparently, very little attention has been devoted to this problem. One is left to hypothesize about the nature of this relationship.

The assumption made in this study is that the relationship between pavement and shoulder maintenance expenditure and damage is a very simple one. In particular, it is assumed that these costs are directly proportional to pavement damage (although this assumption must remain tentative until more research is done). Such evidence as is available suggests that this is not an unreasonable assumption. Over the long run, maintenance expenditures seem to vary directly with damage.

The measure of damage used in the pavement and shoulder maintenance cost allocation is the sum of the products of total axle kilometers of travel on each class of road in each axle-load category times the equivalence factor for that axle load. These factors are similar to those given above, but were made to correspond more closely to the available axle-load data. These were calculated directly from the AASHO Road Test results as presented in the report of that study (6). Thus, pavement and shoulder maintenance expenditures by road class are allocated in propor-

Table 1. Total expenditures and payments: 1956-1975.

| | Amount ($ billion, current prices) | | | | | | | |
| | Pay-as-You-Go Approach | | | | Roads-as-an-Industry Approach | | | |
Type of Road	Expenditures[a]	User Payments[a]	Difference: Payments Minus Expenditures	Ratio of Expenditures to Payments	Outlays	Receipts[a]	Difference: Receipts Minus Outlays	Ratio of Outlays to Receipts
Rural	186.3	138.8	-47.5	1.34	211.8	144.3	-67.5	1.47
Urban	119.7	138.5	+18.8	0.86	128.7	158.2	+29.5	0.81
All	306.0	277.3	-28.7	1.10	340.5	302.5	-38.0	1.13

[a] Rural-urban breakdown based on splitting overhead expenses and yearly or one-time tax components between these roads in proportion to distribution of vehicle-kilometers of travel.

Table 2. Road expenditures and payments: 1956-1975.

| | Rural Roads | | Urban Roads | | All Roads | |
Year	Expenditures	Payments	Expenditures	Payments	Expenditures	Payments
1956	4 493	4051	2 628	3 438	7 121	7 489
1957	5 004	4486	3 008	3 790	8 012	8 276
1958	5 884	4363	3 492	3 713	9 376	8 077
1959	6 386	4951	3 785	4 158	10 171	9 109
1960	6 212	5140	3 854	4 303	10 066	9 443
1961	6 524	5459	4 189	4 625	10 713	10 084
1962	6 828	5970	4 471	5 000	11 299	10 970
1963	7 253	6422	4 690	5 310	11 943	11 731
1964	7 792	6909	4 976	5 677	12 768	12 586
1965	8 201	7087	5 192	6 101	13 393	13 188
1966	9 021	7069	5 711	6 370	14 732	13 439
1967	9 395	7214	6 096	6 780	15 491	13 994
1968	10 124	7749	6 578	7 578	16 702	15 327
1969	10 637	8409	6 868	8 532	17 505	16 940
1970	12 045	8467	7 751	9 079	19 796	17 545
1971	12 830	8866	8 579	9 974	21 409	18 840
1972	13 229	8244	8 819	9 811	22 048	18 054
1973	13 876	8757	9 017	10 920	22 893	19 678
1974	14 710	8890	9 473	10 909	24 183	19 799
1975	15 849	9456	10 321	11 571	26 170	21 027

Table 3. Payments and expenditures by vehicle class: 1956-1975.

| | Amount ($ billions, current prices) | | |
Item	Rural Roads	Urban Roads	All Roads
Light Versus Medium and Heavy Vehicles			
Payments			
Light vehicles	94.4	114.7	209.6
Medium and heavy vehicles	43.9	23.8	67.7
Expenditures			
Occasioned			
Light vehicles	0.5	0.3	0.8
Medium and heavy vehicles	43.4	18.7	62.1
Common	142.4	100.7	243.1
Light and Medium Versus Heavy Vehicles			
Payments			
Light and medium vehicles	119.7	129.9	250.6
Heavy vehicles	19.1	7.6	26.7
Expenditures			
Occasioned			
Light and medium vehicles	13.6	5.5	19.1
Heavy vehicles	20.3	6.3	26.6
Common			
All Vehicles			
Payments	138.8	138.5	277.3
Expenditures	186.3	119.7	306.0

Table 4. Payments and occasioned expenditures.

| | Amount ($ billions, current prices) | | | | | |
| | Rural Roads | | Urban Roads | | All Roads | |
Year	Occasioned Expenditures	Payments	Occasioned Expenditures	Payments	Occasioned Expenditures	Payments
Medium and Heavy Trucks and Buses						
1957	1.40	1.70	0.50	0.60	1.90	2.30
1964	2.10	2.05	0.90	0.95	3.00	3.00
1969	2.85	3.05	1.25	1.50	4.10	4.55
1975	4.15	3.90	1.60	2.10	5.75	6.00
Heavy Trucks						
1957	0.55	0.45	0.15	0.20	0.70	0.65
1964	0.95	0.80	0.35	0.30	1.30	1.10
1969	1.20	1.25	0.40	0.55	1.60	1.80
1975	1.80	1.95	0.50	0.90	2.30	2.85

tion to the equivalent axle kilometers traveled on
them. Differences in the age and construction stan-
dards of these road classes resulted in considerable
variation among them in expenditures per equivalent
axle kilometer.

The resulting pavement and shoulder maintenance
expenditure allocations assign a much higher fraction
to heavier vehicles than was the case in the section
210 study. The staff of that study considered an ap-
proach such as ours, but dismissed it because they
felt that automobiles and other light vehicles had a
negligible effect on pavement performance because the
road had been designed to very high standards in order
to carry heavy loads. A thin pavement designed for
and used by automobiles only would, they argued, re-
quire very nearly the same amount of maintenance as
the thick mixed-traffic pavement. Thus, the amount
of maintenance expenditures they charged exclusively
to heavy vehicles was the small difference between
the cost of the mixed road and the cost of an
automobile-only road. To charge heavy vehicles both
for construction costs and maintenance costs would,
they thought, constitute double counting. Whatever
the merit of this rationale, however, it reflects es-
sentially a different interest from ours. The section
210 study was concerned with what should be allocated
to different vehicle classes. We are concerned with
the determination of the costs actually occasioned by
different vehicle classes; thus, we can ignore the
difficult question of the determination of just what
an optimally designed pavement for differing vehicle
classes would look like and use the AASHO-based fig-
ures to represent our best estimate of what actually
occurred.

STUDY RESULTS

Road Users as a Whole

The results of the accounting for the road system as
a whole are shown in Table 1 (1). Congressional ob-
jectives to achieve a pay-as-you-go system were not

achieved for the roads as a whole; expenditures exceeded payments by $29 billion, or 10 percent. A sharp distinction exists, however, between rural roads and urban roads. Whereas payments exceeded expenditures for urban roads, expenditures were about one-third more than payments in the case of rural roads. Viewing the individual components of these totals, it seems fairly clear that this rural-urban contrast should be interpreted as a distinction of between-urban use and within-urban use, rather than a rural-dwellers versus town-dwellers contrast.

If one considers the trend of events over the 20-year period, a somewhat different picture emerges (Table 2) (1). When all urban roads are taken together, payments exceed expenditures throughout the period except for a few years in the late 1950s, when there was an approximate balance. However, payments were consistently below expenditures for all rural roads taken together, and this discrepancy grew with time. For all roads in aggregate, expenditures exceeded payments in all years except the mid-1950s and the early 1960s, when there was an approximate balance.

These contrasting trends over time underline the need to present the second approach--that of regarding the roads as an industry or industries. A private industry faced with a time lag of this sort between expenditures and receipts would be forced to borrow money to make up the difference. Interest charges on these loans are real costs, because they represent the opportunity cost of other types of output foregone. Application of the industry analogy to the road system requires the computation of the finance charges incurred because of the lag between receipts and expenditures and their addition to the expenditure accounts.

The results of viewing the roads in this way are also shown in Table 1. Comparing the results of the pay-as-you-go approach with those of the roads-as-an-industry approach shows that the contrast between road types is sharper in the latter approach. For roads as a whole, outlays exceed receipts by 13 percent, rather than 10 as before. The rural roads together appear worse, and the urban roads appear better when compared with the pay-as-you-go approach. For all three road categories, the imbalances tended to get cumulatively worse.

Individual Vehicle Classes

Here, we consider three user classes. Occasioned expenditures consist of those due to climbing lanes, structural strength, vertical clearance, and lane and shoulder widths and of those due to maintenance and resurfacing expenditures. Table 3 brings together the payments and expenditure data.

In discussing all road users, we saw that urban roads were distinguished from rural roads in that urban payments exceeded expenditures in total and in most years, whereas in the rural case, the opposite was true. From Table 3 it is clear that, because of the incidence of common costs that cannot be assigned to any one class, the picture changes greatly when direct attribution to users is attempted. Total payments for all road users greatly exceed occasioned expenditures. When vehicle classes are considered, lighter vehicles paid much more than they occasioned, especially for urban roads. For heavier vehicles, there is a much closer balance. Here, occasioned expenditures just exceeded payments for rural roads, but did not do so for urban. When heavy vehicles are grouped with medium trucks and buses, so that a greater proportion of expenditures can be attributed to the group as a whole, a rather different pattern emerges, in that payments now just exceed expenditures for rural roads and, for urban, payments exceed expenditures quite comfortably. Thus, the contrast between urban and rural roads is confirmed here, but it

is difficult unequivocally to assert that any vehicle class was not meeting its expenditures on a pay-as-you-go basis.

The closeness of the payments and occasioned-expenditures figures for the heavy and heavy-plus-medium categories again makes the time trend important. Table 4 compares payments and expenditures for 4 of the 20 years--1957, 1964, 1969, and 1975. For heavy and medium trucks and buses, payments in every case exceeded occasioned expenditures for urban roads and the difference tended to increase over time. There was a close and fluctuating balance for rural roads. For heavy trucks, the trend is fairly clear for both types of roads--an early position of deficit with respect to occasioned expenditures is reversed in later years, reflecting a shift in the taxation borne by that class.

As in the analysis of the road system as a whole, the discrepancies between occasioned expenditures and payments described above and their time trends can be picked up in the requirement for financing, year by year, in the industry approach. The discrepancies sharpen for this approach. The heavy-truck receipts are now clearly lower than the occasioned outlays for rural roads and for all roads taken together. For heavy and medium trucks and buses taken together, the receipts clearly exceed the occasioned outlays throughout the 20-year period for rural, urban, and all roads. For heavy trucks, the overall picture is quite similar to that for the pay-as-you-go approach except that, under the industry approach, the occasioned outlays on rural roads exceed receipts in all years except the last two. Thus, the trend toward a balance is apparent only over the past few years. When all roads are taken together, as for the pay-as-you-go approach, the heavy-truck occasioned outlays exceeded receipts during the earlier years before the picture was reversed. The only difference is that this changeover occurred later for the industry approach.

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Toward Rational Road-User Charges

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This paper considers how to set road-user taxes most efficiently within the constraint that user payments must cover road expenditures. The charges levied on different vehicle classes are required to cover at least the maintenance expenditures incurred because of use by those classes. Four policies for determining an extra charge or markup sufficient to balance the budget are evaluated—the vehicle-kilometer proposal, the ton-kilometer proposal, the imputed-gross-revenue proposal, and the inverse-elasticity proposal. For 1969, the vehicle-kilometer proposal suggests the least change from present policy, followed by the ton-kilometer, the imputed-gross-revenue, and the inverse-elasticity proposals respectively. The inverse-elasticity basis suggests especially higher payments from heavy vehicles than were collected. The inverse-elasticity proposal uses estimated responsiveness of demand to price changes to place heavier burdens where the reduction in use would be relatively less. The other three methods refer to various output measures for apportionments of tax burdens among vehicles. On the criterion of efficiency, the proposals are ranked inverse elasticity, imputed gross revenue, ton kilometer, and vehicle kilometer in descending order. However, on the criterion of availability and quality of information required and difficulty of implementation, the proposals are ranked in the opposite order. Consequently, the radical revision in payment structure suggested by the inverse-elasticity proposal should be regarded only as a desirable direction of change. Much more precise analysis would be necessary to suggest a detailed structure for tax revision.

A review of the legislative history of the federal-aid highway program suggests that one of the principal concerns of the U.S. Congress in providing for the financing of the program was with equity. It was deemed desirable that the road system should be paid for by its users and that each particular user should shoulder a fair share of the burden. In practice, the latter requirement was interpreted to mean that each user should pay enough to cover the costs occasioned by his or her use of the highway system. A number of studies were commissioned by Congress and by the U.S. Department of Transportation to measure these costs (1,2,3).

