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Authors of the Papers in This Record

Evmolpidis, V., Doxiadis Associates International Co. Ltd., 24 Stratiotikou Syndesmou Street, Athens, 136, Greece
Gordon, F., Department of Civil Engineering, Virginia Polytechnic Institute and State University, Blacksburg, VA 24061
Henion, Loyd, Oregon State Department of Transportation, Transportation Building, Salem, OR 97310
Hobeika, Antoine G., Department of Civil Engineering, Virginia Polytechnic Institute and State University, Blacksburg, VA 24061
Hoffer, George E., Department of Economics, Virginia Commonwealth University, 901 West Franklin Street, Richmond, VA 23284
Kimboko, Andre , Oregon State Department of Transportation, Transportation Building, Salem, OR 97310
Kutz, Scott A., Fiscal and Systems Management Center, Pennsylvania Department of Transportation, 1216 Transportation and Safety Building, Harrisburg, PA 17120
Lindley, James T., Old Dominion University, Norfolk, VA 23508
Manidis, P., Doxiadis Associates International Co. Ltd., 24 Stratiotikou Syndesmou Street, Athens 136, Greece
McLeod, Douglas S., Environmental Science and Engineering, Inc., P.O. Box 13454, Gainsville, FL 32604
Muthusubramanyam, M., School of Civil Engineering, Purdue University, West Lafayette, IN 47907
Ravindran, A., School of Civil Engineering, Purdue University, West Lafayette, IN 47907
Sinha, Kumares C., School of Civil Engineering, Purdue University, West Lafayette, IN 47907
Soilemezoglou, G., Doxiadis Associates International Co. Ltd., 24 Stratiotikou Syndesmou Street, Athens 136, Greece
Tran, Thanh K., Department of Civil Engineering, Virginia Polytechnic Institute and State University, Blacksburg, VA 24061
Weiss, Willard D., International Engineering Company, Inc., 180 Howard Street, San Francisco, CA 94105

Abridgment

Programmed Project Management in Pennsylvania: Statewide Data Access

SCOTT A. KUTZ

One aspect of the Pennsylvania Department of Transportation's commitment to provide a vastly improved transportation program to the commonwealth is the implementation of responsible and practical management systems. One of these systems, the project management system (PMS), is making major contributions in the area of planning and scheduling the use of dwindling resources that must be used efficiently to maintain and restore an extremely large highway system. PMS is a computerized information management system that integrates project-related data from the engineering and planning communities with accounting data from the financial community. These data are stored in a common data base and are accessed by users located in the department's central office and the 11 engineering districts. PMS has enabled people in various branches of the department to obtain consistent information on all projects because everyone has access to the same data base. The project-related and accounting-related data maintained in PMS enable it to track the physical and fiscal progress of the projects on the department's program. PMS employs on-line updating to make changes in the project data. It also serves, therefore, as a powerful communications tool because a change made anywhere in the state is instantly available to all other system users.

At the beginning of the current administration, Pennsylvania's transportation program was so far behind that of other states that extraordinary measures were required to gain control of program management. On a system that includes 45 000 miles of highway and 27 000 bridges, deferred maintenance and lack of good management controls had created a crisis situation. In addition, the revenues and buying power of the department of transportation were cut severely by the combined effects of inflation and reduced fuel consumption.

One of the many new management initiatives introduced to address these difficulties was the development of a project management system (PMS). PMS is a computerized information management system that integrates project-related data from the engineering and planning communities with accounting data from the financial community. It employs a centralized data base and data can be updated on-line by users in the department's central office and in its 11 engineering district offices statewide. As such, PMS is essentially an electronic filing cabinet that contains the equivalent of an electronic manila folder for each project on the state's program.

The storage of project data in a common data base for the entire state has, for the first time, enabled people in various branches of the department to obtain consistent information on all projects. The classic problem of getting different answers to the same question has been virtually eliminated.

The on-line updating also permits PMS to serve as a powerful communications tool because a change made from anywhere in the state is instantly available to all system users. Many time-consuming manual tasks are being automated through the use of PMS data, which results in significant savings of staff time.

SYSTEM OBJECTIVES AND CONCEPTS

PMS has the following objectives:

1. Identify projects on the department's program and monitor the status of their federal funding;
2. Track the physical and fiscal progress of each project by maintaining information concerning previous activity, current status, and future estimates;
3. Eliminate confusion that could result from multiple lists of project-related information by maintaining a common data base for statewide use;
4. Provide a communications tool that will provide instant transmission of project information to all system users; and
5. Enable information requests to be met by inquiring into the data base (maintained as part of daily operations) instead of short-fuse telephone inquiries to the engineering district offices.

System Concepts

The programmed project managed by PMS is the aggregate of all phases (design, utilities, right-of-way, and construction) and incorporates all federal agreements that are used across the phases. The relation between a project and the federal agreements for its phases is depicted in Figure 1. At the state level, the federal agreements are essentially charge numbers in the department's accounting system. The preparation of management-level information on any particular project requires that PMS reach into the entire population of accounting charge numbers, extract only those that relate to the project in question, summarize the detailed information (costs incurred and future cost estimates) contained with each of these charge numbers, and report the aggregated information.

Data Integration

To accomplish the above summary function, PMS integrates data that historically has been separate--that maintained by the engineering and planning communities and that maintained by the financial community. This integration is demonstrated by the links in Figure 1 and the diagrams in Figures 2 and 3. Figure 2 shows the situation in which there are two distinct communities of data: the engineering and planning community (big picture) and the financial community (detailed picture). By using the linkages shown in Figure 1, PMS provides the means for integrating these data (Figure 3). As shown in Figure 3, someone in the engineering and planning community can inquire about the item that is familiar (a programmed project) and, without knowledge of the specifics of accounting data, he or she receives summarized data selectively extracted from the accounting system. Similarly, a person in the financial community can inquire about the item most familiar (accounting charge number) and, without knowledge of the specifics about programming projects, he or she receives information about the programmed project to which the accounting charge number relates. The ability to traverse the links in either direction and move, selectively, from detail to aggregate or aggregate to detail gives PMS its power as an extremely useful management tool.

Any single project can have many related accounting charge numbers (federal agreements) across its phases. To accommodate this one-to-many situation, PMS employs two separate data bases (linked by pointers shown in Figure 1): one for programmed projects and one for accounting charge numbers. The

Figure 1. Relation between projects and federal agreements.

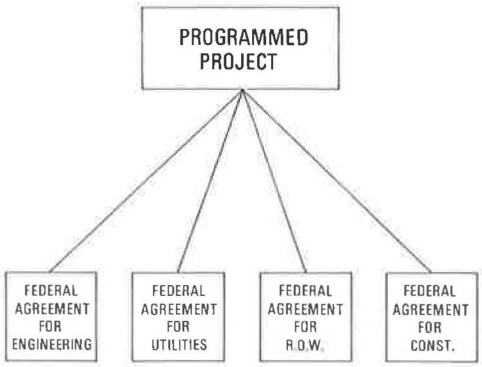


Figure 2. Two communities of project-related data.

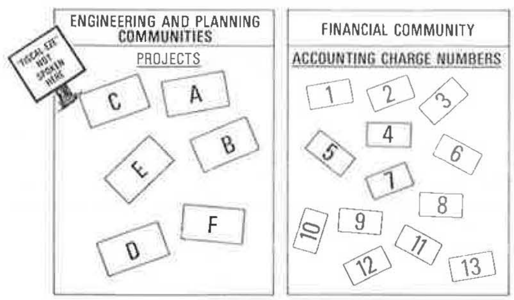
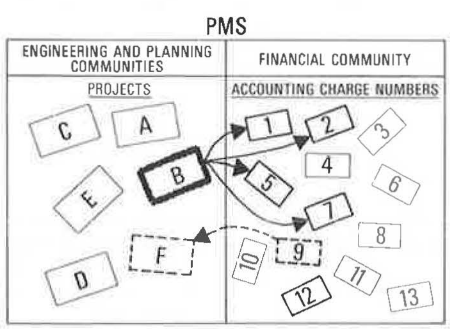


Figure 3. Data integration and retrieval supported by PMS linkages.

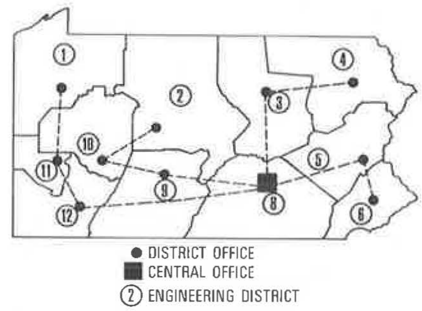


general data categories contained in the programmed project data base are basic project information, narrative, project location, related accounting charge numbers (links), overall project costs, milestone achievement dates (physical progress), and senatorial and legislative districts. The general data categories for the accounting charge numbers are basic accounting information, narrative description, related programmed projects (links), prior costs, current costs, and estimated future costs.

PMS IMPLEMENTATION

PMS was designed, coded, and implemented by using department personnel and computer resources. System development started in June 1979 and the extraordinary transportation situation described in the introduction to this paper required that the system be designed and implemented within six to seven months. By overlapping the raw data collection and the beginning of the data entry with the development of the test system, implementation of the production

Figure 4. PMS communications network.



system was possible in January 1980. The initial user's training was conducted during January and early February 1980. At the same time, a communications network was installed that connected all engineering district offices and the central office bureaus to the main computing facilities in Harrisburg (Figure 4). In February 1980, the engineering district offices began updating their respective portions of the data base. Since that time, system users have been involved daily with data entry, update, and extraction, and the PMS staff has been working on system maintenance and enhancement.

System Structure and Report Preparation

The PMS operational flowchart is shown in Figure 5. The focal point is the two data bases: one for programmed project data and one for accounting charge number (SPN) data. The upper portion of Figure 5 shows that data enters the data bases either through on-line data entry from system users or from an interface with the department's accounting system. The lower portion of the flowchart shows that reports are extracted either directly from the data bases or from fixed-length records written to a separate storage device. These records contain data merged from both data bases and were developed to meet special reporting requirements. The significant point is that, although some data manipulation is accomplished with conventional programming languages (PL/I), all reports generated for system users are created by using a standard report-generating package. One of the main selling points for PMS is that it is flexible enough to meet almost any reporting need (within the limitation of available data). Seldom will two system users need exactly the same report (differences would occur in selection criteria, sort sequences, output formats, and time period covered) and the use of the standard report-generating package has enabled the preparation of literally hundreds of different reports in response to user requests.

System Users

PMS is a lot of things--data bases, reports, computers, display terminals, printers, and telephone lines. But most of all, it is people. The computerized information system is not an end in itself but, rather, what the people who use the system do with the information it stores determines the success or failure of the system. Producing a user-oriented system has been a continuing goal throughout the development of PMS.

Most of the more than 200 system users have never encountered a computerized system before and, as might be expected, many of them had a great deal of apprehension about getting started. PMS was designed for easy use and this, combined with hands-on

Figure 5. PMS operational flowchart.