A recent reexamination of these issues has indicated that, for the road program as a whole, these concerns with equity have not been met (4). Payments by road users have fallen short of total road expenditures. For particular classes of users, however, the picture is different. All vehicle classes have paid enough to cover the costs occasioned by their use of the road system, although the difference between costs and payments has varied enormously from one class to another.

Some insight into the nature of this somewhat contradictory result may be gained by pursuing an analogy between the road system and an industry that must simultaneously serve the demands of several classes of customers. The decision that must be made is whether to provide separate facilities for each or to produce for all classes in combination. The crucial factor here is the relative costs of joint versus separate production.

For the road industry, the current cost advantage is strongly on the side of joint production. The road system in this country had its beginning long ago and was already highly developed by the post-World War II period. The length of roadways constructed since that time is very small in relation to what was then in existence. Separate provision for different vehicle classes in, say, 1956, would have entailed large expenditures to build new systems

of adequate coverage and quality. These would have greatly exceeded the payments made by any vehicle class. In the absence of a massive reallocation of tax responsibility, joint production of roads for the several vehicle classes must be considered beneficial to all.

Once the decision is made to produce jointly, the problem of assigning costs to the different classes of customers becomes very difficult. Under these circumstances, it is highly probable that much of the total cost will be common to all classes of users and impossible to assign in any but an arbitrary way.

This appears to be the case for the road system. In the study cited above, attempts were made to assign cost responsibility to various classes of road users. In none of the schemes considered were total occasioned expenditures more than about 25 percent of total program expenditures. The requirement that each vehicle class cover these occasioned expenditures says nothing about how the remaining 75 percent of costs (those that are common) might be met. Answering this question requires the introduction of additional criteria, either implicitly or explicitly.

This paper considers the question of what these criteria should be. Although some historical evidence is examined, the perspective is essentially forward looking. Several possible methods for meeting the requirement that payments match expenditures are considered. These methods suggest ways for revising user-charges policy.

FACTORS IN ROAD PLANNING

A rational scheme of road-user charges must take into account the technology and cost structure for providing road services. As far as possible, one would like information about how such costs are likely to vary with differences in vehicle type and frequency of use. Our investigations disclosed important gaps in knowledge of this relationship.

One major uncertainty concerns the relationship between maintenance and original capital outlay. Thicker pavements are more durable and require less subsequent maintenance. The AASHO Road Test (5,6) provided evidence of a strong relationship between initial construction standards and subsequent rates of pavement deterioration. Pavement strength was found to increase very rapidly with thickness—approximately in proportion to the seventh power (5,6,7). A small increment in its thickness can thus lead to a large increase in the durability of a pavement. From this technical point of view, the trade-off between inputs of maintenance resources and capital appears to favor a high proportion of the latter, at least under conditions of heavy axle loadings.

However, the AASHO tests provided little information about the effect of maintenance policy on pavement durability. Because their object was to test to destruction, very little maintenance was performed. This implied a rate of pavement deterioration faster than would have been experienced had regular and careful maintenance procedures been followed. Hence, we know very little about how maintenance policy influences the rate of pavement deterioration. The possibility of varying the level of maintenance provided affects the choice between initial and future inputs in a way that requires new clarification.

Determining the economic level of original capital inputs relative to maintenance activities is not simply

a matter of the technical relationships between use and wear. The relative prices of initial capital, preventive maintenance, and later reconstruction are also relevant. Regarding this point, we encountered a notable gap in the literature. First, although the AASHO tests have led to a better understanding of the relationship between highway traffic and pavement damage, the relationship between damage and the expenditures to repair it is still not clear. The record does not tell us how much of the money spent on highway maintenance has gone toward repairing damage caused by use versus how much was devoted to making good the different effects of weather, time, and other such factors. There are difficulties even in discriminating between expenditures that had an expansion component and those that did not.

Part of the answer to the question of economical construction standards depends on future trends in the real prices of inputs. Relative to original capital construction, maintenance is labor intensive. There is, of course, potential for increasing labor productivity in each form of activity, but it is clear that the relative labor intensity will remain. If labor becomes more expensive in real terms, maintenance will cost relatively more. How much, how fast, and for what kinds of maintenance and construction are open to questions.

We are thus, by these points, raising the general question of the optimal design of highways. Current road design procedures are based on the assumption of a finite expected lifetime. It is expected that traffic volumes and patterns as well as road service standards will change over time and that, after a number of years, it will usually be necessary to undertake major widening or reconstruction of the road regardless of the condition of the pavement. Given this, it is usually thought that the most efficient design procedure is to build the pavements strong enough, but no stronger than that, to last the required number of years--about 20. An examination of the trade-offs indicated might well lead to different and more variegated design standards. We suspect that, if these economic factors were to be taken explicitly into account and an attempt made to develop designs that minimize the total lifetime cost of the highway, the results would call for thicker pavements requiring less maintenance. This would increase the share of the total road costs that are common to all users.

Design decisions ultimately depend on traffic forecasts as well as cost trade-offs. The nature of the vehicles that use the roads is another question that must be considered. Several studies have emphasized the importance of axle loads in determining the pavement damage caused by a vehicle (5,6,7). A clear implication of this is that such damage can be greatly decreased by reducing the axle loads. Vehicles could be (and indeed are being) modified by the addition of axles to spread masses and reduce loadings for a given vehicle capacity. The effects of the heavy-vehicle fleet on highway pavements could be substantially altered in these ways. Policies to encourage use of vehicles that have better mass-transmission characteristics hold substantial promise as a means of reducing pavement damage and extending the lives of existing roads. These might involve, for example, encouragement of those toll highways that now charge by number of axles to set toll rates on a transmitted-mass basis instead. We could not find any satisfactory exploration of these possibilities despite their obvious relevance to debates about causation of expenditures.

These issues regarding the relationships between vehicle design and pavement damage and between damage and maintenance are all the more important given the changing pattern of highway expenditures. Capital expenditures have been declining as a proportion of total road expenditures since 1963 and in absolute

terms since 1968. In contrast, maintenance expenditures have risen steadily for the past 2 decades and, in the period of the 1970s, have come to absorb an increasingly large share of the total road budget. The opinion of highway engineers seems to be that these trends will continue and, if anything, intensify (8). Secretary of Transportation Brock Adams has stated, in a speech to the Annual Meeting of the Highway Users Federation, October 27, 1977, in Washington, D.C., that it is essential that the federal government "start the shift that is necessary toward resurfacing, restoration, and rehabilitation to protect the large investment we have made in our national highway system." If, in fact, maintenance does become an increasing problem, these questions surrounding the determinants of maintenance costs and the ways of minimizing them take on an added significance.

TOWARD A REVISED CHARGING SYSTEM

If capital expenditures are actually declining, it becomes reasonable to consider what can be done, within the constraint imposed by a requirement to raise payments from road users equal to road expenditures, to set prices in such a way as to ensure the best use of the roads. Attention is confined here to the problem of balancing the monetary budget. Nonpecuniary costs such as congestion or pollution are not considered explicitly, primarily because of the difficult problems associated with their empirical measurement, as discussed at length elsewhere (4).

In a context in which the basic decisions about the size and quality of the road system have already been made, the function of prices (or taxes) is to ensure that road-users' decisions about use will be guided by the continuing expenditures made on their behalf. In practice, this means ensuring that charges are at least enough to cover the maintenance expenditures incurred as time goes by. Short-run decisions to use roads continue to be made, and the value to users of these trips should at least be sufficient to cover the value of resources used up by them. So long as this condition is fulfilled, the greater the output of road services, the better. Thus, as a first principle, the charging system should maximize the output by the various classes of road users while covering those short-run variable expenditures clearly occasioned by them.

These short-run variable costs of road use consist principally of expenditures for pavement and shoulder maintenance. As we have observed, there are gaps in our knowledge that make it difficult to determine exactly how these costs should be assigned. The problem of determining these costs associated with road use is important enough to warrant further attention but, in the meantime, one must proceed on the basis of such knowledge as is available. At present, the most appropriate basis for determining these costs is the frequency of application of various axle loadings because this, as we have seen, governs the rate of pavement deterioration.

These costs fall short even of the noncommon [that is, the small proportion of capital costs that were estimated to be occasioned by various vehicle classes (4)] costs that can be attributed to particular user classes. Thus, setting user charges equal to short-run variable costs provides even less of a solution to the problem of how to finance the road system than does the criterion of equity. What should be done if the constraint to raise enough revenues from users to equal total road expenditures is imposed? The problem becomes one of ensuring that the money is raised with the least reduction in road use. Any charge (tax) in addition to the charge for maintenance will reduce this output. We wish to minimize these losses.

A theoretical solution to this problem results in

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what economists term the inverse-elasticity rule (9, 10,11,12) (proposal A). This formula states that the price charged to each class of user should be marked up from short-run marginal costs in proportion to the inverse of the price elasticity of demand of that class. In essence, this amounts to charging whatever the traffic will bear. Vehicle classes that have extremely inelastic demands are charged quite heavily, and other classes are made to carry a much lighter burden so that they are not priced off the road.

Theoretically, this scheme is very appealing, because it is derived from a straightforward application of the aim stated above. However, there may well be practical snags in applying it that imply that it is not necessarily the dominant solution. Beyond theoretical considerations, it is also necessary to consider the accuracy of the information on which the extra charge or markup is based; the practicality of the whole scheme and its likely cost to operate as a system; and (not least) how fair it will be seen to be fair by the users, which depends primarily on how radical a departure from current methods of raising road taxes is implied. For these reasons, we shall also appraise three other possible reforms of the current methods. The possibilities are

1. Proposal B: charging in proportion to vehicle kilometers traveled,
2. Proposal C: charging in proportion to gross ton kilometers carried, and
3. Proposal D: charging in proportion to the imputed gross revenue each vehicle class generates.

The first two proposals are based on simple output measures. They are included because of their simplicity and because they have in the past been proposed as methods for determining user-charge levels. The third represents an attempt to base charges in an approximate way on benefits received.

A proposed change in any tax system must consider the difference made to activities by the proposed reform. It is important, then, to fix at least the approximate incidence of the several possibilities on vehicle classes and to see what magnitude of changes in behavior are implied. To do this, it is convenient to focus on 1969, a recent year for which relatively complete data are available.

Payments and expenditures are computed for two breakdowns of vehicle class. In the first, light vehicles (automobiles and two-axle, four-tire trucks) are compared with all others. In the second, heavy vehicles [semitrailer and full-trailer combinations that have registered gross masses exceeding 27 000 kg (50 000 lbs)] are compared with light- and medium-mass vehicles. User-charge payments for these classes are taken from the estimates developed by Bhatt and others (7) and shown in Table 1. Pavement and shoulder maintenance and resurfacing expenditures are taken as the short-run variable costs of running the roads that we require each class to cover. These are assumed to be equal to short-run marginal costs and are allocated to the vehicle classes in proportion to relative amounts of pavement damage, as measured by the equivalent-axle-kilometer method described by Bhatt and others (7). The results are shown in Table 2.

The present concern is to fix the total payments implied by the various proposals. Accordingly, short-run variable costs are assigned to the appropriate classes. The remaining expenditures are then allocated to the vehicle classes in four ways, corresponding to the four charge schemes, according to the methodologies described by Bhatt and others (4).

For the vehicle-kilometer and ton-kilometer allocations, this involves a fairly straightforward application of readily available data. The other two allocations are based on much cruder information. The

imputed gross revenue calculation uses estimates of revenue per passenger kilometer and per ton kilometer derived from intercity bus and common-carrier freight data. The inverse-elasticity estimates depend on estimated values of the price elasticity of demand for fuel by various classes of users. The results of these calculations are shown in Table 3, and the details of the methodology used are described by Bhatt and others (4).

Table 4 compares the apportioned expenditures given in Table 3 with the estimated total payments given in Table 1. From Table 4, it can be seen that, for all roads and the main divisions, rural and urban, the respective proposals imply an increasingly radical departure from actual payments. The vehicle-kilometer basis is least radical, and the inverse-elasticity basis is by far the most radical. This holds true whatever the combination of vehicle classes selected. The direction of change is toward charging heavier vehicles more than they have paid, except for the vehicle-kilometer basis, where little difference from present payments is implied. The inverse-elasticity basis suggests especially higher payments from heavy vehicles than were actually collected. Taking the most notable changes within each proposal, we find the following highlights:

1. For the vehicle-kilometer proposal, the relief for light vehicles on secondary urban roads and the very much increased charges for heavy vehicles on other rural roads;
2. For the ton-kilometer proposal, the similar relief for light vehicles on secondary urban roads and the increased charges for heavy vehicles on other rural roads;
3. For the imputed gross-revenue proposal, the decreased charges for light vehicles on Interstate rural roads and the increased charges for heavy vehicles (again) on other rural roads; and
4. For the inverse-elasticity proposal, the relief for light vehicles on the Interstate system (both rural and urban) and the increased charges for heavy vehicles (yet again) on other rural roads.

To get an indication of how the relationships between these proposals and existing payments have changed over time, user-charge payments under the various schemes were calculated for several different years. Data permit only rough comparison between payments and apportioned expenditures; however, the analysis indicates that the degree of change implied by the proposals has decreased over time (4). This is especially true of the inverse-elasticity proposal, where, for both the heavy and the medium plus heavy classes, the ratio of apportioned expenditures to actual payments decreased markedly. This was due to both a decrease in apportioned expenditures and an increase in actual payments.

EVALUATION OF POSSIBLE CHANGES IN
PAYMENT REQUIREMENTS

The first criterion suggested for comparing the approaches was the relative impact of each on the use of the road by the different vehicle classes. Only one of the approaches--the inverse-elasticity rule--is explicitly designed to encourage optimal patterns of use. As noted above, in this case, the estimated responsiveness of demand to price changes is used to place heavier burdens where the loss of benefits is relatively least (in economic parlance, where the elasticity of demand for trips is lowest). In this case, the markup above cost is proportional to the inverse of the own-price elasticity of demand for road use by each vehicle class. The other three approaches are alternative methods of taxing the activ-

ities of the various vehicle classes, but refer only to various output measures. The relative sizes of output as determined by the three measurements--vehicle kilometers of travel, gross ton kilometers hauled, or total (imputed) revenue--determine the apportionment of payments above short-run marginal costs among vehicle classes. Because the inverse-elasticity rule takes the likely loss of benefits into account, we can regard this rule as a benchmark. There emerges a clear ranking of the approaches on this criterion. The inverse-elasticity approach is, by definition, superior, and the others are, in ascending order, the vehicle-kilometer, ton-kilometer, and imputed-gross-revenue approaches, which is closest to the benchmark.

Each approach, however, has relatively better features for some of the different types of roads than does the present payment scheme. For example, an outstanding common feature relative to the existing payment scheme was the indicated increased charge for heavy vehicles on other rural roads.

Of course, conclusions about the approaches depend heavily on the way in which levels of user charges are estimated. The second criterion for judging these schemes is, therefore, the quality of information on which proposed changes are made. In all cases, information is relatively sparse, although its quality and quantity vary from one to another. The inverse-elasticity method uses values derived from estimates

Table 1. Payments by user class and type of road: 1969.

	Payments ($ millions, current prices)			
Type of Road	Light Vehicles	Medium and Heavy Vehicles	Light and Medium Vehicles	Heavy Vehicles
Federal aid				
Interstate rural	1 075	889	1 476	488
Interstate urban	1 002	408	1 231	179
Primary rural	2 002	1045	2 535	512
Primary urban	1 718	424	1 993	149
Secondary rural	1 352	595	1 798	149
Secondary urban	665	141	771	35
Nonfederal aid				
Rural	1 087	421	1 438	70
Urban	3 567	664	4 120	111
All rural	5 516	2950	7 247	1219
All urban	6 952	1637	8 115	474
Total	12 468	4587	15 362	1693

Table 2. Short-run variable costs by vehicle class.

	Expenditures ($ millions, current prices)			
Type of Road	Light and Medium Vehicles	Heavy Vehicles	Light Vehicles	Medium and Heavy Vehicles
Federal aid				
Interstate rural	12	63	2	73
Interstate urban	7	22	0	29
Primary rural	80	247	3	324
Primary urban	31	39	2	68
Secondary rural	277	377	13	641
Secondary urban	16	19	1	34
Nonfederal aid				
Rural	465	335	24	776
Urban	289	196	20	465
All rural	834	1022	42	1814
All urban	343	276	23	596
Total	1177	1298	65	2410

Table 3. Apportioned expenditures by vehicle class and proposal: 1969.

	Expenditures ($ millions, current prices)															
	Light Vehicles				Medium and Heavy Vehicles				Light and Medium Vehicles				Heavy Vehicles			
Type of Road	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D
Interstate rural	4	1 749	670	350	2 138	393	1472	1 792	21	1 884	960	610	2 121	258	1182	1532
Interstate urban	0	1 841	1086	651	2 032	191	946	1 381	12	1 942	1 406	1 019	2 018	90	626	1013
Primary rural	6	2 085	1073	571	2 660	581	1593	2 095	135	2 303	1 573	1 111	2 531	363	1093	1555
Primary urban	4	1 313	932	617	1 468	159	540	855	54	1 407	1 182	953	1 418	65	290	519
Secondary rural	25	1 975	1330	777	2 806	856	1501	2 054	440	2 409	2 071	1 769	2 391	422	760	1062
Secondary urban	2	356	274	207	409	55	137	204	30	388	349	329	381	23	62	82
Other rural	45	2 025	1528	1009	2 953	973	1470	1 989	810	2 636	2 453	2 324	2 188	362	545	674
Other urban	32	2 382	1993	1445	2 945	595	984	1 532	674	2 765	2 617	2 404	2 333	212	366	573
All rural	80	7 834	4601	2707	10 557	2803	6036	7 930	1406	9 232	7 057	5 814	9 231	1405	3582	4823
All urban	38	5 892	4285	2920	6 854	1000	2607	3 972	770	6 502	5 554	4 705	6 120	390	1338	2187
Total	118	13 726	8886	5627	17 411	3803	8643	11 902	2176	15 734	12 611	10 519	15 351	1795	4920	7010

Note: A = inverse-elasticity proposal; B = vehicle-kilometer proposal; C = ton-kilometer proposal; and D = imputed-gross-revenue proposal.

Table 4. Apportioned expenditures as a percentage of payments by vehicle class and proposal: 1969.

	Expenditures (percentage by class)															
	Light Vehicles				Medium and Heavy Vehicles				Light and Medium Vehicles				Heavy Vehicles			
Type of Road	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D
Interstate rural	0	163	62	33	240	44	166	202	1	128	65	41	435	53	242	314
Interstate urban	0	184	108	65	498	47	232	338	1	158	114	83	1127	50	350	566
Primary rural	0	104	54	29	255	56	152	200	5	91	62	44	494	71	213	304
Primary urban	0	76	54	36	346	38	127	202	3	71	59	48	952	44	195	348
Secondary rural	2	146	98	57	472	144	252	345	24	134	115	98	1605	283	510	713
Secondary urban	0	54	41	31	290	39	97	145	4	49	45	43	1089	66	177	234
Other rural	4	186	141	93	701	231	349	472	56	183	171	162	3126	517	779	963
Other urban	1	67	56	41	444	90	148	231	16	67	64	58	2075	191	324	516
All rural	1	142	83	49	358	95	205	269	19	127	97	80	757	115	294	396
All urban	1	89	62	44	419	61	159	243	9	80	68	58	1291	82	282	461
Total	1	110	71	45	380	83	188	259	14	102	82	68	907	106	291	414

Note: A = inverse-elasticity proposal; B = vehicle-kilometer proposal; C = ton-kilometer proposal; and D = imputed-gross-revenue proposal.

of short-run price elasticities of demand for gasoline
and diesel fuel by trucks and for gasoline by automo-
biles (13). It was assumed that such elasticities
would be the same for any change in input costs and
that the reaction to any tax change could therefore
be computed from these elasticity estimates. But
their use in this context clearly involves extrapola-
tion. Considerable aggregation was also necessary.
Values for gasoline-powered and diesel-powered trucks
had to be combined. Light trucks were assumed to be
like automobiles and buses like trucks. The only
variability over road types was due to different pro-
portions of gasoline-powered and diesel-powered heavy
vehicles, because elasticity estimates for gasoline
and diesel trucks differed substantially. The elas-
ticity measures aggregate over market conditions; for
example, surely the elasticity of demand for use of
some road types by heavy trucks would be considerably
lower than for others. It is also clear that, given
price changes of this magnitude, elasticities will
change as adjustments to new price levels proceed.
The effect of this among vehicle classes is unknown,
yet it is relevant to policy because a move to a new
taxation system has a long-lasting effect.

Presumably these estimates could be refined
through the use of more precise elasticity estimates
and a more appropriate disaggregation of markets.
The analytical requirements would be substantial,
however. This charge scheme remains very information
intensive.

The vehicle-kilometer data are relatively the
simplest to measure and quite easily predictable.
Gross ton kilometers are somewhat more difficult to
estimate because of variations in loadings. In this
scheme, passengers are treated in the same way as
freight. The imputed-gross-revenue apportionment
was derived for passenger vehicles from the average
revenue per intercity bus passenger kilometer traveled
by applying this figure to all passenger travel. Values
for freight were similarly derived from freight reve-
nue divided by ton-kilometers carried, converted to a
vehicle-kilometer basis, and extrapolated to private
freight carriage. Thus, the estimates of imputed
gross revenues are again based on few observations
and much averaging.

In terms of the information criteria, we find the
ranking of the charging schemes reversed. The more
radical the proposal, the less secure is the informa-
tion that it requires. Regarding the practicality
and cost of operating the different proposed schemes,
it is worth noting that the means of payment can only
be approximately accurate. A vehicle-kilometer base
can be reflected, reasonably but not entirely, by a
fuel or a tire tax. Further accuracy would require
monitoring odometer readings and would considerably
increase the costs of collection and enforcement. A
ton-kilometer base brings in the extra dimensions of
goods carried and amount of empty running. New ef-
fort would be required to measure these factors. An
imputed-gross-revenue base would imply collection of
data on revenue earned as well as information on pri-
vate carriage for which no revenue is generated. It
would be difficult to devise a base applicable to
both types of operation. The information base for
the inverse-elasticity method appears formidable in-
deed. Much more study of activity at a disaggregate
level would appear necessary to establish reasonably
accurate elasticity estimates by road type and vehicle
class.

Common to all policies under consideration is the
need for a more complete methodology for the attribu-
tion of variable expenditures among vehicle classes
and road types. The assumption of year-by-year pro-
portionality between pavement damage, as estimated
by axle loadings, and short-run variable expenditures
deserves much closer scrutiny than it has, to our

knowledge, been given. Individual road segments are
not on maintenance schedules that guarantee that
damage caused in a given year is repaired that year.
But no information is available on the nature of the
lag structures involved. Furthermore, our research
has not considered differences due to frost damage,
nor have we been able to find information on road
deterioration due to time and weather alone, inde-
pendent of axle loadings. Thus, more precise rela-
tionships between road damage and pavement and
shoulder maintenance expenditures would be needed
to develop more precise proposals regarding vehicle
classes and road types than the aggregations con-
sidered in this paper.

Individual road-user classes cannot be required
to pay for all the resources they use because the
amount is indeterminate. The joint production of
road services makes any determination of appropriate
payments by vehicle class somewhat arbitrary. Under
the constraint that payments equal expenditures for
the totality of all classes, the inverse-elasticity
rule emerges as the most efficient way to tax vehicle
classes. Our calculations for this rule using the
aggregate data available resulted in an apportionment
of nearly 90 percent of program expenditures to heavy
vehicles. This result could not be implemented for a
variety of reasons.

First, the magnitude of these payments would be
such that heavy vehicles would either be redesigned
or withdrawn from most or all of the road system.
Surely much of the existing road system is not es-
pecially valuable for heavy vehicle use. It is very
likely that operators of heavy vehicles would confine
themselves to portions of the road system rather than
bear this massive increase in tax burden. Second,
the estimates of short-run variable expenditures by
different vehicle classes and the elasticities of de-
mand for vehicle classes are nothing more than crude
averages applied across the board to different circum-
stances. Consequently, it seems wise to regard the
payment structure suggested by the inverse-elasticity
proposal as only an indication of a desirable direc-
tion of change that points to higher payments for
heavier vehicles.