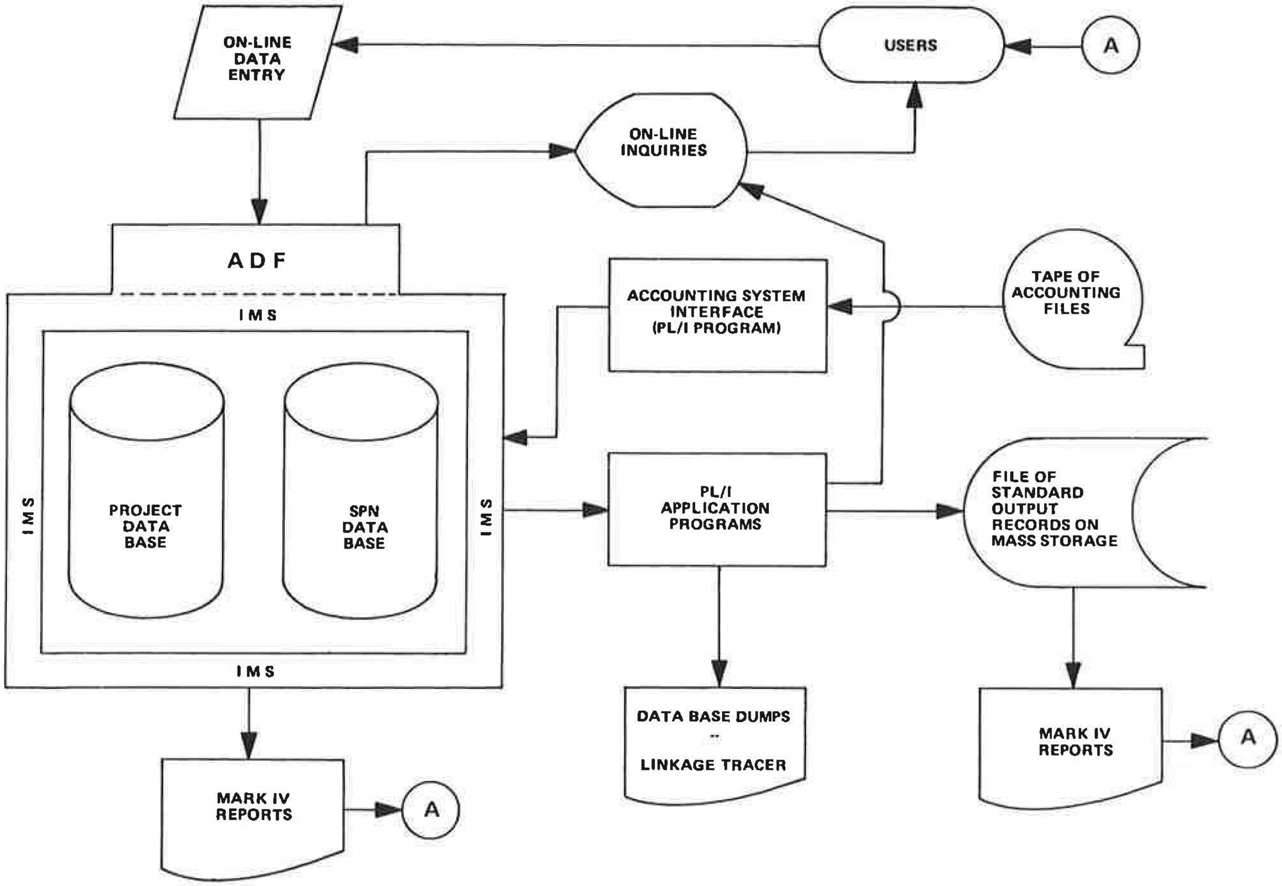
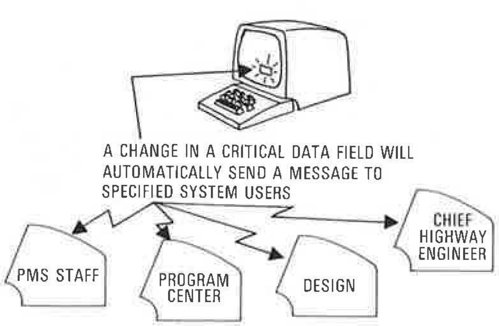


Figure 6. Automatic message sending.



training and a comprehensive user's manual, has enabled most people to become proficient without a great deal of difficulty. The list of users includes the secretary, district engineers, most of the executive staff, fiscal personnel, engineering and programming personnel, and support staff.

Security

The commitment of the department to PMS in terms of personnel, time, and resources, makes security of the system a major consideration. This includes both physical security of the data and necessary security measures to prevent invalid data from entering the data base.

In the area of physical security, daily data base backup copies are made and stored on computer tape. The tape copies are first migrated to a fireproof vault and eventually to an off-site storage location to ensure that a means of recovering the data bases will always be available.

Protection of the data bases during normal operation involves control of system access and data quality. Each user has a unique identification code that must be used to gain access to PMS. Within that authorization, each user has a profile that defines his or her capabilities (retrieve, update, add, or delete) for each data entry screen (transaction). Each engineering district only has access to its own projects for update. In addition, individual data fields are checked for validity. Invalid data are rejected and must be corrected prior to being accepted by the system.

Automatic Message Sending

One of the objectives of PMS is to serve as a communications tool. A typical problem is that a change in a project schedule or estimated cost occurs, but only a few people find out about it. Automatic message sending facilitates the dissemination of this critical information, as shown in Figure 6. Any change in a specified data field causes a message to automatically be sent to any number of users on the message's mailing list. Typically, these messages are used for notification of project additions or changes in a project's schedule or estimated costs. Users may access their messages through the computer terminals and are also given a daily printed listing of these messages for a permanent record.

On-Line Inquiry Capabilities

More than 3700 individual programmed projects are in PMS and any single district office has between 250 and 650 projects. It would be difficult and time consuming to sequentially search through all the projects every time a list of projects that have some common characteristics was needed. The PMS inquiry system was developed to permit users to selectively interrogate their portions of the data base. The inquiry capabilities are in three areas:

1. Select all projects that meet criteria specified by the user;
2. Select all projects that will achieve a certain milestone date (physical progress) within a specified time frame; and
3. Select all projects that have missed specified milestone dates by more than a tolerance specified by the user.

The PMS inquiry has proved to be an effective tool for enabling managers to focus their attention on a subset of the projects within their responsibility instead of having to contend with large listings of projects. A hard copy of the inquiry results can be obtained on printers located with the computer terminals. In this regard, the PMS inquiry also functions as an on-line report generator.

PMS APPLICATIONS

Physical progress of the programmed projects is tracked by using a series of milestone achievement dates that range through preliminary design, right-of-way acquisition, utilities, final design, letting, award, and the construction phase. The milestone dates are posted into the PMS as either estimated dates, actual dates, or not applicable (for a particular project). For the most part, engineering district offices enter the estimated dates but many of the actual dates may only be entered by central office bureaus. The prime concern here is to capture a data element at its source and have it input there. For example, the Bureau of Highway Design receives notification of federal approval of funds for a specific project phase so it enters the actual approval date.

Scheduling the Obligation of Federal Funds

In addition to the milestone dates, project cost data (broken into federal, state, and other shares) is available in the PMS. PMS accesses the estimated costs and estimated federal obligation dates simultaneously to place the federal fund requirements into the appropriate federal fiscal year (or month within the year) based on the estimated obligation date. These data, summarized across all projects, result in the obligation plan.

Developing the Letting Schedule

An important document prepared by the department is the letting schedule, which shows the bid dates for various projects. The ability to meet letting schedules will have a significant impact on the department's ability to manage its cash flow and accomplish the needed physical work on the highway system. By using a processing mode similar to that described above for the obligation plan, projects available for letting in a specified time frame are evaluated in light of established criteria (achievement of required approvals) and, if all criteria are met, placed on the schedule for letting within a specified month. The letting schedule is prepared every three months for the following six-month period.

Planned Applications

Several other applications can be implemented from PMS data. The department is developing techniques for producing a 12-month forecast of cash needs for payments to contractors for both construction and maintenance projects. Plans are also under way for using estimated data on future expenditures to identify sources of accrued unbilled costs before these costs actually occur. Early identification will permit timely corrective action. Another tedious process that can be aided by PMS is the development of the annual Title 23, Section 105 of the U.S. Code program. This program requires submission of all federal-aid projects for which federal obligation will be requested within a given fiscal year. This can be prepared by combining narrative, cost, and scheduling data for the individual projects.

CONCLUSIONS

The implementation of PMS is one of many steps taken by the Pennsylvania Department of Transportation to address the difficulties created by the current tight fiscal constraints, the effects of poor management in the past, and the pressing maintenance needs of one of the largest highway systems in the nation. PMS is making major contributions in the areas of scheduling the efficient use of dwindling resources and managing the department's overall program.

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Abridgment

Optimization Approach for Allocation of Funds for Maintenance and Preservation of the Existing Highway System

KUMARES C. SINHA, M. MUTHUSUBRAMANYAM, AND A. RAVINDRAN

This paper discusses the development and application of goal programming techniques to achieve optimum allocation of federal and state funds for highway system improvement and maintenance. The methodology is applied to the Indiana highway system. An example problem that involves six improvement activities, four routine maintenance activities, and four system objectives is presented. Several scenarios are tested with the model to understand the model's operation and to gain insights into the trade-offs involved. The model is flexible enough to analyze other scenarios that involve revised standards or revised system objectives.

The automotive transportation system is in a state of transition. During the next decade the challenge to transportation agencies throughout the country is how to maintain and preserve this extensive network of facilities. In the face of competing needs for public money and in view of the increasing costs and inflationary effects, transportation agencies at all levels of government are concerned with how to allocate limited financial resources for highway improvement and maintenance.

The problem of highway financing and programming is greatly affected by prevailing energy constraints. The largest portion of the highway revenue is generated through the user tax on fuel. The combined effect of increased vehicle fuel efficiency and conservation efforts has drastically affected the amount of highway revenue available for construction and maintenance. The problem is aggravated because a significant part of the highway system is aging and, due to the increase in heavy truck traffic, maintenance needs have also increased sharply. At the same time, increased public awareness of safety and environmental quality has required a high level of highway service.

The costs of highway construction and maintenance have increased sharply in recent years due to the increased costs of labor, materials, and related items. However, the revenues available for maintenance have not kept pace with the need.

The problem of a shortfall in highway revenue is critical throughout the country. The highway taxation policy, primarily based on a user fuel-consumption tax, needs to be changed. At the same time the funding policy has to be moved from new construction to the maintenance of the existing system so as to increase the operational efficiency.

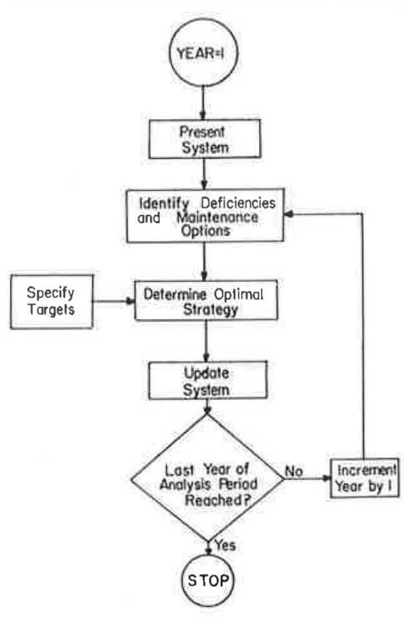
BACKGROUND INFORMATION

A definite need exists to examine possible legislative actions to change the revenue-generating structure and taxation schemes substantially in order to provide sufficient resources for the maintenance and preservation of the highway system. A study has been undertaken at Purdue University to analyze various aspects of the problem of highway maintenance and financing. In the first phase of the study (1) a computer model was developed that can be used to analyze and estimate the complex interactions between the critical factors that influence highway financing and their ultimate impact on the performance of the highway system. In the present phase of the study the model has been extended to incorporate an optimization routine for the allocation of highway improvement and maintenance funds. A schematic framework of this extension is given in Figure 1. The analysis can be done in cycles of one or more years for the entire analysis period. The process begins with initial highway system characteristics described by physical and traffic conditions. Analysis of this information leads to the identification of all feasible improvement and maintenance activities on different sections of the existing highway system. A mathematical optimization technique is then used to select the optimal set of improvement and maintenance activities over the entire system, given limited financial resources and a set of objectives. This completes one cycle of analysis. The performance of the highway system with regard to condition, service, safety, energy, and environment is evaluated after the system characteristics are updated. This process is repeated for each cycle until the last year of the analysis period.