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Concepts, Principles, and Objectives of Economic Analysis Applicable to Traffic Accidents

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In the many years that cost-benefit analysis has been used as a management tool for decision making between different alternatives for highway improvements, a penetrating study has never been made of the factors of personal injury and fatality accidents as they relate to economy of transportation. Specifically, the economic gains and losses related to wage and salary incomes foregone because of lost work time (including death) have never been determined. This paper sets forth concepts, theories, and principles that can serve as guides in the search for dollar amounts to represent consequences of highway improvements that impinge on traffic accidents. Descriptions of 32 main consequences are given that indicate the role of each and how it could be priced for input to the cost-benefit analysis. It is proposed that these factors and others should be studied in depth by professionals from the several disciplines involved.

PREFACE

In past discussions, I have had difficulty in getting others to understand my position. It may be difficult for some persons to distinguish between making an analysis of the transportation economy of alternative investments in highway improvements and in pricing traffic accidents for other purposes or for viewpoints other than that of the economic community as a whole. In the evaluation of this paper, the differences in these two concepts must be kept in mind.

This paper takes the position that the analysis for the economy of highway transportation investments should (a) evaluate all economic factors in market dollars; (b) include all economic consequences that can be market priced and exclude economic factors that cannot be market priced; (c) exclude all factors that are not related to the conservation of resources; and (d) price highway costs, motor-vehicle costs, and accident costs in economic cost dollars and not in value dollars.

The ultimate decision maker can accord such weight to the humanitarian factors as he or she believes just and right. For calculating a benefit-cost ratio or a rate of return, however, that includes highway and motor-vehicle costs, traffic-accident costs must likewise be expressed in market price dollars that relate to economic conservation of resources.

SETTING AND SITUATION

It is encouraging to find increased use of economic analysis, or cost-benefit analysis, as a means of calculating the relative index to the transportation economy that exists between any pair of alternatives for the investment of capital in a highway improvement (whether for construction, reconstruction, or alteration of the highway structure) and traffic facilities.

There is agreement that the procedure of analysis should involve the economic costs of fatal traffic accidents; in fact, some new highway and motor-vehicle investments have had as their major objective the reduction in the number, cost, and rate of accidents that result in human death. The factor of accidents has brought new discussions, new literature, and new analysis to bear on the dollar cost of a traffic fatality. However, some of the dollar sums arrived at as costs are actually values that have been calculated without proper attention to the principles of economic analysis, the application of the results, or the role of economic analysis in the decision process.

The capital-investment analysis of any proposed highway improvement that involves the factor of fatal traffic accidents is, in reality, no different than the analysis of a proposed project that does not involve consideration of traffic fatalities. But many persons consider such a proposal to be different because of the human, emotional, and social implications. Although a fatal accident is different from a nonfatal accident because of these human and social factors, it remains equally true that the concept, principles, and theories of economic analysis do not differ. A change in concept can be injected into the analysis without changing the basic set of principles. The one significant change needed is that of separating the emotional and social factors from the highway costs, the motor-vehicle costs, and nonfatal accidents. In substance, this concept restricts the main cost-benefit analysis to strictly market-based economic-resource factors and sets aside the social and human factors for a cost-effectiveness analysis, or no analysis at all other than to be considered by the decision maker along with the other irreducible factors.

Some current writers have gotten away from the concept of placing a value on the life of a traffic fatality, which change in thinking is progress in the right direction. On the other hand, the procedures often used point to a value calculation, rather than to an economic cost calculation. Agreement is rather widespread now that there should be no attempt to actually value human life as life or a person as a living being or as a social member of society. The alternatives that remain, then, must lie in determining a person's economic productivity within the social and economic system, or in determining his or her economic role as a consumer, or by using a combination of the two.

For purposes of a cost-benefit analysis, the finding of a dollar sum to measure a person's worth to economic society must be directed toward an economic base and away from a humanistic, humanitarian, or benevolent base. The cost-benefit concept and calculations are traditionally and correctly geared to the economic base--toward the conservation of resources through the reduction of economic consumption for a given amount of transportation. This concept leads to the question, What is the economic difference to society in going ahead with the living person for the number of future years to the normal death year and going ahead the same number of years after the death of that person because of a traffic accident (or any cause of death)? When this net difference in economic consequences between being living and being dead is found, the dollar factor in cost-benefit analysis that measures the role of decreasing traffic fatalities in the economy of proposed highway investments can be calculated.

For investment economy analyses, the human and social factors of a traffic death should be dealt with separately, reported separately, and used by the decision maker as separate factors. Therefore, this paper does not recommend pricing pain, suffering, bereavement, family love, social entities, and the value of life as life as opposed to death, except as a firm economic market price may be found. This position does not infer, or at least it is not intended to infer, that I believe that these human factors are not important to people and to society in general. My position is simply that these factors are not direct economic factors, they cannot be priced on the market, and there is no procedure by which dollar amounts can be found for them except by the wide-open path of personal opinion. It is this lack of a market basis that has resulted in the past in a wide range of dollars, perhaps from $25 000 to $500 000/fatality, that have been applied in economic analysis.

Before a generally acceptable and conceptually sound procedure can be developed for the treatment of traffic fatalities and bodily injuries in cost-benefit analysis, two tasks must be accomplished. First, the scope of the total system should be defined with respect to objectives, concepts, theories, principles, and applications. Second, representatives from the various disciplines and working groups concerned with the analysis should exchange views and come to an agreement on the overall features and procedures of analysis. These disciplines include subjects that lie within the professional competences of highway engineers, economists, sociologists, planners, political scientists, comptrollers, and public works officials.

One of the objectives of this paper is to show the need for consistently priced traffic-accident costs and how to solve that problem by putting all dollars on a common base--a base directly related to economic market prices. The same kind of market dollars are customarily used for costs of highway construction and maintenance, motor-vehicle operation, and traffic accidents (exclusive of fatal ones).

Proper procedure, however, requires the fatality dollar to be market priced also and not determined from opinions, willingness-to-pay valuations, and worth of a life as a life valuations.

This paper outlines the process of analysis, discusses the factors in the entire system involved, determines the role of each factor, and then indicates how each includable factor should be quantified and priced. No attempt is made to price any factor in specific dollar amounts.

VIEWPOINT--FROM WHOSE EYES

When traffic accident costs and their inclusion in an economic analysis of a proposed highway-improvement investments are being considered, the viewpoint should be specifically kept in mind. Consider a human death from a traffic accident. Possible viewpoints are those of the insurance company; the highway engineer; the vehicle driver or owner; the estate of the person killed; the family of the person killed; the friends of the person killed; the social community; and, lastly, the total economic society that may be affected.

The economic analyses of proposed new investments in highways are made for the purpose of informing the decision maker about the calculated transportation economy that will probably result over a period of future years from each alternative considered. Because the economic forces to be considered are general and widespread, they must include all types of people and a wide geographical area. Therefore, the viewpoint of the economic analysis and the input data and consequences must be the last cited above--the total economic community.

A person is both a producer and a consumer. Production and consumption are both economic activities, but adding them together would be double counting. A choice of viewpoint--production or consumption--should be made at the outset of a cost-benefit analysis of a proposed highway improvement. Traditionally, and correctly, in concept, this viewpoint has been taken as the conservation of consumption of resources. Engineering economy has always been based on the conservation of resources, one aspect of which is striving for the minimum consumption of resources to achieve an objective.

CONCEPTS AND OBJECTIVES OF ECONOMIC
ANALYSIS

An understanding of the concepts and objectives of economic analysis is an essential beginning to a study aimed at finding a dollar sum by which to represent a traffic fatality in an economic analysis of the choice of highway-improvement investments. The economic analysis attempts to answer the question, "Of a pair of alternatives, which one, within a selected future period, will consume the minimum or lesser amount of resources?" Another way to frame the question is to ask, "Which alternative will maximize the return on the investment?"

In public works types of construction investments, as contrasted to private business and industry, there is usually not a cash sales income against which to measure the profitability of the investment. Therefore, in public works (highways), the net return is measured in terms of a cost reduction in the ownership and operation of the facility. Additional capital is invested in the existing highway network in the expectation that vehicle running costs, travel times, and accident costs will be reduced. These reductions in transportation cost are the dollar return against which the economy of the proposed dollar investment is measured.

The analysis is carried out on a discounted cash-

flow basis. This means that all cash flows are combined into equivalent sums as of a common date. The concept also requires that dollars must be of the same price level; that is, the pricing of all factors must be as of a common date.

The cash flows include the costs of such items as planning, design, construction, maintenance, and operation of the highway facility combined with the costs of operating motor vehicles over the facility. Traffic accident costs are a part of motor-vehicle use.

In this concept of economic analysis, a fatal traffic accident should be represented by a cash flow based on market pricing. If this is not the case, then the pricing of the fatality is not in the same dollars as are the items of highway cost and motor vehicle use. A fatal traffic accident should be priced to include all the known or determinable direct economic costs and gains of the accident, including property damage, medical service, and other direct economic consequences that are market priceable and that represent consumption of resources. The decision maker wants to know that the economic analysis is based wholly on true consumption of resources.

These concepts and objectives set the stage for the economic analysis. But, in the execution of the analysis (data gathering and their arrangement, included), there is need for guidelines. These guidelines, constraints, or criteria are discussed below.

PRINCIPLES OF ECONOMIC ANALYSIS

Although this paper is primarily addressed to the single factor of traffic accidents, the concepts described above and the principles to be discussed below apply to economic analysis (cost-benefit analysis) for all applications--public works and private works. The nine principles presented here do not embrace all principles, but are those especially applicable to the analysis of traffic injuries and fatalities.

1. The analyst must exercise complete objectivity. There is no room in economic analysis for an analyst who tries to get a chosen answer. Every factor within an alternative must be included, whether favorable or unfavorable to that alternative, and each factor must be priced according to the same standards. Unfortunately, there have been analyses of traffic fatalities wherein there seems to have been an attempt to arrive at the highest possible total net cost of a fatality. This attempt is characterized by the finding of high costs, not discounting the future costs, and the omission of factors of apparent gain to society.

2. At the outset, the viewpoint from which the analysis is to be made must be established. Possible viewpoints are the decedent, the family and relatives of the decedent, the community of the decedent, the social aspects of society at large, and the total economic society as partially represented by the system of highway transportation, including all road users. Our highway systems are constructed and operated by use of public funds, produced mainly from highway user taxes, from property taxes, and from (in new urban areas) the price of land and buildings served by the highways and streets. These highways are part of the public works systems and available for use by the public without restriction. Thus, the economy of highway transportation facilities should be determined on the basis of total economic costs and use, regardless of specific classes of users or financial supporters. Therefore, in an economic analysis of a proposed highway improvement, the viewpoint should be that of the people at large as highway users. There has been some tendency to treat traffic fatalities from the viewpoint of the decedent's family. In the concept of conservation of resources, the

highway-user population shares, losses and gains. Thus, the viewpoint of the community as a whole should be adopted with respect to a fatal accident as well as for all other traffic accidents and all economic costs and gains.

3. All analyses must be conducted on the basis of alternatives based on the concepts of "with and without" or "to do or not to do." These two expressions relate basically to comparing an existing situation (the now-being-used facility) with another one as proposed. There are always two alternatives--that of doing something and that of doing nothing. In comparisons, however, of two alternatives of doing something the principle of "with and without" holds. The alternative that has the lower cost may be chosen as the base with which the higher cost alternative is compared. If traffic fatalities are at issue, this principle may be correctly interpreted as meaning with and without the death. In other words, What are the economic forces and factors to be evaluated had the fatality lived as compared with the economic forces and factors without his or her living? What are the economic impacts on society after death compared with the economic impacts had the person continued to live?

4. The differences between the two alternatives in the pair of alternatives being studied are the significant factors in decision making--not the magnitude of individual factors. In reality, this principle is a supportive statement to the "with and without" principle. It is the "with and without" comparison of a pair of alternatives that permits obtaining the difference between them. This principle is often violated by a failure of the analyst to compare each possible pair of alternatives by differences.

5. The analysis should include all consequences to whomsoever they may accrue--a form of system analysis. This principle includes both the priceable and nonpriceable consequences. Obviously, however, the nonpriceables cannot be included in the numerical calculations. They must be handled by separate descriptions or on a cost-effectiveness analysis basis. With respect to fatal accidents, this principle dictates the inclusion of all consequences to all people and to all activities. Naturally, there is a practical limit of how far afield the analyst may go in running down every consequence. But with certainty, the analyst should include every significant economic consequence and all those that are readily obtainable and easily and positively market priced.