Optimization Approach

This paper outlines the formulation of a model for optimal allocation of funds for highway improvement and maintenance based on the goal-programming technique. Goal programming is an approach for handling multiobjective optimization problems. In this approach, targets or goals are assigned for each of the identified objectives. The goal-programming

Figure 1. Optimal improvement and maintenance strategy model.



algorithm determines a satisficing solution that comes as close as possible to all the given goals or targets.

The problem is to determine how many miles of various sections will receive an improvement or maintenance activity. The decision variable is, thus, the length x_{ij} of the jth section that receives ith activity. In total, there are N highway sections in all of the functional classifications considered, and there are M improvement and maintenance activities. However, not all activities may be feasible for a given section.

System Objectives

System objectives include the improvement of system condition, provision of a higher level of service, increased system safety, and reduction of energy consumption and environmental pollution. Implementation of a highway improvement or maintenance activity helps to achieve some of these objectives, and the extent of the impact is measured by the activity-performance impact matrix, $P = \{p_{ki}\}$, where the matrix elements p_{ki} denote the improvement in system objective k due to activity i. The total (systemwide) improvement in objective k, considering M activities and N sections, is then given by the following expression:

$$\sum_{i=1}^{M} \sum_{j=1}^{N} p_{ki} x_{ij} \quad (1)$$

The problem is to achieve given levels of improvement in condition, service, safety, energy, and environment. If we denote these by T_k, we can express the system objectives as:

$$\sum_{i=1}^{M} \sum_{j=1}^{N} p_{ki} x_{ij} \geq T_k \quad k = 1, \ldots, K \quad (2)$$

In goal programming, the system objectives are represented as constraints that have positive and negative deviational variables to denote overachievement and underachievement of the targets.

The system objectives can then be expressed as:

$$\sum_{i=1}^{M} \sum_{j=1}^{N} p_{ki} x_{ij} + d_k^- - d_k^+ = T_k \quad k = 1, \ldots, K \quad (3)$$

The above expression says that the systemwide improvement in objective k actually achieved may exceed the target T_k (if $d_k^+ > 0$) or may fall short of the target (if $d_k^- > 0$).

Objective Function

The objective function of the optimization problem is to minimize the negative deviations (underachievement) from the targets. This is expressed as

$$\text{Min } Z = \sum_k w_k d_k^- \quad (4)$$

where d_k^- = underachievement in objective k and w_k = weight (penalty) associated with the underachievement of the objective.

The weights or penalties can be assigned separately for different classes of highways and for different objectives. For example, the penalty for not achieving the target for service may be greater than that for system condition for an Interstate class of highway, whereas it could be the reverse in the case of minor arterials and collectors.

System Constraints

System constraints are primarily related to the available financial resources for improvement and maintenance activities. These constraints are developed to reflect the requirements of various funding sources as set by government policies. For example, at present no federal assistance is provided for routine maintenance activities, but many of the improvement activities are funded through federal sources on the basis of specified matching ratios depending on the type of activity. Also, the revenue generated within a particular state can be allocated only on highways within that state. On the basis of these considerations, the budget constraints can be expressed as

$$\sum_{i \in M_F} f_i \sum_{j=1}^{N} c_{ij} x_{ij} \leq B_F \quad (5)$$

$$\sum_{i \in M_F} (1 - f_i) \sum_{j \in N_s} c_{ij} x_{ij} + \sum_{j \in N_s} \sum_{i \in M_s} c_{ij} x_{ij} \leq B_s \quad s = 1, 2, \ldots, S \quad (6)$$

where

- c_{ij} = cost per mile for improvement or routine maintenance activity i for section j,
- B_F = total federal funds available for distribution to states for highway improvement projects,
- M_F = set of all improvement activities that can use federal funds,
- M_s = set of all routine maintenance activities using state funds,
- f_i = matching ratios that indicate fraction of the cost of activity i that can be supported by federal funds,
- B_s = funds generated at a state level for all activities within state s,
- N_s = those highway sections located within state s ($N = \sum_{s=1}^{S} N_s$), and
- S = number of states included in the analysis.

The values of B_F and B_s can be provided exogenously as input information or these figures can be generated endogenously by using the revenue-generation submodel described by Mannering and Sinha (1).

Other constraints necessary for the optimization routine require that the total length of a section that receives improvement or maintenance activity does not exceed the length of that section (ℓ_j). In order to ensure this, a set of constraints of the following form are used in the model:

$$\sum_{i=1}^{M} x_{ij} \leq \ell_j \quad j = 1, \ldots, N \quad (7)$$

State Funding of Improvement Activities

It is desirable to provide for diversion of state funds on improvement activities when federal matching grants are not available. The model can incorporate an additional set of activities that represent those improvement projects that could be financed entirely by the state, after the federal matching funds are fully used. For the example problem, resurfacing alone was considered to be such an activity.

Equity Considerations

Attempts to optimize condition, service, safety, and energy and environmental objectives simultaneously will result in inequity if all activities cannot be done due to limited resources. In practice, it may be necessary to guarantee a predetermined minimum of some improvement activities so that serious deficiencies are corrected. These minimum levels may be specified as a fraction of current needs for each activity. They may depend on the number of years within which it is desired to catch up with the backlog and the proportion of the system expected to need the respective activities each year. A minimum of 1 percent of each improvement activity needed and 30 percent of routine maintenance was specified as minimum needs to be fulfilled for the example discussed.

EXAMPLE PROBLEM: INDIANA CASE STUDY

The optimization model was tested on Indiana data. Physical and traffic characteristics for the base year of the Indiana highway system were generated by a Monte Carlo sampling of 1976 national highway summary data (2). Six periodic improvement activities and four routine maintenance activities were considered, as shown in the list below.

Periodic improvement activities are as follows:

1. Reconstruction,
2. Major widening,
3. Minor widening,
4. Restoration and rehabilitation,
5. Resurfacing, and
6. Safety and other traffic engineering improvements.

Routine maintenance activities are as follows:

1. Pavement maintenance,
2. Shoulder maintenance,
3. Appurtenance maintenance, and
4. Right-of-way and drainage maintenance.

The four routine maintenance activities are of such a nature that any one or any combination of two or more of them can be carried out on a particular section of highway, depending on the type and extent of deficiency. Any combination of periodic improvement and routine maintenance activities can also be considered.

Identification of Maintenance Needs

The highway system data as generated by sampling were stored and analyzed to identify feasible improvement and maintenance activities that can be undertaken. This was accomplished through a set of threshold values for the performance measures and associated improvement and maintenance activities. The thresholds were developed along the lines of minimum tolerable standards used in similar studies (3,4).

Activity-Performance Impact Matrix

This matrix, {P}, was developed primarily on the basis of an opinion poll. The responses from a group of experts in the area of highway planning, programming, construction, and maintenance were collected. The elements of this matrix give the expected value of the gain in each objective as a consequence of a highway section that gets the appropriate improvement or maintenance activity. The values were adjusted to reflect the difference in the number of years or duration of the effectiveness of various improvement and maintenance activities.

Financial Resources

The sources of funding were broadly divided into funds from federal sources and funds from state sources. For the purpose of testing the optimization model, the financial resources and budget allocations for Indiana were given as input data.

In order to gain insights into the problem of funding levels and also to understand the various trade-offs involved, three funding scenarios were considered, as given in the table below in 1975 dollars.

Funding Source	Amount Available ($000s) Scenario 1	Scenario 2	Scenario 3
Federal	94 029	190 000	280 000
State	36 093	70 000	110 000

The federal-state matching ratios for various improvement activities were obtained from the Indiana State Highway Commission.

Unit Activity Costs

The costs associated with periodic improvement activities were estimated by developing an average cost per mile by using the national data provided in the 1972 National Highway Needs Report (5). The unit costs for routine maintenance were derived from maintenance budget information furnished by the Indiana State Highway Commission for FY 1979-1980. All figures were converted to 1975 dollar equivalents by applying the construction cost index.

Targets for System Objectives

The targets for the achievement of system objectives were set as values on a scale of 0-100. A value of 100 for a system objective represents total fulfillment of that objective. These values can be changed for sensitivity analysis to gain further insights into the problem.

Analysis and Results

With the model set up as described above, computer runs were made for each of the three funding scenarios. Solutions were obtained for two different policy options under scenario 2. One option assumed noncategorical funding, wherein the state government is free to use federal funds on maintenance activities. A second option assumed equal weights for all four system objectives across all classes of highways, as in Equation 4. These analyses were done without equity constraints. From the output of the optimization routine, reports can be generated that give miles that receive various activities, dollars spent, and achievement in each system objective. These can be done at any level of aggregation of interest to the user, such as all rural highways, all Interstate highways (urban and rural), and all improvements, to mention a few. These results for the sample problem are discussed in detail elsewhere (6).

A comparison of the two policy alternatives is useful in revealing trade-offs among objectives and highway classes. These are shown graphically in Figures 2 and 3. The numbers in these figures are the improvement scores achieved on a scale of 1-100. The optimization with unequal weights has resulted in more overall improvement of urban minor arterials at the cost of rural minor arterials and urban principal arterials (Figure 2). This brings out the conflict between system optimization under one value system (reflected in the priority weights assumed) and another. Figure 3 illustrates the trade-off among objectives in one class of highway. The greater importance given to the achievement of safety under the unequal weights option has resulted in improving safety at the cost of other objectives.

CONCLUSIONS

A major challenge to transportation agencies

Figure 2. Trade-off among highway classes.

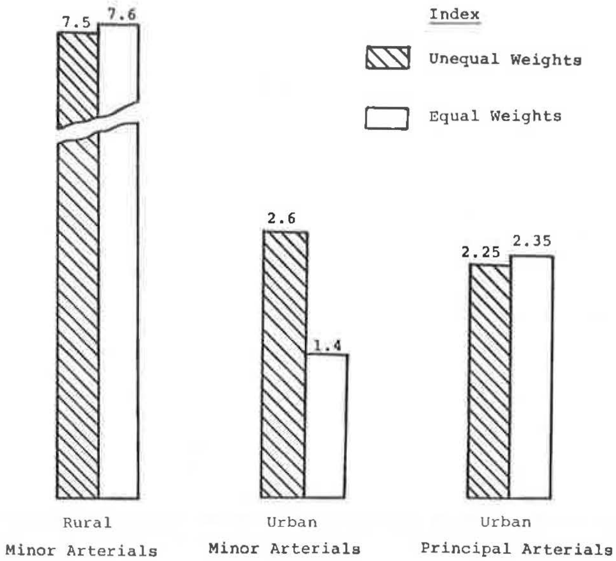
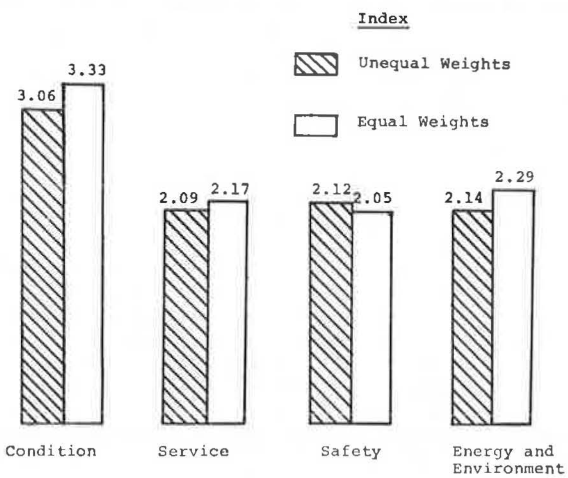


Figure 3. Trade-off among objectives—urban principal arterials.



throughout the country today is how to maintain and preserve the extensive network of highway facilities in the face of competing needs for public money, increasing costs, and inflation. A technique that has great potential to address this issue of optimal use of limited resources in a multiobjective decision situation is goal programming. The experience of the research at this point is encouraging and confirms the suitability of this approach to highway system programming and management. The overall methodology being developed will enable decision makers to address various issues, such as trade-offs among system objectives, among highway classes, and among activity types. It is also possible to analyze the impacts of different policy decisions on the needs and performance of highway systems.

The model is being expanded for application to the nationwide highway system. The model also has the potential for multiyear analysis and the flexibility to address different sets of system objectives and maintenance or improvement activities.

ACKNOWLEDGMENT

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Abridgment

Linking Europe and Africa Through Greece: A Transportation and Development Study

V. EVMOLPIDIS, P. MANIDIS, AND G. SOILEMEZOGLOU

This study examines the way transportation can be used to facilitate the worldwide trend toward economic integration and the resultant economic benefits through trade for both Europe and northeast Africa. The emphasis is on northeast Africa, however, because of its state of underdevelopment. In general, transportation networks in northeast Africa are poorly developed. Historically, these transportation networks have tended to form separate systems that are oriented outward to ports that have few links among African countries. Recently, African countries have upgraded their transportation networks and started to forge links among each other. This development is still in a premature stage, but it is considered very desirable in facilitating the development of northeast Africa. The major hypothesis of this paper is that, by promoting the development of a permanent, continuous transportation axis that links Europe and northeast Africa through Greece, as well as various African countries to each other, transportation costs can be reduced, which will facilitate economies of specialization and scale through trade. In addition, this transportation axis would facilitate the development of areas that have agricultural, mineral, and industrial potential that are previously unexploited because of limited access.

The need for faster and more reliable transportation is introducing significant changes to the traditional patterns of cargo transportation among countries. One of these changes is the trend toward the combined transportation of goods, which is an increasingly popular way of handling world trade. By using this concept, one of the potential routes between Europe and Africa recommended for further study by the International Road Federation (IRF), namely the route that links Europe and northeast Africa through Greece, is evaluated. The study is therefore concerned with the development of both Europe and northeast Africa. As regards the spatial and economic implications of such a link, however, emphasis is on northeast Africa because this part of the study area is underdeveloped compared with Europe. In addition, future land transportation networks in northeast Africa are expected to be markedly influenced by such a link, whereas the effect on the land transportation networks of Europe is expected to be marginal.

EXISTING TRANSPORTATION NETWORKS

Transportation networks in northeast Africa are poorly developed compared with those in Europe because of the generally low level of economic development of the area, scarcity of agricultural land, and vast deserts (Figure 1). In Europe, particularly in Western and Central Europe, the road and rail networks are almost complete. Projects are also under way for the improvement and development of the respective networks of Eastern Europe and Greece. Of these, the Trans-European Motorway (TEM), which links Poland, Czechoslovakia, Austria, Hungary, Rumania, Yugoslavia, Bulgaria, Greece, and Turkey, is the most important. In Greece, as well as the above mentioned project, there is an ambitious program of railway modernization, which is striving for significant network improvements by 1985. In northeast Africa, on the contrary, the road networks are incomplete and many are missing. In addition, these transportation networks tend to form separate systems orientated outward to ports that have few links among the northeast African countries. As a result of the nature of these transportation networks and because of the low level of economic development, little secondary economic activity has located within the northeast African countries.

Recently African countries have upgraded their road networks and started to forge links among each other. The United Nations Economic Commission for Africa (UNECA) and IRF have proposed the construction of 10 700 km of roads at a cost of $1 billion (1978 U.S. dollars) of which 6400 km require engineering studies. The major hypothesis of this paper is that, by promoting the development of a permanent continuous transportation axis that links Europe and northeast Africa through Greece, the implementation of the road construction program for links among African countries will be triggered off, which will facilitate the development of northeast Africa. The major advantage of such a transportation axis would be the reduction of transportation costs and facilitation of economies of specialization and scale through trade.

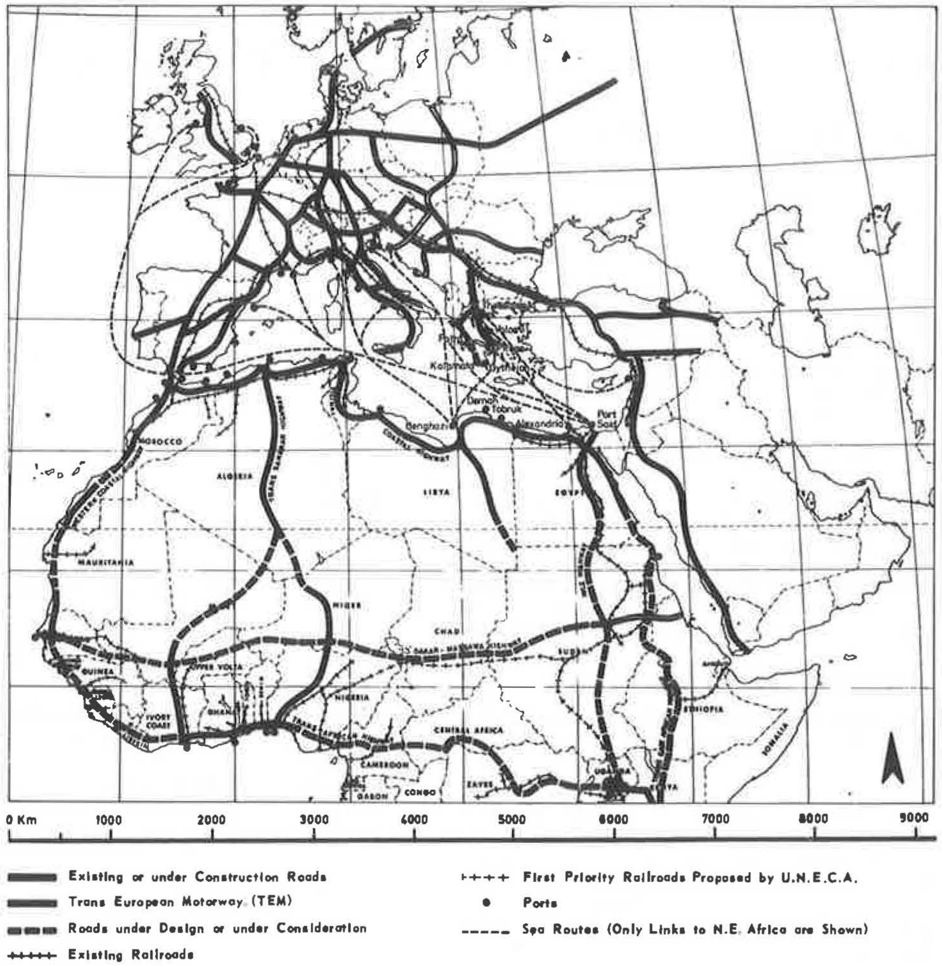
EUROPE-NORTHEAST AFRICA TRANSPORTATION AXIS

The proposed axis would require a permanent link between Europe and northeast Africa in contrast to that provided by a general cargo service. This can be best realized by roll on-roll off (RO-RO) or container roll on-roll off (CO-RO) vessels, which will result in faster and more reliable deliveries than those achieved by a conventional general cargo service--aspects that are very important to prospective freight forwarders. For example, a conventional general cargo vessel covers the Bremen-Alexandria trip in 25 days; however, the same distance can be covered in 10 days if a truck and RO-RO are used through Greece.

To determine the potential of the RO-RO link in greater detail, the economic structure and trade patterns of the countries of the study area were considered and marked differences were revealed between European and northeast African countries. The former are in an advanced stage of industrialization and have highly developed economies; the latter are still primary-sector economies where agriculture and mining prevail and raw materials are shipped to more-developed economies for the secondary economic activity of processing. Consequently, there are major differences in European-northeast African trade because Europe mostly exports finished products and imports raw materials from northeast Africa. Also, exchanges between Europe and northeast Africa constitute 65 percent of northeast African trade and only 2 percent of European trade. Between 1972 and 1976 European exports to northeast Africa grew in value at an annual rate of 23.4 percent compared with a growth rate of 11.4 percent in northeast African exports (excluding Libyan oil) and 14.4 percent (including Libyan oil).

A limitation of the permanent link between Europe and northeast Africa that uses RO-RO vessels is that it can only be used for general cargo. In 1975, the volume of general cargo trade between Europe and northeast Africa amounted to 11.0 million tons, of which 7.5 million tons was toward Africa and 3.5 million tons toward Europe. This unevenness of

Figure 1. Major transportation infrastructure in Europe and Africa.



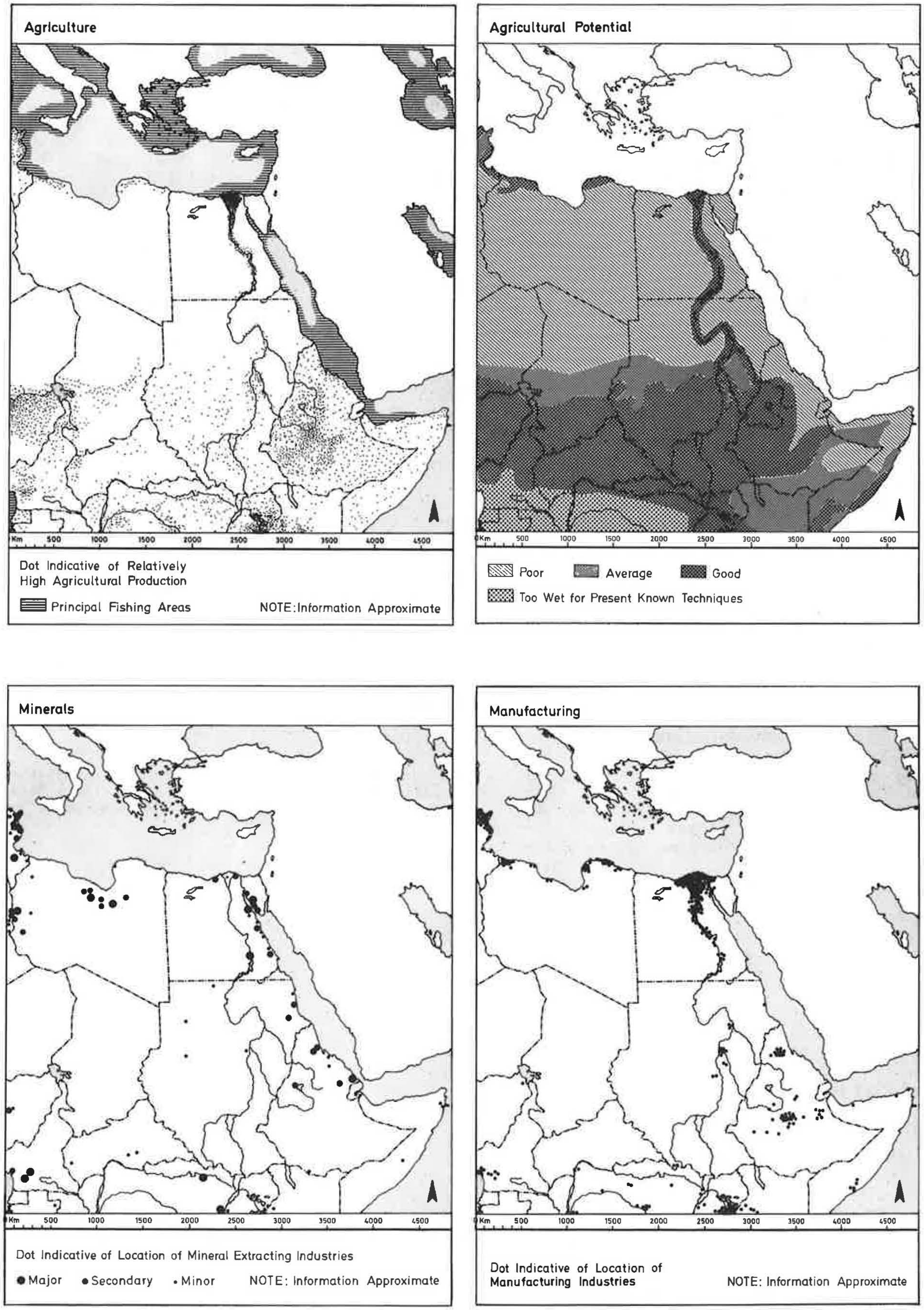
trade flows is another operational limitation of the link. Three European countries, Spain, Portugal, and Italy, account for 32 percent of the trade and are not considered potential customers of the link; 8.5 million tons of cargo remains, which is expected to at least double by the year 2000, by which time the population of northeast Africa is also expected to virtually double. Note that another permanent RO-RO link between the ports of Volos, Greece, and Tartous, Syria, operates profitably on less than 1 million tons of general cargo and almost all traffic is unidirectional. In view of these factors and the location of Greece at the southeastern edge of Europe as well as its present political and economic role as the 10th member of the European Economic Community, a new RO-RO link between Europe and northeast Africa through Greece should have even greater economic potential.