6. All of the market factors included in the calculations of a benefit-cost ratio, a rate of return, or a net present worth should be dollar based in the marketplace. This principle is interpreted to admit dollar pricing on an estimated basis when the estimates result from normal pricing procedures. Included in this category are highway construction and maintenance costs, motor-vehicle running costs, medical costs, and the like. Many of the costs and gains are priced at current prices but estimated for a future period. This market-pricing principle excludes dollar pricing for those factors not quantifiable and not commonly and consistently exchanged on the open market.

7. All cash flows should be discounted to a common specific date. The date is usually chosen as the current date or the date the facility is to be opened to traffic. The logic of this principle is that the worth of money is tied to the time at which the money is available as income or expense.

8. The analyst must select a future time period over which to make the analysis. All plus and minus cash flows from the consequences occurring within this future span of years are accounted for on a discounted basis. Often, this time period is restricted to the period for which the traffic volume is estimated (such as a 20-year period).

9. The analysis is based on the net of costs and gains of all factors. The word "net" is an indication that there may be two types of cash flows, one positive and one negative, but in the analysis it is the net, or difference in the two flows, that is used. Examples of types of factors where a hunt for the net is advisable are the cost of food included in hospital costs less the cost of food that would have been purchased by the victim otherwise; a proper accounting between insurance premiums, damages and other payments received, and the cost of the accident; and the use of rental vehicles adjusted by the cost of using own vehicle had it not been damaged.

PAST PROPOSALS FOR PLACING A DOLLAR
SUM ON A TRAFFIC FATALITY

The one significant item to be priced in determining the economic cost of traffic fatalities is the dollar amount to use in cost-benefit analyses to represent a fatality. Both social and economic concepts have been used. Some of the concepts and procedures are discussed here to point out more directly the importance of this controversial factor.

Many analysts speak in terms of the value of life, the value of living, the value of a person to society, and other value terms. Perhaps it would be preferable to consider the net economic production that is made by a person as the base dollar amount to use in economic analysis. This production can be measured in terms of one's net wage earnings as a surrogate for the real contributions to economic society. But even this measure of net production may be objected to on the grounds that, on the death of any productive person, his or her production is taken over by some living person, so that there is actually no reduction of production in the total community. Witness our ever growing economic production over the years, despite the deaths per year.

1. Present worth of earnings foregone less present worth of cost of maintaining earning capacity: For many years, analysts have used the total earnings foregone because of death, without a time discount, as the cost of a fatality. More recently, the calculation of the present worth of the earnings foregone by use of a time-discount factor has been used. At present, some analysts take the difference between the present worth of earnings foregone and the present worth of the yearly costs of maintaining the worker in an earning capacity. These sustaining costs are related to cost of living and working. Under the principle of including all consequences, the cost of maintaining a wage or salary earning must be considered equally with the amount of earnings. It is the net amount that is significant.

When a working person is removed from the work force for any reason, including as a traffic fatality, there is a presumption that his or her place is taken by another worker. The replacement worker comes from the unemployed, by transfer from another position, or from the age group just entering the labor force. When the vacancy is filled by transfer from within the working force, often with a promotion in wage, there may be a chain reaction that provides a promotion for two or more levels of employment.

These actions of changing the labor force and wage incomes are certainly consequences of the traffic fatality that should be considered. The process of simply taking the future expected earned income of the decedent as a measure of the cost of the fatality ignores completely the gain to society of the new employment or the increased wage or salary. If salary foregone is a cost, should not salary increases be a gain? Both actions are a part of the same economic system and are equally important.

If the earned income foregone is accepted as the measure of a person's productive contribution to society, then the next step is to find a measure of that person's consumptive contribution. The net of the two economic factors is what is desired for use in economic analyses.

The consumptive contributions that persons make to society are found in what is expended in their behalf that enables them to sustain their productivity. These expenditures are for such items as food, clothing, shelter, health, education and training, transportation, work expenses, entertainment, and recreation as they contribute to working capabilities.

The earned income foregone as a measure of productivity and the cost of living as a measure of economic consumption should both be calculated on a year-by-year basis with a present-worth factor for each of the years covering the death year to the year of probable death by other causes as determined from mortality tables in the life insurance industry.

Exception to the subtraction of the cost of maintaining the person in a working condition is sometimes based on the concept that the inclusion of the subtractive element of living consumptions takes away the benefit to society of this consumption. If a person is to be kept alive to consume some of his or her own earnings and increase economic consumption, why then are the reduction in consumption of motor fuel attained by better designed highways and the reduction in medical supplies obtained by reducing the number and severity of traffic accidents considered desirable goals? We justify highway improvements by reducing economic consumption and not by maintaining or increasing consumption of scarce resources. Conservation of resources is the guiding concept in economic analysis.

2. Lost work time at wage rate: Because the cost of lost work time for temporary disability is often measured in terms of the injured person's wage rate, the lost work time by death could also be measured the same way. Death is permanent lost work time over the period of remaining work-time expectance as compared to lost time from temporary injury. At least, as between these two types of accident severity, there should be consistency as to how work time is converted into an economic factor to use in cost-benefit analysis.

3. What society is willing to spend: The social point of view as measured by what society is willing to spend to reduce the number of traffic fatalities has been advanced as a measure of the dollar evaluation of human life. This approach is a value concept, rather than an economic cost approach. There exists no completely open forum from which to determine how much society is willing to spend. It is doubtful that enough persons in each economic class could be found who would have any particular basis of making a determination of how much the public should spend on highways to reduce fatalities. These same persons have little knowledge about the differences in human values and economic values in the concept of economic analysis.

If the willingness-to-pay concept is used for fatalities, why not also apply the same concept to pain and suffering and to reduction in gasoline consumption and tire wear?

4. Individual person's evaluation: Another method that relates to value of life is found in the proposal to ask people what they would take in current dollars to avoid death. In other words, How much are they willing to pay to remain alive? Few persons would be able to give any sensible answer to this question. There would be many factors not understood by the person answering the question. When would death take place? If not to be dead, how long would I live? The answer would be related to the

Table 1. Item consequences of traffic accidents by time periods.

Consequence	Includable in Cost-Benefit Analysis	Accident Period	Postaccident Recovery Period	After Recovery but With Permanent Disability	Death Period	Post-death Period[a]
Property damage to vehicles, highways, adjacent property, cargo, and personal effects	Yes	a				
Emergency crews and rescue vehicles	Yes	a				
Police and traffic officers	Yes	a				
Disruption of traffic flow—vehicle costs	Yes	a				
Traffic delay time and travel time at time of accident	Yes	a				
Travel expense of accident by concerned persons	Yes	a	a	a	a	a
Postaccident travel time	Yes	a	a	a	a	a
Rental of substitute vehicle	Yes	a	a	a	a	a
Accident investigation, reporting, and analysis	Yes	a	a	a	a	a
Hospital service charges	Yes		a	a	a	
Medical professional services	Yes		a	a	a	
Medical supplies	Yes		a	a	a	
Prosthetic devices and equipment	Yes		a	a		
Incidental hire	Yes		a	a	a	a
Legal services	Yes		a	a	a	a
Court expenses and witness fees	Yes		a	a	a	a
Flowers, gifts, telephone, postage, and such	Yes		a	a	a	
Funeral and associated expenses	Yes[b]				a	
Pain, suffering, grief, and remorse	No	a	a	a		
Induced illnesses and accidents	Yes-No[c]	a	a	a	a	
Community activities and labor and professional groups	No		a	a	a	a
School days missed and delayed promotions	Yes-No[c]		a	a		
Welfare payments by governments	Yes[b]			a^b	a^b	a
Tax levies by governments						
Income	No					
Sales	No					
Social security	No					
Inheritance	Yes[b]					a^b
Insurance						
Motor vehicle	Yes[b]	a				
Workmen's compensation	Yes[b]	a^b	a^b	a^b	a^b	a^b
Personal accident and disability income	Yes[b]	a^b	a^b	a^b	a^b	a^b
Health and hospitalization	Yes[b]	a^b	a^b	a^b		
Life	No					
Exchange of assets after death	No					a
Family services to the home	Yes		a	a	a	a
Services by neighbors and others without charge	No	a	a	a	a	
Training of job replacement	Yes[b]		a	a	a	a^b
Cost of working and payroll burden	Yes[b]					
Nonproductive time of employee absence and position vacancy	Yes[b]		a	a	a	
Economic cost of death	Yes		a	a	a	a^b

Note: a = applicable to time period whether or not includable.

[a] Coded on basis that death could occur at moment of accident or at some future time. [b] With restrictions and under certain conditions. [c] Includable but not practical to price.

economic status of the individual. But more important, it is unreasonable to assume that people at large in society would have any basis at all of offering sound, well-considered answers to such a question. But even if the approach were successful, the answers would not deliver the economic answer that is sought. This statement goes back to the concepts and principles discussed above. If one digresses from the economic concept and wishes to use a value concept, then to be consistent, the whole cost-benefit approach must be a value-benefit approach on all dollar evaluations. But such an approach does not lead to a measure of the economy of transportation alternatives--the objective that this whole effort is trying to reach.

5. Principal sums of life insurance policies: A procedure often suggested for the determination of the dollar value of human life is to sum up the principal amounts stated in life insurance policies and accident risk insurance. Insurance carried by a person is not specifically related by the insured to his or her evaluation of his or her life. It is determined more by ability to pay the premiums and who the beneficiaries of the policy are. Much short-term insurance (airplane travel, for instance) is not taken on the basis of the value of life, but as a gamble--risking a small sum for a small chance of a large gain. Again, the holders of life insurance policies are not a representative sample of the persons killed in traffic accidents. Finally, as in the concepts of willingness to pay and personal evaluation, there would be little direct relation between the dollar amounts gotten from insurance policies to the economic truths needed in cost-benefit analyses. This insurance concept is a value concept, not an economic cost concept.

6. Jury and court awards: Each year, the courts decide cases wherein specific dollar amounts are awarded on the death of persons as a result of responsibility for such death. These awards have no sound foundation to make them acceptable for economic analysis of death from traffic accidents. The amount of the award, in addition to being based on ability to pay, is influenced by the situation of the trial, the judge, the jury, and the attorneys. Finally, these awards are not acceptable because they are not representative of the individuals across the nation who meet death from traffic accidents; they have no relation to the economic factors of death.

ITEMS OF TRAFFIC ACCIDENT COST

Table 1 lists 32 consequences that are pertinent to compiling the costs of traffic accidents for use in cost-benefit analyses. This table is somewhat detailed in some instances and is rather gross in others. These 32 consequences are part of the total system picture. No claim is made as to the completeness of Table 1.

One of the purposes of Table 1 is to supply a listing by which to identify consequences that are contro-

versial or for which the handling in cost-benefit analyses is uncertain. Certain of the consequences will be discussed in depth in accordance with the above statements on concepts, principles, theories, and viewpoints.

The division in Table 1 of the listings into five columns by time periods, as related to traffic accidents, is to facilitate the selection of consequences for discussion and to show that some consequences are common to all time periods, starting with the accident itself and continuing into days or years thereafter. The costs of permanent bodily injury would continue for years after the accident and after direct medical attention ends. The same is true of death. In this analysis, the consequences of death need to be considered over a time period equal to the estimated life expectancy of the accident victim had the traffic death not occurred. But some of the consequences may be effective through many years thereafter.

1. Property damage: Traffic accidents cause property damage to motor vehicles, highway structures, private property adjacent to the roadside, cargo in commercial vehicles, and personal effects of drivers and passengers. Costs are based on repairing the damage, including both labor and materials. If the property is not economically repairable, the cost would be the current market value of the property in its preaccident condition less its scrap price.

2. Emergency crews and rescue vehicles: At the site of the accident, tow trucks, paramedic crews, and ambulances may be needed. The costs of these vehicles and their crews are usually priced on the basis of the trip or per hour, including wages, vehicle operations, and travel times. All such incremental expenses are wholly chargeable to the accident, as part of the on-site costs.

3. Police and traffic officers: When police or traffic officers are called to the site of the accident, their personal time and vehicle use is chargeable to the accident. This charge is determined on the basis of wage and salary rates plus vehicle operation on an hour or distance basis. Police and traffic officers are on a public payroll, without direct charge to the owners of the vehicles in the accident, but there is still an incremental economic cost involved. Without the accident, these officers would be available for other assignments and, if accidents could be reduced sufficiently, the number of officers on the force could be reduced.