Assuming, therefore, that this type of link is feasible, alternative possibilities for the alignment are considered. After a detailed consideration of the ports and land transportation facilities in the study area, as well as the distribution of existing and potential economic activities in northeast Africa, it is concluded that, in the short- and medium-term, the link between Volos, Greece, and Port Said, Egypt, which follows an eastern alignment along the Nile, would probably be most suitable. In the long term, an alternative or additional link could develop between the ports of Kalamata or Thessaloniki in Greece and Tobruk in Libya, which will follow a western alignment through Kufra, Libya, with a connection either southward to Chad or eastward to the Sudan.

These two alternative alignments are evaluated in terms of their general development impacts on Africa. In Figure 2, the existing distribution of economic activity (agriculture, mining, and manufacturing) and the agricultural potential of the study area are indicated. They are converted into general development potential in Figure 3. On the basis of population projections for the year 2000, the large urban agglomerations expected to develop in the study area are also indicated. Finally, the major transportation axes either in existence or those that have the potential of developing by the year 2000 are presented diagrammatically. It is quite evident from these maps that the eastern alignment has great potential as a permanent continuous transportation axis. It links many northeast African countries and facilitates international and inter-African trade. It also links a number of significant urban systems, passes through concentrations of existing economic activity, and will serve a large area of agricultural and mineral potential.

By facilitating the development of this axis, freight travel times will be reduced by 30-60 percent, reliability of deliveries will be greatly improved, transportation costs will be reduced, and transportation inputs will be substituted for other factors of production. The result will be economies of specialization and scale through trade. More specifically, the African countries will realize new comparative advantages in the production and export of certain goods. As a result of increased transportation efficiency, it may become economical for these countries to start processing more raw materials instead of exporting these unprocessed. Al-

Figure 2. Distribution of economic activity in northeast Africa.



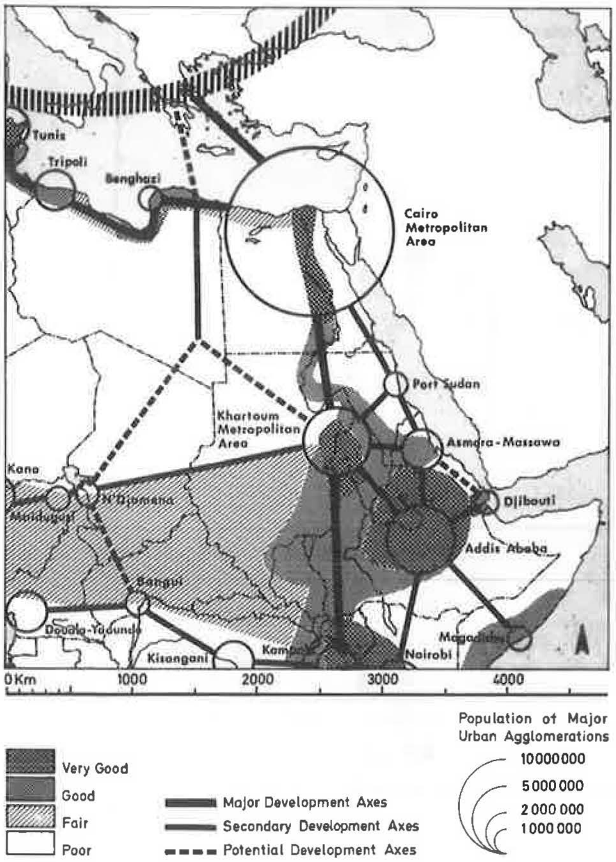


Figure 3. General development potential, year 2000.

though trade between Europe and northeast Africa will still tend to be that of northeast Africa--exporting mostly unprocessed materials and importing finished goods--the semiprocessing of raw materials is expected to become more economical, which is advantageous because of the value added. In addition, the linking of urban systems will result in positive scale effects, such as the increased size of the markets. This will provide new opportunities for the location of market-orientated industries. Finally, the transportation axis is expected to trigger the development of agricultural, mineral, and industrial potential previously not exploited because of limited access.

Although the western alignment does not at present have any potential as a trade route, it may have a completely different potential, namely, that of opening new resource frontiers. In the past, a symbiotic relationship existed between any transportation route and economic activity. Roads were first developed to serve areas of known agricultural and mining potential. With the development of the transportation route, new areas of agricultural and mineral potential were discovered and more roads were then developed to serve these as the cyclical process continued. The development of roads along the Nile is a good example of this process serving either agricultural or mining activities. In the case of the western alignment, its major potential is in opening new resource frontiers and the important question is whether it is necessary to first construct the road before determining the mineral potential of the adjoining land. With remote sensing techniques and mobility other than road transport, it is more advisable to determine the mineral potential to some extent before investing in the road.

CONCLUSION

In conclusion, the research supports the major hypothesis of the paper that there is a case for promoting the development of a permanent, continuous transportation axis to link Europe and northeast Africa as well as to link various African countries. A spillover of this research is the substantiation that transportation routes have different potentials depending on the nature of the economic activity along the alignment. Finally, this study indicates the role of transportation in facilitating the worldwide trend toward economic integration in northeast Africa.

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Graduated System of Fees for Automobile Registration in Virginia

ANTOINE G. HOBEIKA, THANH K. TRAN, AND F. GORDON

A system of graduated registration fees based on the classification of the automobile stock into subcategories by weight is examined for Virginia. The feasibility of such a fee system and other alternatives for classification of the automobile fleet are explored. An econometric forecasting model based on a series of multiple-regression equations is then developed to model the weight classification scheme and to determine the potential impacts of such a system of registration fees on the transportation revenues of the Virginia Division of Motor Vehicles. Registration revenues are expected to decline under any tax scheme. However, a weight-based system of graduated fees that favors smaller automobiles will precipitate the decline. Under the moderate-inflation scenario, the loss may amount to well over $6.5 million/year by 1985. Future fuel and automobile prices will merely dictate the speed and the degree of loss in revenues.

The Division of Motor Vehicles (DMV) of the Commonwealth of Virginia receives revenues from 16 sources. More than 90 percent of these revenues come from three motor-vehicle sources:

1. Fuel tax,
2. Sales and use tax, and
3. Registration fees.

These funds are allocated for administration and for capital outlays and maintenance of the state's highways. The recent decline in DMV revenues, coupled with the rapidly increasing costs of highway construction and maintenance, made it necessary to improve the revenue base of the Virginia DMV by means of changes in the transportation tax system. Among the options explored in this paper is a system of graduated registration fees based on weight classification of automobiles.

All automobiles in Virginia must now pay a $15 annual registration fee. The increasing of this fee to keep pace with inflation and with rising costs is difficult to do from a legislative point of view because the fee is a highly visible form of taxation.

One measure that is used in many other countries may pose a solution to this dilemma. This option, which has come under consideration by the Virginia General Assembly twice in various forms, is a graduated registration fee for different classes of automobiles.

Such a fee system would have two advantages over the present single-fee system:

1. A tax differential between certain types of vehicles could be justified as promoting the general welfare of the commonwealth. For example, fees that were higher for automobiles that have high air pollution emissions or gasoline consumption could be touted as contributing to the general welfare of the populace or reducing reliance on foreign oil.

2. The institution of penalty fees for certain vehicle classes could provide an additional source of revenue to the DMV and raise less public protest than would an across-the-board increase.

CRITERIA FOR SETTING UP FEE CLASSES

Several different criteria could be used to create classes of automobiles for the purpose of fee differentiation. Among the more frequently discussed possibilities are the following.

Horsepower

Horsepower classes could serve as a way of differentiating according to approximate fuel consumption. A bill was submitted to the general assembly that would have set a horsepower classification scheme three years ago, but it was not passed. Two major problems would confront a horsepower classification scheme:

1. There is no agreement concerning what measure of horsepower would be appropriate to use. Different engines are rated in different ways, at different revolutions per minute levels. Not all engines are designed to provide peak power under the same set of circumstances. Any single rating scheme would be objected to as having a discriminatory effect against certain automobiles.

2. A horsepower tax would not differentiate between energy-efficient and energy-inefficient high-powered cars. For this reason, people who need large, high-powered cars for business or other purposes would complain that this scheme discriminates against them.

Air Pollution Ratings

An argument could be made that the public health would benefit from a fee system that discriminates against automobiles that have high levels of air pollution emissions. Since U.S. Environmental Protection Agency (EPA) air pollution ratings are available for all automobiles sold in the United States since 1968, it would be relatively simple to set up a fee system based on this criterion. The only classification problem would be for pre-1968 automobiles. However, two factors cloud the attractiveness of this option from an equity perspective:

1. During most of the year, critical air pollution problems are isolated in a few urban corridors of Virginia. A statewide tax that is higher for high-pollution vehicles would discriminate unfairly against rural drivers, who make a negligible contribution to air pollution problems. Most federal air pollution regulations discriminate in this way against rural drivers. However, that does not justify the discrimination or mean that such a tax would be palatable to Virginia voters.

2. The reliance on ratings fails to deal with one of the biggest problems in enforcement of air pollution regulations--that of owners of automobiles deliberately having pollution-control equipment disconnected.

Ad Valorem Registration Fee

One option that is currently under review by the general assembly is an ad valorem registration fee. This proposal would replace the fixed registration fee with a tax based on a percentage of the assessed value of the automobile in its current condition. In effect, the registration fee would be converted into a personal property tax. Although this form of taxation would be only remotely related to such public welfare considerations as air pollution and gasoline consumption, it would have an added advantage in that it would make the fee a federal income tax deductible. This would allow the DVM to increase their revenues without increasing the tax burden to Virginia residents.

Some problems would be created by the task of assessing the present value of used automobiles. However, the same problems are surmounted by the many Virginia localities that charge a personal property tax on automobiles. The value of automobiles could either be appraised by using some standard, such as the blue book, or by using state-hired appraisers.

Weight Classification

A weight classification option appears to be relatively simple to administer and easy to justify on social equity grounds. Researchers have found that weight is highly correlated with gasoline consumption for automobiles (1). Weight classification information is readily available for all mass-produced automobiles. It would be simple enough to require weighing for all custom automobiles.

One additional possible justification for this measure is the correlation between vehicle weight and road wear and tear. However, most studies of this relationship have concentrated on trucks and on far greater differences in weight classes of automobiles (2). The difference in road wear between a 5000-lb automobile and a 3000-lb automobile may be negligible.

EPA Mileage Rating Classification

EPA mileage rating classification would draw a more direct connection between automobile fuel economy

Table 1. Sales of automobiles in Virginia by year and weight class.

Year	Weight Class 3000 lb	3500 lb	4000 lb	4500 lb	5000 lb	Total
1968	24 779	52 613	67 670	37 158	16 189	198 389
1969	30 741	47 102	32 503	66 808	23 111	200 265
1970	41 724	22 767	43 096	52 683	20 293	180 545
1971	56 307	26 496	44 437	59 510	37 225	223 975
1972	59 072	30 910	50 353	61 103	46 019	247 680
1973	70 703	31 053	32 104	66 943	62 131	262 934
1974	58 174	19 066	22 203	44 252	47 522	191 236
1975	40 024	23 643	29 085	35 994	56 962	185 727
1976	60 299	30 172	31 252	51 234	57 573	220 553
1977	57 697	21 102	72 473	70 101	25 698	247 096
1978	63 978	70 598	52 936	48 489	13 815	249 817

and tax levels. The only problem would be in rating older automobiles that predate the EPA mileage tests.

PROBLEMS COMMON TO ALL CLASSIFICATION SCHEMES

Treatment of Vehicles That Have Already Been Purchased

Changes in the registration fee system that result in increases in fees for automobiles that are already on the road will be resisted by owners of the vehicles that are in the penalty classes. They would assert that, since the automobiles are already on the road, the taxes do not encourage conservation and penalize them for decisions that they cannot reverse. At the same time, an increase in fees that only applies to automobiles purchased after this system was changed would be slow to raise much new revenue. New cars account for less than 10 percent of the automobile fleet in any given year.

Impact of Tax Increase on Consumer Behavior

Unless the fees are increased dramatically, they are not likely to have much of an impact on gasoline consumption, air pollution, or any other aspect of consumer behavior. Most people who can afford to buy a gasoline-guzzling automobile, for instance, are wealthy enough that a doubling of their registration fee to $30 would not serve as much of an inhibition. Dramatic increases in fees for some vehicle classes are not likely to receive legislative support.

Additional Data Processing Costs

Introduction of any of these graduated fee systems would require that additional information be added to all Virginia vehicle registration records. DMV records do not contain a detailed enough description of vehicles to serve any of these classification schemes. The first-time cost for collecting the additional information for all automobiles that are already on the road would be considerable.

MODELING A GRADUATED REGISTRATION FEE SYSTEM

A system of fee differentiation based on classification of automobiles by weight was chosen to model and to illustrate the characteristics of a differential registration fee system. The choice was based on the relative practicality and justifiability of the weight criteria and on the availability of the necessary data to stratify present and future automobiles in Virginia into weight classes. The results are, however, illustrative of many of the possible problems and revenue impacts that the weight classification scheme shares with all the other classification criteria listed above.

Projecting Future Automobile Purchases by Weight Class

To project automobile sales by weight class for this study, it was necessary to develop a separate regression equation for each weight class. The independent variables used in this analysis were the gasoline price index (CPIGC), the price index for new automobiles (CPINC), and the average household income in 1967 dollars (AHHI67).

Data Base

An estimate of the number of automobiles in each of several weight classes sold in Virginia each year for a period of time was needed in order to explore the relationship between the independent variables and automobile purchases in each class. Information was obtained to show the percentage of total U.S. annual automobile sales that fall into each of 10 weight classes (3). The 10 classes were aggregated into 5 in order to simplify the analysis. For the rest of this paper, the term 3000-lb weight class will denote all automobiles in the 2000- to 3000-lb weight classes, and the term 5000-lb weight class will refer to the combination of the 5000- and 5500-lb weight classes.

The assumption was made that the percentage of automobile sales in each weight class was approximately the same in any year in Virginia as in the entire United States. This assumption makes it possible to apply the national percentages to figures for annual sales of new automobiles in Virginia, obtained from the Virginia DMV.

The resulting estimate of numbers of new automobiles sold in Virginia by year by weight class is shown in Table 1.

Regression Analysis

By using historic values from the period 1968-1978 of the three independent variables (4), a number of different regression relationships were tested. Among the relationships that were experimented with were $\log_e$-$\log_e$, $\log_e$-linear, linear, and power functions.

Although some very strong regression coefficients and F-statistics were obtained by using power functions for gasoline and automobile prices, the use of power functions was ultimately rejected as being unrealistic. With even high assumed rates of price increases, the power functions produced exorbitant increases in automobile purchases in some classes by 1985. For instance, automobile purchases in the 3500-lb weight class were found to increase by 1985 to a number larger than the total purchases in 1978.

The $\log_e$-linear relationships showed a similar tendency to produce extreme and irrational results and were therefore also eliminated from the model. Thus, all equations selected use either $\log_e$-$\log_e$ or linear functions.

The regression equations that produced the best fit were found to vary widely in form from weight class to weight class. Some weight classes showed a stronger relationship to income if purchases were regressed against the previous year's income in 1967 dollars (AHHIL) instead of the current year's income (AHHI67). The income measure that showed the strongest relationship was used in each equation.

Not all of the independent variables could be added to all of the equations to be statistically significant. This is a result of the small size of the historic data base used in the regression analysis (11 years) and the high degree of collinearity among the independent variables.

In order to make the model as effective as possible in showing shifts in purchases from one weight class to another with changes in the independent variables, it was necessary that most of the independent variables be included in all the equations. Thus, as long as the sign of the relationship indicated a logical causal pattern, coefficients that have low F-statistics were allowed in the equation.

After a series of equations were developed by using the three causal variables listed above, it became apparent that there was a need to recognize interrelationships between the five weight classes in the model. It is apparent that, as fewer consumers buy large automobiles, more of them are likely to purchase smaller automobiles. This sort of transfer of consumers from one weight class to another occurred during the 1968-1978 period and was accordingly reflected in the regression equations. However, if at a future date all buyers of large cars have switched to smaller models, transfer of purchasers from the larger to the smaller weight classes ceases to be a contributing factor to increases in sales of small cars.

As the next section will show, two out of three of the scenarios for future prices result in the extinction of at least one of the larger weight classes before 1985. The regression equation predicts a negative purchase of automobiles in these classes after this point. Beyond this point, the purchase of smaller automobiles, particularly in the 3500-lb weight class, continues to rise at a rapid rate. The net result is an unreasonable increase in the total number of automobiles purchased in later years.

Two adjustments to the model were made to alleviate these problems. First, a lower limit of 500 new automobile purchases in any weight class for a single year was added to the model. Then, the projected purchases of automobiles in the 4500- and 5000-lb weight classes were added as independent variables to the equations for projecting purchases in the smaller weight classes. It was hoped that this would result in a moderation of the growth rate for small car sales when sales in the larger classes moderated.

The results of this experiment were mixed. Purchases in the 4500-lb weight class could only be added to the equation for the 3500-lb weight class without producing an illogical relationship and an unsatisfactory F-statistic. However, the sales in the 5000-lb weight class entered into three out of four of the equations for the smaller weight classes with an F-statistic of 1 or more. As the following few pages will show, the modification did not have the full desired effect; however, it did result in improved projections for the years 1983, 1984, and 1985.

Equations Used in Model

The following equations were used to predict future automobile purchases in Virginia by weight class.

5000-lb Weight Class

$$W5000 = -112\,537.8 + (2.159 \times AHHI67) - (785.30 \times CPINC) \quad (1)$$

$R^2 = 0.394$
F-statistics: AHHI67 = 5.09, CPINC = 3.20.

The 5000-lb weight class proved to be the most difficult to model. Although the R^2 for this equation is relatively low, the predictive characteristics of the equation are reasonable. Under most circumstances, the equation would predict a decline in purchases of automobiles in future years that is consistent with the sales activity of the last five years. Previously, sales in this class had been on the increase.

4500-lb Weight Class

$$W4500 = -174\,397.6 + (18.57 \times AHHI67) - (729.28 \times CPIGC) + (1079.40 \times CPINC) - (0.15 \times W5000) \quad (2)$$

$R^2 = 0.693\ 27$
F-statistics: AHHI67 = 6.79, CPIGC = 8.22, CPINC = 2.74, W5000 = 0.52.

Although the relationship between purchases in the 5000- and 4500-lb weight classes was not strong, it was included for the sake of consistency in the model. A positive relationship between the price of new automobiles and purchases may seem strange. This is probably a result of consumers turning from higher-priced automobiles to those in this weight class.

4000-lb Weight Class

$$W4000 = 10\,288.87 - (0.24 \times W5000) + (1602.49 \times CPINC) - (475.99 \times CPIGC) - (7.28 \times AHHIL) \quad (3)$$

$R^2 = 0.62$
F-statistics: W5000 = 1.30, CPINC = 2.78, CPIGC = 1.36, AHHIL = 0.62.

This equation shows characteristics that are similar to those described for the 4500-lb weight class equation. The positive relationship between automobile prices and purchases is due to transfers from the 5000- and 4500-lb weight classes.

3500-lb Weight Class

$$W3500 = -280\,430.8 - (0.93 \times W5000) - (1.36 \times W4500) + (36.20 \times AHHI67) - (1070.86 \times CPIGC) + (1374.55 \times CPINC) \quad (4)$$

$R^2 = 0.74$
F-statistics: W5000 = 9.95, W4500 = 5.98, AHHI67 = 6.60, CPIGC = 4.00, CPINC = 1.60.

This equation showed both a small R^2 and low F-scores until both purchases in the 5000- and 4500-lb weight classes were added as independent variables. The very strong relationship with income is different from that in the other equations. These features indicate that this equation is not as strong as the R^2 would imply.

3000-lb Weight Class

$$W3000 = 2.854 \times 10^{-15} \times (CPINC^{2.81}) \times (CPIGC^{-1.70}) \times (AHHIL^{4.21}) \quad (5)$$

$R^2 = 0.68$
F-statistics: AHHIL = 8.24, CPIGC = 3.40, CPINC = 2.47.

This equation is the only one that uses a natural logarithmic relationship. This is because a higher R^2 was obtained from the $\log_e$-$\log_e$ equation only for this weight class. The relationship shown here was the most consistent through all of the calculations of all the weight classes. However, neither of the larger weight classes could be factored in as an independent variable without producing low F-statistics and irrational results. Although it may have been possible to factor in the 4000- or 3500-lb weight classes as independent variables, it was decided that the adding of another step to the causal chain would not be wise.