4. Disruption of traffic flow--vehicle costs: Even minor accidents can disrupt traffic flow. Vehicles are slowed in speed, stopped, and detoured around accident vehicles in either one-way traffic or over other routes. The result is added vehicle running costs resulting from changes in speed, idling engines, turning movements, and extra distance traveled. These extra running costs are wholly chargeable to the accident.

5. Traffic delay time and travel time at time of accident: The increases in traffic delay time and in travel time due to the accident are a chargeable expense. The rate of time charge should be that being used for normal travel as applied in cost-benefit analysis. (Consequences 4 and 5 apply only to the traffic and travel consequences caused directly and immediately by the accident.)

6. Travel expense of accident-concerned persons: The travel by all modes by relatives, neighbors, friends, and business associates that results from personal-injury traffic accidents is a chargeable expense to the extent that this travel would not otherwise have been made. The includable items are common-carrier fares, taxis, distance charges on personal vehicles, lodging, meals, and incidentals. Subtracted from this gross expense to get net expense

are the normal expenses foregone such as home and restaurant meals, personal vehicle use, and the expense of other activities permanently canceled. These costs, however, should be incremented or at least discounted on the basis that the costs would be incurred later on death by another cause.

7. Postaccident travel time and its pricing: The pricing of travel time is still somewhat a controversial factor, primarily for two reasons. First, even for high daily traffic volume of vehicles, there is doubt that a few seconds or a minute or two not used in travel would be economically and productively used in other activities. A second factor relates to whether travel time is or can be expressed in terms of the market. For commercial vehicles, the market base can be used (1). For automobiles, the Stanford Research Institute (2) reports dollar expressions for travel time based on comparing nontoll and toll routings. On this basis, it is concluded that the travel time of personal vehicles and occupants has been priced on a market base.

As shown in Table 1, travel time is a common factor in all time periods except the last. The postaccident travel is by accident victims, relatives, friends, associates, witnesses at court, and others when visiting accident victims, caring for business items and home items, for preparing and filing legal documents. Professionals associated with the accident who are working for a wage, salary, or fee (such as attorneys and medical personnel) normally include vehicle-operating or travel-time cost elements in their professional charges. Work time, travel time, and vehicle use by public employees (such as police, accident-associated employees, and volunteers) should be charged to the accident on an incremental basis.

8. Rental of substitute vehicle: Because of damage to vehicles at the accident, their owners may rent vehicles or use taxis for local transportation. This direct expense is a cost of the accident. But the net cost of this travel by hired vehicles would be this direct expense less what the owner would have incurred by using the owned vehicle had it been available. This procedure illustrates the principle of difference, the principle of net cost, and the principle of all consequences.

9. Accident investigation, reporting, and analysis: Official accident reports are normally required to be filed with a designated governmental agency for all accidents that cause property damage of more than a minimum total and every accident that causes personal injury needing professional attention. In addition to the reporting, many accidents are investigated on site at the time of accident or later. These investigations and reports require the use of vehicles and the time of field personnel, the accident victims, their associates, and witnesses. This total of both travel expense and time are chargeable to the accident on an incremental basis. For all but the official motor vehicles used by safety agencies and other public agencies, both travel expense and time of others could be included in consequences 6 and 7. Some of the costs, however, for collecting and analyzing the data are used in finding ways to reduce future accidents and, therefore, the net costs could be negative.

10. Hospital service charges: The net cost of hospital charge is the hospital billing less any reductions in expense that would have been incurred had the victim not been injured. A major item in this category is that of food. By going to the hospital, the cost of meals outside is reduced by at least the cost of the food not eaten at home or at restaurants.

In addition to meals at the hospital, other expenses avoided should be deducted. Among these other

expenses are such items as recreation, entertainment, the net of automobile use for all purposes, and social expenses. For privately operated hospitals, any profits above costs should be excluded as being transfer items.

11. Medical professional services: Medical professional services other than those included in the hospital billing include home calls, office calls, and hospital calls of private physicians, dentists, and nurses, and outside laboratory services. These services are usually billed on the basis of including all travel, overhead, and assistants. In addition, there will be medical supplies that are furnished through the professional in charge. These professional charges can continue over days, weeks, and months, until the injured is fully recovered or dies.

12. Medical supplies: Medical supplies, including prescriptions, are procured from three main sources: (a) through the hospital billing, (b) through the physician's billing, and (c) through direct purchase. Regardless of the source of supply and the process of billing, they all represent costs of the accident.

13. Prosthetic devices and equipment: Such items as canes, crutches, braces, artificial limbs, beds, and exercise machines may not be included as medical supplies. These items may be directly purchased and discarded or sold at the end of their use, or they may be rented. In either case, the net cost is chargeable to the accident.

14. Incidental hire: Because of the problems of time allocation and the absence from home of the injured, it may be necessary to hire help for jobs at home or in connection with business, managing the home, child care, or in getting errands and accident incidentals cared for. The cost of such hired help is a justified expense against the accident.

Without question, the cost of any hired help to care for the injured person at home would be a justifiable charge against the accident. But when such care is given by family members, there is some question whether it would be an economic charge. If a family member gave up gainful-employment cash income to care for the injured person, then the charge against the accident should be sustained.

15. Legal services: Legal services for all parties to the accident constitute a real cost and should be included. The legal services that are furnished through the motor vehicle insurance companies would be included in the insurance administration and overhead costs. But legal expense is optional with the individual, except when he or she is sued by another party. These optional costs are not community expense and do not involve conservation of resources. The personal-client type of legal expense would consist of services before, during, and after any court proceedings for all matters that were consequences of the accident. As with medical professional expenses, legal fees normally include travel, office assistants, and overhead of the professional service.

16. Court expenses and witness fees: All normal public expenses of official legal proceedings, whether by trial judge, jury trial, or by conference, should be a charge against the accident on an incremental basis. For jury and witness fees, there will be a direct cash outlay; but for the court in general (including judge, assistants, and administration expense), there will be some general incremental charge. Here again, these court costs are optional and not a community cost of the accident, except to the defendant.

17. Flowers, gifts, telephone, postage, and such: Throughout the period between the accident and the funeral, there is an accumulation of miscellaneous expenses on the part of relatives, friends, and associates who are concerned. These expenses, on the basis that they would not have been incurred had the accident not happened, are normal costs of the accident. Getting at their net total may prove a difficult fact-gathering task. Their total may not be significant relative to the grand total cost of the accident, but they should not be neglected. Even if they are not included, they should be recognized as being omitted from the total.

Two general restrictions should be observed. The expenses chargeable to the accident are the net of those that would not have occurred in the normal course of social and business actions. Any items associated with a funeral should be time discounted.

18. Funeral and associated expenses: Because every person will die someday, the expenses of a funeral are not unique to a traffic accident. For cost-benefit analysis, the funeral charges should be included on a discounted basis over the time between the date of the funeral and that future year when, according to life-expectancy tables, the individual would have an expectancy of death. The calculation of this present worth or discounted cost should be made for each death separately for the period of expectancy of life and not by an average expectancy for all deaths. The exponential character of the calculations precludes using the average expectancy.

19. Pain, suffering, grief, and remorse: Without doubt, the injured person sustains considerable pain and suffering because of bodily injury. In addition, relatives also suffer and grieve because of the injury. These physical and mental feelings are not economic gain or loss, although they may sometimes result in some loss of economic production and a change in consumption. Pain and suffering do not have a market base for pricing and probably do not have any trait of conservation of resources. In view of the governing concepts and principles, there is no sound basis for including a dollar sum in cost-benefit analysis for the combined item of pain and suffering.

For pricing this item and for compensation for death, whether or not for insurance settlement, some analysts have turned to awards by court juries or judges. This source of evidence of acceptable dollar amounts for either pain and suffering or for death does not furnish any reliable, soundly based, or generally acceptable results. The reaons for this rejection of jury and court awards for use in cost-benefit analysis lie in the following factors: First, the cases that reach the courts are the unusual ones, and the sample of awards that may be collected from court cases is not a good statistical sample. The cases from court records are neither chosen at random nor taken from a homogeneous population. Second, the judgments that are awarded are based on the ability to pay whether or not through an insurance company. Third, awards are only a matter of the personal opinion of the judge or the jury and have no factual basis or market base for setting the amount. Fourth, the awards made are customed to fit the specific case and should not be used as representative sums for the average accident. The influence of the attorneys, the judge, and the witnesses greatly affects the result.

Any weight to pain, suffering, and grief for the highway-improvement alternatives under study must rest on the decision maker's judgment for each proposal individually. No dollar amount for any pain, suffering, and grief should be included in the cost-benefit analysis. Pain and suffering as yet have not been related to conservation of resources.

Finally, if an analyst insists on considering court awards for a fatality or injury, the cases wherein the award was zero dollars should be included along with the dollar awards.

20. Induced illnesses and accidents: There are cases of record where such events as a serious traffic accident resulted in additional tragedy. The

shock of the accident may induce sickness or mental distress that leads to a stroke, heart failure, or another accident. Fortunately, these cases are relatively rare. They may be hard to identify. Therefore, the best procedure in cost-benefit analysis is to neglect them.

21. Community activities and labor and professional groups: On the death of a person or on confinement due to permanent disability, there follows a wide scope of social, business, and professional consequences, some favorable and some unfavorable, to the remaining population and its social, business, and economic actions. The highly organized population in the United States reaches all the way from local neighborhood groups to wider scope citizen associations, regional groups, county committees, state committees, and national committees. Conventions of associations, societies, unions, and institutes that represent social, religious, health, athletic, recreational, business, trade, labor, and professional persons continue, seemingly with no end.

These types of social, business, and professional groups undergo continuous changes in memberships and officers for many reasons. Any loss or gain by death is no different internally to these groups than any other change in membership or leadership. These groups and their activities will continue after the death of any member or officer in whatever way those in charge desire. What worthwhile economic contribution is made now to society that will not continue to be made after the death of the principal contributor? This is the critical question. If the economic contribution is not continued after the death and is important to society, then there is an economic loss; if some other person continues the contribution, then there is no loss (i.e., no change in the economic balance). For cost-benefit analysis of proposed investments in highway improvement, there is no need to explore the consequences of these social, business, and professional orders. It is doubtful that any positive net gain or net loss of a worthwhile magnitude would be found.

22. School days missed and delayed promotions: When students, in the range from primary school through college, are the victims of accidents other than death, there can be interference with the educational process. Many days or weeks in attendance may be lost. In case of a prolonged period of recovery or partial recovery, a grade promotion may be delayed and, in some instances, the formal education could be ended.

The consequences of a traffic accident to the educational progress of school-age persons are uncertain and difficult to measure in terms of economic gains and losses. Perhaps the best procedure is to admit these difficulties and uncertainties and exclude the item from the analysis. The total magnitude in dollars would be relatively small.

23. Welfare payments by governments: To the extent that persons who become traffic fatalities are being supported through government welfare payments or other public support, there is a gain to society as a whole in the ending of these payments at the time of the accident as opposed to ending them at some future date. Such a gain accrues to the public at large when the total of payments is reduced. In theory, all other factors being constant, the tax rate could be reduced by death of persons on the welfare rolls.

Should the fatality be supported by public welfare and engage in little or no productive employment, the net economic change would be the present worth of the reduction in consumption by the cost of living. The welfare payments would be stopped but, being paid from taxes, this cash flow can be considered to be a transfer of funds.

24. Tax levies by governments: This discussion applies to all forms of tax levies--income, sales, social security, and inheritance--there is little difference among these in relation to economic analysis. A closer examination of all taxes than is given here is appropriate, however, to determine the net effect on social and economic welfare factors as consequences of a traffic accident and a fatality.

Taxes are imposed by the people upon themselves for their common welfare. Most taxes can be considered as transfers within the accounts of the people (governments are agents of the people) and, therefore, tax payments and tax incomes are neutral in their effect with respect to production, consumption, and conservation of resources. By this logic, taxes can be omitted from calculations of the gains and losses due to traffic accidents in analyses of the economy of proposed highway investments.

Income taxes, sales taxes, and social security taxes are influenced at the locale of incidence by the costs and incomes from traffic accidents. Similarly, in the long run, accident costs and incomes therefrom affect the size of estates and resulting inheritance taxes. The effects are largely in the forces that cause redistribution of incomes, expenses, tax levies, and wealth. But it is within reason that, for economic analysis, taxes can be omitted without undue effect on identifying the investment alternative that has the greatest transportation economy.