To summarize the characteristics of the regression analysis, the series of equations were chosen first for their high explanatory powers by using historic data on automobile purchases. The equations were further refined to maximize consistency and interdependency. Due to the problems of a small data base for the regressions and strong collinearity among the independent variables, the resulting equations are not perfectly consistent and rational. However, they are adequate to provide an approximation of the future distribution of automobile purchases according to weight class.

PROJECTIONS

These equations were used to forecast future automobile purchases. Three scenarios were developed to depict an array of future economic conditions, and a separate set of projections was made for each scenario.

For all three scenarios, uniform assumptions were used about the level of income for future years. In this way, attention could be focused on the future impact of gasoline and automobile prices, and the number of scenarios is held to a manageable number. Also, we feared that some of the income-based coefficients would tend to produce unrealistic results if the values for income strayed too far from those in the historic data.

The rates of real income growth used in the DMV revenue model (4-6) were also used in this model. The values for average household income, in 1967 dollars, increase at an increasing rate, ranging from 1.2 percent in 1980-1981 to nearly 2 percent by 1984-1985.

It was also decided that gasoline prices should vary over a wider range than automobile prices in the three scenarios. This reflects the greater amount of uncertainty about future gasoline prices due to the instability of the world oil market.

The price levels for the three scenarios are as follows:

1. Low-inflation scenario: Gasoline prices up 5 percent/year; new car prices up 4 percent/year.
2. Moderate-inflation scenario: Gasoline prices up 15 percent/year; new car prices up 10 percent/year.
3. High-inflation scenario: Gasoline prices up 20 percent/year; new car prices up 10 percent/year.

The price indexes for gasoline and new cars used for each of these scenarios are listed by year in Table 2. The resultant purchase patterns when these rates are entered into the regression equations are shown in Table 3.

In most respects, the purchase patterns shown in Table 3 are consistent. In response to increased prices, sales of large automobiles decrease, and sales of smaller automobiles increase. As the sales of cars in the larger classes reach the limit of 500, the rate of increase in purchases of small cars should slow. However, the response differs among those weight classes. But, since the distribution of purchases is shifted outward to the two classes on either side of the 3500-lb weight class, the estimate of net revenues collected under a graduated registration fee system that differentiates according to weight class should not be greatly affected.

Table 2. Projected annual gasoline and new-car price indexes under low-, moderate-, and high-inflation scenarios.

	Low Inflation		Moderate Inflation		High Inflation	
Year	Gasoline	New Car	Gasoline	New Car	Gasoline	New Car
1978[a]	200.2	147.8	200.2	147.8	200.2	147.8
1979[a]	265.6	165.9	265.6	165.9	265.6	165.9
1980	281.5	172.5	305.4	182.5	318.7	182.5
1981	298.4	179.4	351.3	200.7	382.5	200.7
1982	316.3	186.6	404.0	220.8	459.0	220.8
1983	335.3	194.1	464.5	242.9	550.7	242.9
1984	355.4	201.8	534.2	267.2	660.9	267.2
1985	376.8	209.9	614.4	293.9	793.1	293.9

[a] Based on actual data.

Survival Rates for Automobiles

The second factor that influences the number of automobiles in Virginia in each weight class in any year is the scrappage rate for old cars. In the original version of the DMV revenue model, a cohort survival model was set up to predict future survival of automobiles according to an assigned percentage survival rate associated with each year of an automobile's age (4,5,7).

The model used a fast retirement rate and a slow retirement rate, depending on the estimated average age of the automobile fleet. Both rates are shown in the table on the following page.

Table 3. Automobile purchases by weight class under three scenarios.

		Weight Class					
Scenario	Year	5000 lb	4500 lb	4000 lb	3500 lb	3000 lb	Total
Low inflation	1979	26 209	35 926	52 547	40 814	60 173	215 769
	1980	24 049	34 349	53 747	42 093	68 696	222 934
	1981	21 955	32 614	56 458	43 374	72 807	227 208
	1982	19 561	30 464	59 175	44 735	77 516	231 451
	1983	17 126	28 006	61 885	46 114	82 401	235 532
	1984	14 792	25 168	64 292	47 450	87 691	239 393
	1985	12 296	21 995	66 708	48 847	93 714	243 560
Moderate inflation	1979	26 209	35 926	52 547	40 814	60 273	215 769
	1980	16 196	28 889	61 088	45 016	70 065	221 254
	1981	5 228	19 531	71 145	49 450	75 599	220 953
	1982	500	6 275	78 770	48 610	82 030	216 185
	1983	500	500	84 288	27 875	88 887	202 050
	1984	500	500	88 887	500	96 485	186 872
	1985	500	500	92 247	500	105 026	198 773
High inflation	1979	26 209	35 926	52 547	40 814	60 273	215 769
	1980	16 196	19 190	54 757	44 013	65 166	199 322
	1981	5 228	500	56 294	42 015	65 415	169 452
	1982	500	500	52 590	500	66 025	120 115
	1983	500	500	43 258	500	66 545	111 303
	1984	500	500	28 579	500	67 186	97 265
	1985	500	500	7 187	500	68 037	76 724

Year	Survived at Fast Rate (%)	Survived at Slow Rate (%)
0-1	100	100
1-2	100	100
2-3	99	100
3-4	98	99
4-5	97	98
5-6	95	97
6-7	93	94
7-8	89	90
8-9	84	87
9-10	74	89

After much consideration and testing, we decided that, for the period 1980-1985, the fast rate would not be appropriate. This is because, in a period of stagnant or declining automobile sales, people can be expected to keep their automobiles for a longer period of time.

Accordingly, the slow retirement rate was chosen. Other studies have shown that this rate is only slightly slower than that experienced through the mid-1970s (8).

The DMV revenue model (4,5,7) also projected future migration of automobiles into and out of the state. The migration rates were not used in this analysis because the impact of automobile migrations over a five-year period is not likely to be very significant.

Age Distribution of the Automobile Fleet for Future Years

The data base for estimating the number of automobiles by age in 1978 was obtained from Automotive News (9). The information was converted into percentages of the fleet in each year class. These percentages were applied to the total number of automobiles registered in Virginia in 1978 to get an estimate of the number of automobiles in each vehicle age in Virginia in 1978. By using the estimates of the percentage of U.S. automobiles in each weight class for each model year from EPA (3), the vehicle stock from each year was divided into groups according to weight classification. The resulting estimate of the number of automobiles by weight group and year in 1978 is shown in Table 4.

Table 4. Automobile distribution in Virginia by weight class and year.

Year	Weight Class 3000 lb	3500 lb	4000 lb	4500 lb	5000 lb
1978	63 409	69 970	52 465	48 058	13 692
1977	65 722	24 037	82 554	79 852	29 272
1976	70 298	35 174	36 434	59 730	55 462
1975	42 576	25 150	30 939	38 289	60 595
1974	77 745	25 480	29 672	59 139	63 510
1973	76 940	33 791	34 936	72 848	67 612
1972	59 101	30 926	50 378	61 133	46 042
1971	49 929	23 495	39 403	52 769	33 008
1970	42 487	23 183	43 884	53 646	20 664
1969	25 319	38 795	26 770	55 025	19 034
1968	16 655	35 365	45 487	24 977	10 881
Pre-1968	88 007	56 220	134 691	78 126	25 850

By using the survival rates chosen in the above table, the automobiles in the table were moved forward each year to 1985 to find out how many of them in each year class would still be on the road. The projections for new car sales in the period 1979-1985 were also multiplied by the survival rates to project how many would remain on the road.

In using uniform survival rates for all weight classes, we assumed that cars of the same age were scrapped at the same rate regardless of weight. Although the heavier, less-fuel-efficient automobiles will probably be scrapped at a faster rate, no numerical basis for projecting this difference could be derived from available data. Thus, these projections probably underestimate, by a small amount, the speed of the shift in the total automobile fleet to smaller cars.

The projections of total automobiles registered in each year of the period 1980-1985 in each weight class for each of the three scenarios is shown in Table 5. Under the moderate- and high-inflation scenarios, the total number of automobiles declines over the five-year period. This is a direct result of consumer response to increases in automobile and fuel prices.

Although the revised DMV revenue model does not project a steady decline in registrations, as is projected by the moderate-inflation scenario here, it does project a decline in registrations in the early 1980s. However, a steady, but very gradual, increase in registrations is projected by the DMV revenue model for 1984-1985. This is similar to the low-inflation scenario presented here. All inputs considered, the numerical differences between the results of the moderate-inflation scenarios of two models is not very large. Accordingly, the two are considered to be consistent.

The difference in automobile purchases between the moderate- and high-inflation scenarios presented in Table 5 is considerable. By 1985, more than

Table 5. Virginia automobiles by weight class for 1980-1985 under three alternate price scenarios.

Scenario	Year	Weight Class 3000 lb	3500 lb	4000 lb	4500 lb	5000 lb	Total
Low inflation	1980	662 831	429 140	602 824	655 148	500 108	2 850 051
	1981	697 161	431 997	585 339	595 094	430 425	2 740 016
	1982	727 931	446 585	599 509	575 030	413 292	2 762 347
	1983	759 547	461 904	617 524	550 661	389 412	2 779 048
	1984	793 375	478 309	637 870	522 707	361 733	2 793 994
	1985	832 039	494 933	659 293	491 855	332 279	2 810 399
Moderate inflation	1980	706 687	438 230	611 365	643 223	456 031	2 855 536
	1981	701 322	440 996	607 367	576 551	405 845	2 732 081
	1982	736 606	459 459	641 132	532 298	369 651	2 739 146
	1983	774 708	456 539	681 550	480 423	329 145	2 722 365
	1984	817 316	425 965	726 417	427 855	287 252	2 684 805
	1985	867 237	394 124	773 087	375 747	246 325	2 656 520
High inflation	1980	701 818	437 227	605 034	633 524	456 031	2 833 604
	1981	686 239	432 558	586 185	547 821	405 845	2 658 648
	1982	705 518	402 911	593 770	497 793	369 651	2 569 643
	1983	721 278	372 616	593 158	445 918	329 145	2 462 115
	1984	734 636	342 052	577 780	393 447	287 252	2 335 167
	1985	747 767	310 305	539 664	341 721	246 325	2 185 782

Table 6. Total annual automobile registration fees under three alternate scenarios.

		Fee System ($)		
Scenario	Year	Option A	Option B	Option C
Low inflation	1980	42 750 765	45 302 502	59 552 757
	1981	41 100 240	42 729 131	56 429 211
	1982	41 435 205	42 695 053	56 506 788
	1983	41 685 720	42 510 231	56 405 469
	1984	41 909 910	42 247 246	56 217 206
	1985	42 155 985	41 958 590	56 011 585
Moderate inflation	1980	42 833 040	44 799 819	59 227 299
	1981	40 981 215	42 347 099	56 077 504
	1982	41 087 190	41 843 123	55 538 853
	1983	40 835 475	40 956 114	54 567 939
	1984	40 272 075	39 782 166	53 206 191
	1985	39 847 800	33 304 567	52 006 317
High inflation	1980	42 504 060	44 452 313	58 620 483
	1981	39 879 720	41 201 793	54 495 033
	1982	38 544 645	39 383 732	52 231 947
	1983	36 931 725	37 264 674	49 571 523
	1984	35 027 505	34 832 553	46 508 388
	1985	32 786 730	32 058 108	42 987 018

470 000 additional automobiles are registered under the moderate-inflation scenario relative to the high-inflation scenario. However, the total difference between the moderate- and low-inflation scenarios is only about 154 000 automobiles by 1985. The 5 percent additional annual increase in the gasoline prices under the high-inflation scenario is apparently critical to predicting future automobile purchases.