When considering taxes in respect to cost-benefit analysis, the general practice is to focus on only the current or near future cash flows of taxes. This leads to total neglect of the fact that the current retail price of any commodity has buried in its price an accumulation of taxes of all sorts that are paid by all handlers of the commodity from raw materials to final sale to consumers.

25. Insurance: The five types of insurance listed in Table 1 are discussed here. In each type of insurance, the factors that relate to cost-benefit analyses, in connection with traffic-accident injuries and death, are the actual costs of accidents, premium payments by policy holders, claims paid to policy holders, and expenses of overhead, administration, and operation (simply called overhead hereafter). In any insurance company, the total of claims paid will not equal the total of premiums received because of the overhead expenses. Because of this, the cost of overhead becomes an item that varies with the number and character of the accidents that result in claims for reimbursement.

Risk insurance expenses, as may be affected by traffic accidents, must be carefully evaluated to arrive at the net cost as related to the traffic-accident cost. If the total of premiums was used in place of the net cost of the accident, it would be necessary to adjust this total for any overcost or undercost of the accident as compared with the claims paid. Thus, the direct method of using cost of accident plus insurance overhead is the preferred procedure.

In cost-benefit analysis, the procedure should be to determine the current costs of accidents and insurance overhead and use these in the base alternative. Then, on the basis of effecting through the proposed highway or vehicle improvement a reduction in the severity of accidents or the number of accidents or both the existing accident cost would be adjusted to the proposed conditions, together with a corresponding adjustment in the insurance overhead cost.

In theory, a reduction in the rate of traffic fatalities through improved safety measures should result in an increase in longevity and, therefore, a reduction in the life insurance premium for a given policy. Because of the millions of persons insured, the effects on policy premiums would be so small that

no real errors will result from ignoring this economic gain in cost-benefit analyses. Any determination of the true cost would require considerable research and calculations, and the effort would have doubtful utility.

A reasonable, practical, and technically acceptable method of handling all insurances that relate to traffic accidents is to determine the actual total cost of the accident and add to this amount the total overhead cost of the insurance policies in effect. The overheads should be based on their marginal cost, and the overhead cost should reduce as the number of accidents and their severity are reduced by improved highways.

26. Exchange of assets after death: A deceased person may have left an amount of worldly property to be distributed to heirs, friends, and others as directed by the will or by the court. There may be financial, business management, and legal affairs to be handled by the executor of the estate. This overall settlement requires many types of expenditures borne by the estate. Such expenses may properly be considered chargeable to the accidental death. Such costs, however, should be discounted by the time factor between the date of death and the date of probable future death from other causes. Whether the estate would increase or decrease in dollar amount in this time period would be difficult to determine. Unless there are specific evidences to the contrary, the estate at the date of death could be chosen for any necessary calculations.

One special item with respect to personal values of estate property concerns those goods that to the deceased and his or her household family or dependents provided considerable satisfaction to daily living. On death, these properties may be disposed of through estate settlement. These goods could be motor vehicles, furniture, recreational supplies, forms of arts and crafts, and heirlooms. The concept is that these goods would be sold after death and would bring an income considerably less than the value to the owner before death. Another concept involved is that, because the deceased's probable future earnings are to be included, it is logical also to include the effects of past earnings that at the time of death were in the form of non-income-earning assets.

There is no way to determine the economic value of these goods to the deceased, because there are certainly no records. Original cost or market value may be determinable, but personal value is not.

Selling such goods at market price does not result in any economic loss to society. The sale merely transfers the utility of the goods from one owner to another. There is no consumption of resources and no creation of resources. Values and satisfactions of ownership of the properties could be greater to others than to the deceased at time of death. This possibility is high with respect to relatives, which implies that, if consideration is to be given to such personal property, then equal attention must be given to gains as well as to losses.

As far as market prices are concerned, it must be presumed that the owner--the decedent--has already used up the service of these properties down to the level of market price at the time of death.

Thus, it is necessary to give serious attention to the differences between price, cost, and value. Highways cannot be built on the basis of values to owners of properties. The market price is the only sound base for such analyses. Cost-benefit calculations must be based on market prices and conservation of resources. What the decedent, before death, and the relatives and friends, after death, would pay in dollars for these personal goods is a biased value judgment that has no role in cost-benefit analysis of proposed highway-improvement investments.

27. Family services to the home: In case of the injury or death of a housewife or other family member, there may be economic loss to society when they cannot perform their normal duties in the home. Total duties in the home are such a miscellaneous and varied set of tasks that there is no market experience for the hire of a person to perform them. The normal hire of housemaids, cooks, and yard workers does not cover the range of duties of family members for their joint benefits. To include these contributions in the economic analysis, they could be considered as the equivalent of an employed worker at a wage prevailing for the type of work the housewife or other family member is qualified to handle.

Obviously, these family accomplishments have economic value to the family and allow part of the income from wages to be spent on other family needs and desires. But should they be included in the cost-benefit analysis for proposed highway improvements? There is no conservation of resources involved. The work simply enables the family to spend less on household operations and more on other items of choice; it is a reallocation of expenditures or savings. The economic society at large is not affected through production or consumption of resources; only the internal home is. Many of these accomplishments by family members could be priced at market rates but, in the end, there does not seem to be any justification for their use in the form of an economic cost reduction that could be used to support highway-investment improvements. In case of a fatality, the home will continue to accomplish the tasks as needed and will adjust to the absence of the deceased member. For major tasks, however, these household labors could be priced at market rates and the resulting dollars be added to earnings outside, if any, as commonly has been done in the past with reference to the housewife.

Perhaps the most important factor related to these home and household tasks by family members is that the activities do not end with the death of a family member. To the extent that the tasks are needed, they will be performed by one of the living family members. This family work performance is somewhat in the same category as the work done by any employed person, in that the work done will continue to be done after death of the current employee should there be economic reason why it should be continued.

28. Services by neighbors and others without charge: In times of distress, relatives, neighbors, and friends perform a wide variety of services for a family and do so at their own expense and on their own time. Although these services have economic cost and are an economic gain to the family, their identification and pricing is highly uncertain. The grand total would also be small in relation to the total economic cost of a traffic accident. These neighborly services are closely related to the home services performed by family members. The total analysis would be relatively unharmed by complete omission of these services, which are distinguished by their sudden initiation and short duration in time. They do consume the resource of time, but the time used probably does not interfere with other desirable accomplishments by the persons performing them.

29. Training of job replacement: In all employment types of activities, the list of employees is in a state of continuous change for many reasons--illness, retirement, resignation, labor-force reduction or expansion, discharge for cause, and death. Management is continuously faced with training newly hired employees or employees given changed assignments. The expense of this training is absorbed in labor productivity, supplies, and other forms of overhead when the training is not performed in an organized training department.

The death of an employed person often results in the expense of training a replacement employee. Such expense is justifiable in a cost-benefit analysis, provided that it is discounted over the years the employee would be expected to remain in the position.

30. Cost of working and payroll burden: There are many items of expense to the employee working for pay outside the home and to the employer that are associated with the activity of working. For the employee, these include such items as transportation, clothing (ordinary and special), tools and instruments (in the crafts especially), professional society memberships and union dues, travel and conventions, job-oriented literature, self-supported continuing education, and training.

For the employer, there are the fringe benefits, payroll taxes and insurance of all categories, and normal overheads that relate to employee affairs (e.g., payroll, statistical reporting, and compliance reports).

Which of these expenses are includable in a cost-benefit analysis of the economy of measures to reduce the cost and number of traffic accidents? If includable, just how are the items to be priced and calculated?

To begin, these items should be viewed in three ways: (a) for temporary off-duty accidents, (b) for permanent types of injury, and (c) for traffic-fatality accidents.

The points to look into are these, Is there a change in economic production or consumption of resources? Will there be, in the future, any change in the magnitude of the gain or loss related to these items in terms of the principle of with and without or in comparison of a pair of alternatives?

The personal working expense items of the employee would not be expended after death any more than would consumption of food, clothing, shelter, and other expenses of living. But if his or her position in employment is retained by the employer, the working expenses continue (although by and for another individual), so the societal economic costs and consumptions are not altered. To include these personal working cost items in the before-and-after data (with and without) in both of the alternatives would make no difference in the final calculated answer; thus, the item becomes neutral in its effect. However, if the concept chosen is that of finding the present worth of future estimated earnings less the present worth of the probable future expense of maintaining that income, the costs of working expense should be included in the interest of consistency. This inclusion applies only to permanent disability and death. For a few days or weeks of temporary absence from work, these items could be omitted in the interest of simplicity and because their total would be minor. However, those expense items not incurred after death become a gain and offset part of the cost of maintaining the worker.

The employer's expense of maintaining the employee in the position could be excluded in its entirety because it may be assumed that a replacement employee will incur the same support. The expense items then become continuous within the employment and do not alter the community economic production or consumption after the accident as compared with before the traffic accident. This conclusion applies to all three levels of severity of the accident.

31. Nonproductive time of employee absence and position vacancy: Because most employment is on a continuous basis, except strictly seasonal and sports job engagements, employers are concerned with how to keep production up to normal for those days employees are not at work. This includes situations of temporary disability, permanent disability, and death.

The general practice in economic analysis is to calculate wages lost at the dollar equivalent of the normal wage as a charge against a traffic accident that necessitates absence from work for a few hours, days, or even weeks. When the time reaches or goes beyond a few months, then other procedures are considered. First, look at the short-term absence from work. For economic analysis, the factor of importance is whether there is, in reality, any loss in production compared with payroll. Two factors are involved with respect to payroll. Is extra help provided at extra payroll expense, and does the pay of the absent employee continue under some form of employee agreement or employer policy? Does or does not the employee suffer a loss of income? Does or does not the employer suffer a loss of production? Is the work normally produced by the absent employee produced by fellow workers along with their own work? Is overtime work paid for or donated? Is the normal workload of the absent employee just held up? Is compensation in any way covered by insurance?

The answers to these questions provide the information on how to handle this temporary absence from work in determining the cost of an accident. Should there be no actual loss in production regardless of how or by whom the work is performed, then, in the sense of economic production, there can be no reduction. And likewise, there would be no change in consumption because the factors of economic consumption have not changed.

All forms of employment have daily absence from work for a variety of reasons--sickness, marriages, funerals, sports, family business, vacations, and social and business meetings. Business is geared to this and so successfully that, over the year, there is no particular lack of performance because of these absences from work. At least the performance is as expected and a few days of absence because of a traffic accident results in no positive, identifiable gain or loss to the employment, as compared with the accident not happening. On this basis, there is no real economic justification for including in the cost of a traffic accident an item for any decrease in economic production.

The payroll factors can be considered separately. If the employer continues the payment of wage, then the worker has lost no income. If the wage is continued through some form of insurance, then, economically speaking, there could be a justified charge in the cost of insurance overhead to maintain the wage income.

If the employer hires help or pays overtime to produce the work and, at the same time, continues the wage of the absent employee, this extra wage payment would be a charge against the accident. But if the absent employee is not paid in any form and additional hire is paid, then, although the absent employee does suffer a loss of wage, the wage is paid to others and there is no net loss to society, just a redistribution. But if the absent employee is not paid and the wage is not paid to others, this reduction in total wage could be a charge to the accident on the basis that the money available for consumptive spending has been reduced without a comparable reduction in economic production.

The concept of wages lost and its many factors is a situation that deserves a study in depth to determine the proper handling of the item in cost-benefit analysis. Under current practices, policies, and laws, the wages-lost item could be omitted without injustice to the results of the economic analysis. But if wages lost is an economic cost, why then is not wages earned an economic offsetting gain?

32. Economic cost of death: Throughout this paper, I have referred to the major decision of determining the dollar amount that should be used in economic analysis to represent the economic cost to

society of a traffic fatality. The past proposals need no further discussion, and neither do the basic principles and concepts. As is evident here, I reject all value-based concepts and accept concepts that are based on economic production and conservation of resources. But if proposed improvements in highway transportation systems are to be examined for the relative economy of alternatives, a dollar sum for fatalities is a factor that must be included.

CONCLUSION

This paper presents three main bodies of information: (a) objectives and main concepts of economic (cost-benefit) analysis, (b) principles and concepts on which the economic analysis should be based, and (c) identification of 32 main consequences of traffic accidents and discussion of their role in economic analysis.

The purpose of these three sections is to provide a base for a discussion of the factors involved in determining the economic cost of traffic accidents and their role in an economic analysis of the transportation economy of proposed highway-improvement investments.

The next phase will be to bring persons from all concerned disciplines to a study of just how the entire system of economic analysis should be handled, specifically including the role of traffic accidents. An important and complex phase will be to agree on which of the accident factors (and others not included here) should be included in the analysis and what pricing procedures should be used.

Finally, there will still remain the large task of data gathering. In this final phase, the process would have the advantage of knowing ahead of time just what to look for and how the findings would be used in the economic analysis.

Although I have taken rather definite positions on the factors in the economic analysis procedure, I have done so on the basis that this definite position will be more helpful to the workers in the next phases than would mere statements of problems. I do not infer that I am correct and others are wrong. I am seeking the best practical answers based on definite principles, theories, consistency, and proven economic consequences.

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Discussion

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Winfrey's paper provides an excellent listing and discussion of many of the costs associated with traffic accidents. Rather than criticizing this listing, we would like to question his basic approach to the evaluation of accident costs, specifically his contention that analysis for the economy of highway transportation investments should "exclude all factors that are not related to the conservation of resources." In addition, we would like to draw attention to economists' research on the value of life saving, much of which has been ignored in recent evaluations of traffic-accident costs.

Jones-Lee (3) and others (4,5) have reviewed different methods of evaluating the value of life that should be used in benefit-cost analyses. Based on his review, Jones-Lee concluded that an anticipated reduction in the mortality rate during some period of time affords any particular individual three major components of value: (a) a reduction in his or her share of the real resource costs occasioned by the death of others, (b) a reduction in his or her share of the loss of net output owing to the death of others, and (c) a reduction in the risk of his or her own death or the death of anyone cared about.

Similar comments apply to an anticipated reduction in the rate of nonfatal accidents (3, p. 147).

For the purposes of cost-benefit analysis, the appropriate value to place on the anticipated saving of one (anonymous) life during a particular time period is (in addition to avoidance of real resource costs and losses of net output) given by the average, over the relevant population, of the marginal value of a decrease in risk. Insofar as the concept of a value of life has any relevance in the analysis of safety improvement, this is the appropriate interpretation of such a concept. Other definitions of the value of life, such as the present value of anticipated future output per capita or court awards to the relatives of accident victims, are irrelevant for conventional cost-benefit analysis (3, pp. 149-150).

Jones-Lee also points out that, as far as the existing literature is concerned, the most neglected component of the value of life is the value of the reduction in the risk of the person's own death or the death of anyone he or she cares about. This neglect has also been pointed out by McFarland (6), who referred to this element as the "value of a person's life to himself." McFarland includes four items in his cost of a traffic fatality: (a) cost of lost resources (e.g., property damage and medical expenses); (b) present value of future gross production net of the deceased's consumption; (c) cost of other pain and suffering by the community, not accounted for by lost net output; and (d) value of the person's life to himself or herself. He also points out that "most individuals pay taxes which are used for public goods, and thus, by the nature of public goods, the person contributes more than he consumes since his consumption takes nothing from others." To the extent that the person's output supports true public goods, the benefits to society may be substantially more than this portion of his or her income, even though the opportunity cost of losing this support would be (roughly) the amount of taxes paid. Winfrey's paper, with its emphasis on evaluating only economic factors, economic consequences, and conservation of resources, does not adequately address Jones-Lee's problem of determining the value of life and thus is an incomplete statement of the problem. Although Winfrey does include a short discussion of the individual person's evaluation, he discusses this evaluation in terms of asking "people what they would take in current dollars to avoid death" and concludes that "even if the approach were successful, the answers would not deliver the economic answer that is sought." Winfrey distinguishes between what he calls economic concepts and value concepts. It perhaps should be pointed out, however, that this distinction, and the way that it is made, contradicts the use of these concepts by econo-

mists; for economists, the economic concept is the value concept.

Most states currently use one of three types of values in calculating accident costs.

1. Direct costs: Several state studies have developed the direct costs of traffic accidents; these direct costs basically include only one of the three items listed by Jones-Lee, the cost of lost resources.

2. National Safety Council (NSC) values: The NSC provides estimates of the costs of accidents of different severities; these costs include the cost of lost resources and, for fatal accidents, the discounted value of future production less consumption for the deceased. California uses a similar concept, and their costs have been reported extensively.

3. National Highway Traffic Safety Administration (NHTSA values): NHTSA values include direct costs and the discounted value of future production (not net of consumption as is the case with the NSC values).

The first method, based on only direct costs, provides values that are ridiculously low, usually less than $30 000 for fatal accidents, because no value of life to anyone is included. The NSC values can be interpreted as including the direct cost of lost resources plus a value that at least partially represents the value of the deceased to others, represented by his or her contribution to others as measured by net production. The NSC values do not include any value for the person's self worth. The NHTSA values do not subtract the deceased's consumption, and this part of their value can be interpreted as being a partial representation of self worth. Recent research, however, indicates that the present value of future consumption underestimates the value of a life; thus, even the NHTSA values underestimate the accident costs that should be used in benefit-cost analysis.

It may be concluded, therefore, that neither the NHTSA values nor the NSC values are appropriate for use in benefit-cost analysis. However, of the two, the NHTSA values are preferable because they include a measure of the value of the person's self worth (the present value of the person's expected earnings that he or she would be expected to devote to his or her own consumption expenditures). The NSC values, by subtracting out this measure, give clearly inadequate representations of the costs of accidents.

Values based on market approaches are preferable to the NHTSA values. Recent theoretical work has shown with certain reasonable assumptions that the amount a person will pay to reduce his or her probability of being killed is greater than the amount that would be calculated by multiplying that reduction in probability by the present value of expected future consumption. More specifically, Conley (7) concluded that, in general, the value of life saving is greater than the discounted lifetime labor income and, in early and middle adulthood, greater than the discounted lifetime consumption.

Although there are both methodological and empirical problems associated with market-oriented methods, recent research indicates that the theoretical problems are being solved. Also, recent empirical research indicates that market-oriented approaches can be used to calculate reasonable values. Among the recent studies that have calculated values for life are

1. Carlson--compensation to pilots for risky flying--$200 000 to $1 000 000 (8),

2. Jones-Lee--from questionnaires about airline choice--approximately $6 000 000 in 1975 dollars (3),

3. Thaler and Rosen--risk premium for working in risky occupations--about $260 000 in 1975 dollars (9),

4. Ghosh, Lees, and Seal--speed of travel on British motorways--about $260 000 in 1975 dollars (10),

5. Melinek--study of choices between crossing a road directly or using a safer but slower subway crossing--about $340 000 in 1975 dollars (11), and

6. Blomquist--study of motorists' decisions to use seat belts--$257 000 in 1975 dollars (12).

These studies, especially Blomquist's, which appears to be both the best and also the one that is most relevant to traffic accidents in the United States, indicate that a value of life that is acceptable for current use can be given. Although more research, both theoretical and empirical, is indicated, the evidence available at this time suggests that a value of about $257 000 in 1975 U.S. dollars would be appropriate for use as the value the average motorist places on the value of his or her own life to himself or herself. The U.S. consumer price index can be used to update this value to current dollars.

To derive total values of life saving to be used in benefit-cost studies, this value should be added to the value of lost resources (i.e., items such as the costs of medical expenses and property damages) and the value of the person's life to others [which, at this time, perhaps can best be estimated as the value of the person's future production less consumption (6)]. [However, it should perhaps be pointed out that recent research has given an indication of the value to relatives of a person whose life is at risk. By using the national age-sex distribution in Great Britain, Needleman (13) has calculated that the total estimated valuation of relatives is 45 percent of the valuation of the person himself or herself.]

Thus, the $257 000 (1975 dollars)/life saved should be added to the direct cost of the accident and the cost to others. For example, the NSC values and also the California (14) and Burke's (15) values, should have added to them $257 000/fatality. To derive costs per accident for different types of fatal accidents, the average number of fatalities per accident must be multiplied by the $257 000 (after updating).

The cost per fatal accident can thus be derived roughly as follows: (a) use the NSC cost per fatal accident of $113 500 in 1975 dollars as representing the costs of lost resources and of lost net output and (b) use the average of 1.17 fatalities/fatal accidents (14), together with a value for life, to the person whose life it is, of $257 000, to derive a cost for this item of about $300 700/accident. Adding $113 500 and $300 700 gives approximately $414 000 as the cost per fatal accident in 1975 dollars. Probably the best estimates to use with these costs for the costs of injury accidents and of property-damage-only accidents are those developed by NHTSA, which are $14 600 and $650 respectively in 1975 dollars.

Using 158.6 as the consumer price index for April 1975 (with the 1967 base of 100) and updating the above values to February 1978 (when the consumer price index was 188.3) gives the following approximate accident costs for 1978.

Type of Accident	Cost ($, 1978)
Fatal	491 000
Injury	17 300
Property damage only	770

Because NHTSA reports the loss of gross output rather than net output, the cost per fatal accident cannot as readily be derived from their values, but presumably this could be done given their basic data.

One difficulty in using the NSC and NHTSA accident-cost values should be emphasized. Neither of these sources gives costs by type of accident (such as head-on, rear-end, or angle collisions), nor do they give breakdowns by type of road (such as two-lane or four-lane undivided), nor by type of area (urban, suburban, or rural). Because of this lack of detail, persons using their costs often use the same cost for a fatal pedestrian accident as for a rural, head-on accident (only one person may be killed in the pedestrian accident but there are an average of 1.4 fatalities and 1.6 nonfatal injuries in rural head-on accidents). Thus, for evaluating accident countermeasures, it may be more desirable to update, by using values such as Blomquist's, accident-cost values such as those for California (14) and Texas (15), rather than trying to modify the NSC or NHTSA values. It should be pointed out, however, that the NHTSA approach for evaluating costs of injuries may be preferable to that used in the state studies and, ideally, the approaches could be combined or better methods could be developed of evaluating the injury costs associated with different types of accidents, taking into account that more severe injuries are associated with certain types of accidents.

Another point perhaps deserves mention; at the 1978 Transportation Research Board session on accident costs, the NSC representative defended the NSC values on the bases that they are conservative, have become widely accepted, and are practical from a political standpoint. However, these values, by subtracting out the individual's expected future consumption, omit any measure of the value of the potentially deceased's life to himself or herself. Although the NSC values reflected the state of the art at the time they were first published, recent research has shown that they no longer do so; neither does the approach reflected in Winfrey's paper. Use of these values can lead to a misallocation of resources (safety funds).

Although further research on the cost of lost resources (property damage, medical costs, and such) may be needed, a more immediate need is for research along the following lines:

1. Values for life, indicating the value of the person's life to himself or herself, should be added to appropriate values for the avoidance of real resource costs (direct accident costs) and losses of net output to derive traffic-accident costs that can be used to evaluate safety programs;
2. The market approach should be used to validate and extend to other situations the values developed to date; and
3. Costs of accidents should be developed that could be used for specific countermeasures; often, the same costs are used for widely varying types of accident countermeasures, even though different countermeasures are intended to affect accidents of different types that have significantly different expected numbers of fatalities and injuries per accident.

This research probably could be accomplished by using existing data and relatively modest funding. This is in marked contrast to the funding of $1 million or more that many people believe is currently justified for developing better estimates of the costs of such items as property damage and medical expenses. It is our contention that research should attempt to derive answers that are vaguely right, rather than precisely wrong.

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Author's Closure

The discussion of my paper presented by McFarland and Rollins is most welcome. Even though I totally disagree with their concept and philosophy, its publication along with my paper offers the readers a ready comparison of the two approaches--the economist's value concept and the engineer's cost concept.

The economist can, by personal judgments, derive a value of human life if he or she wishes to do so. Such value has been rightly ignored in cost-benefit analyses because it is wrong to base the investment in highways on personal judgments of dollar values as compared with market-based dollars. McFarland and Rollins do not state any other application of the dollar value of a life. It is assumed that the value of life as determined is applicable to all of the 2 000 000 deaths in the United States per year.

McFarland and Rollins do not say why the cost concept is wrong because it involves the cost, market price, and conservation of resources. Nor do they say why their value concept is to be preferred to the cost concept. In fact, they do not recognize that there is a difference between cost and value-- these words do not have the same meaning. An analyst should not commit the crime of adding personalized dollar values and marked-price dollars. Such arithmetic makes no more sense than adding U.S. dollars to Singapore dollars just because the two monies are called dollars. In cost-benefit analyses, highway construction dollars and motor-vehicle operating-cost dollars cannot be added to personalized dollar values of a life.