Revenue Impact of Alternative Registration Fee System

Three specific tax systems were chosen for consideration in assessing the possible effects of alternative taxing options. These are shown in the table below.

	Registration Fee Systems by Weight Class ($)				
Option	3000 lb	3500 lb	4000 lb	4500 lb	5000 lb
A	15	15	15	15	15
B	10	13	16	19	22
C	15	18	21	24	27

Option A is the current $15 fee for all automobiles. Option B is a graduated fee based on weight classification, which is designed to produce slightly more revenue in 1980 than does the present flat fee. It increases by $3 increments from a $10 fee for the 3000-lb weight class to $22 for the 5000-lb weight class. Option C also increases according to weight class by $3 increments, but ranges from $15 for the 3000-lb class to $27 for the 5000-lb class.

These fees were applied to the projections of total automobiles registered in each weight class in each year (Table 5) to produce the annual total revenue projections shown in Table 6.

Since options A and B have similar revenue yields in 1980, a comparison between the two is illustrative of the relative disadvantage of the weight classification scheme in terms of revenue production. By 1985, annual revenues are about $197 000 lower under the low-inflation scenario, $6 543 000 lower under the moderate-inflation scenario, and $728 622 lower under the high-inflation scenario. The reason that the gap narrows under the high-inflation scenario is that attrition from the fleet grows much smaller under this scenario with or without the graduated tax scheme. This results in lower total revenues.

Option C will always produce more revenue than the present scheme (option A), because the lowest fee under option C is the overall fee under option A. Yet, on a percentage basis, the revenue yield from option C drops at the same rate as under option B. Clearly, even if a graduated revenue scheme is set up to produce additional revenue, its yields should be expected to decline with time.

CONCLUSIONS

If gasoline prices continue to climb at moderate or high rates, registration revenues are expected to decline under any tax scheme. However, a weight-based system of graduated fees that favors smaller automobiles will precipitate the decline. Under the moderate-inflation scenario, the loss may amount to well over $6.5 million/year by 1985.

Only a graduated revenue scheme that favors larger cars can be expected to appreciate over time. It is inevitable that a large proportion of the state's future automobile fleet will be in the lighter weight classes. Future fuel and automobile prices will merely dictate the speed and degree of the shift.

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Abridgment

International Registration Plan's Impact on State Road User Tax Collections

GEORGE E. HOFFER AND JAMES T. LINDLEY

This paper examines the 1976 operating user taxes paid to five states by a sample of 98 common carriers certificated by the Interstate Commerce Commission. With the exception of Virginia, effective tax collections by the sampled states were in the same order as nominal tax rates. Because of registration reciprocity, foreign carriers paid less to each state than did resident carriers. International Registration Plan (IRP) membership was found to lower the disparity between payments made by resident and foreign carriers to a state. Carriers from IRP states paid lower user taxes to the non-IRP states in which they traveled than did carriers from non-IRP states. This finding implies that non-IRP member states will come under increasing financial pressure to join. When 1976-estimated allocated costs by carrier type were compared with Virginia and federal user tax payments, it was found that no carrier class covered its allocated costs. Consequently, it was concluded that a disinvestment has been occurring in the state highway system.

Two issues are essential to an investigation of highway user charges and user costs. The first issue is equity among the several classes of highway users. Charges to highway users should be structured so that each class of highway user covers its allocated cost. The second issue is equity between in-state and out-of-state users. This paper addresses this second issue.

Ideally, there should be equality in the per mile user charges paid by vehicles domiciled in-state and out-of-state. For light passenger-carrying vehicles (automobiles, light trucks, and vans) such is usually the case, as their use is predominantly within the state of vehicle registration. These light vehicles represent approximately 90 percent of vehicular mileage traveled (1, p. 9).

But, for heavier trucks, which represent most of the remaining 10 percent of vehicular mileage, the close correspondence in user payments per mile between vehicles domiciled in-state and out-of-state is generally not present. Registration reciprocity agreements between states permit a vehicle that is properly registered in one state to operate within other party states without additional license registration. Since all states and provinces are party to one or more registration reciprocity agreements, an interstate motor carrier need pay no registration fees to a given state, even if travel is done in that state. Since registration fees vary widely among the states, a judicious selection of state registration can lower user tax payments significantly. Furthermore, because some states levy ad valorum taxes on vehicles registered therein, additional incentives exist to shop for registration. In 1976, the savings in user costs from registering the largest, five-axle tractor semitrailer combination in the lowest-cost state along the eastern seaboard (Georgia) as opposed to the highest-cost state (Virginia), would have been approximately $0.01/mile for a vehicle that travels 50 000 miles (2).

For several decades state motor vehicle administrators have recognized this problem. Initially, through the Uniform Vehicle Registration and Proration Agreement and, since 1976, through the successor International Registration Plan (IRP), the American Association of Motor Vehicle Administrators (AAMVA), with the support of the motor-carrier industry, has promoted the proportionate registration of heavy vehicles used in interstate commerce. This paper will analyze the impact of IRP membership on operating user taxes paid by Interstate Commerce Commission (ICC)-certificated, common-motor-freight carriers to several states.

STRUCTURE OF ROAD USER TAXES AND THE IRP

Road user taxes traditionally have been divided into three broad classifications:

1. Motor fuel taxes and surcharges, termed first-structure taxes;
2. Motor vehicle registration and license fees, termed second-structure taxes; and
3. Other major road user taxes such as gross receipts or weight-distance taxes, referred to as third-structure taxes.

Fewer than 10 states have significant levies of the latter type.

In the early 1970s, 12 states and one Canadian province became charter members of the IRP, which is sponsored by the AAMVA. With the exception of Kentucky, Tennessee, and Virginia, charter members were located west of or along the Mississippi River, a reflection of previous membership in the Uniform Proration Aggreement. Over the past six years, IRP membership has increased to its present 23; North Carolina and Virginia are the only members along the Eastern seaboard.

Under the IRP, heavy vehicles used to carry passengers or property within two or more IRP states pay registration fees to each participant state in proportion to the mileage done in that state by the carrier during the previous year or that expected to be done during the present registration period. As such, the IRP supercedes registration reciprocity among the member states. The reciprocity agreements previously negotiated between IRP and nonmember states continue to govern vehicle registration between nonmember states and IRP states.

THE MODEL

To determine the impact that IRP has on state revenues from user charges, a sample of 98 motor carriers with class I, ICC common certificates was drawn from the files of the Virginia State Corporation Commission. Because the carriers were drawn on the basis of 1976 mileage traveled in Virginia, the sample represents more than 200 million miles of travel, or approximately 18 percent of total miles traveled in Virginia by large trucks and tractors (25 percent of for-hire carrier mileage) (3). Carriers that report leased mileage in excess of 20 percent were excluded from the sample. To include these carriers would introduce questions of lessee-lessor tax responsibilities in the several states.

Carrier operating user taxes to the federal and state highway trust funds in 1976 were obtained from the carrier M-1 annual reports filed with the ICC (4). The year chosen represents the last year that carriers have been required to report user taxes by state and the first full year of IRP operation for several states. Total annual mileage by each firm

Table 1. Effective 1976 state user tax payments to selected states.

	1976 State User Tax Payments[a] (¢/mile)				
Carrier Paid To	GA	MD	NJ	TN[b]	VA[b]
Non-resident carrier	2.19	2.57	3.32	3.33	2.92
IRP carrier	1.66	2.47	3.21	3.40	3.10
Resident carrier				4.09	4.76

Note: The in-state mileage for the sampled carriers was as follows: Georgia, 76.7 million miles; Maryland, 39.0 million miles; New Jersey, 44.1 million miles; Tennessee, 110.1 million miles; and Virginia, 220.6 million miles.

[a]Does not include state-capitalized taxes, if any. [b]IRP state.

Table 2. Nominal operating road user taxes for selected tractor, semitrailer combinations for sampled states in 1976.

	Nominal Operating Road User Taxes (¢/mile)				
Structure	GA	MD	NJ	TN	VA
First[a]	1.60	1.91	1.70	1.70	2.34
Second[b]	0.77	0.91	1.24	1.75	1.80
Total[c]	2.37	2.82	2.94	3.45	4.14

Note: None of the sampled states levies a third-structure tax.

[a]It was assumed that the vehicle averaged 4.7 miles/gal, the average fuel consumption rate of for-hire fleets in 1976. Excise tax rates per gallon were as follows: Georgia, 7.5 cents; Maryland, 9.0 cents; New Jersey, 9.0 cents; Tennessee, 8.0 cents; and Virginia, 11.0 cents.

[b]Annual registration fee on a for-hire, five-axle, diesel-powered, tractor semitrailer combination, 70 000 lb G.V.W., traveling 50 000 intrastate miles. Registration fees were as follows: Georgia, $385; Maryland, $455; New Jersey, $620; Tennessee, $878; and Virginia $894.

[c]The sampled carriers paid an average 2.62 cents/mile in operating and capitalized federal user taxes in 1976.

was obtained from the M-1 reports; mileage operated in each state was provided by the state tax authorities.

These data enabled us to estimate 1976 road user tax payments by the sampled carriers to Georgia, Maryland, New Jersey, Tennessee, and Virginia. The carriers were grouped on the basis of domicile and classified into one of three groups for each state. If the carrier's corporate headquarters was located within the state, the firm was classified as a resident carrier. Otherwise, the firm was considered a nonresident carrier. Nonresident carriers were also grouped as being from IRP or non-IRP member states. In 1976, two of the five states that responded were IRP members.

Table 1 shows what the carriers paid in operating user taxes per mile to the respective states in 1976. Table 2 shows nominal operating user taxes per mile under basic assumptions for the same year. The latter table represents what the carriers would be expected to pay per mile in operating taxes to the respective states. In Table 1, the first row contains the amount that non-resident carriers from non-IRP states paid in user charges per mile. These payments are generally greater than the motor-fuel tax liabilities (first structure taxes in Table 2) but less than the estimated nominal tax rate per mile (total of first and second structure taxes in Table 2). When we compare what foreign carriers actually paid per mile to states and the estimated tax per mile, New Jersey collects more than the estimate. These collections reflect the pickup and delivery vehicles of foreign-domiciled carriers used in the New York metropolitan area.

Table 1 also shows that Virginia collections from foreign-domiciled carriers are significantly lower than the estimate in Table 2. This finding is consistent with previous findings where the low effective tax rate was attributed to Virginia's high nominal rate (5, p. 917). As noted earlier, Virginia has the highest registration fees on tractor, semitrailer combinations along the eastern seaboard. Approximately 45 percent of the Virginia operating user taxes per mile would be derived from registration fees under the assumptions outlined in Table 2. But, under the registration-reciprocity agreements entered into by Virginia, no registration fee is required from vehicles properly registered in other states and provinces. Since more than 60 percent of the mileage traveled in Virginia by larger vehicles is by foreign-domiciled carriers (3), Virginia's effective rate is significantly less than its nominal rate.

As shown in Table 2, Tennessee has a nominal second structure tax rate only slightly lower than that of Virginia. However, its collections from foreign-domiciled carriers in Table 1 approximates the estimate in Table 2. Unlike Virginia, Tennessee administratively has worked to have foreign-domiciled carriers proportionately register line-haul vehicles in-state on a somewhat ad hoc basis. That is, if a carrier does 15 percent of its line-haul mileage on Tennessee highways, then it is asked to register approximately 15 percent of its vehicles in Tennessee. In essence, Tennessee enforces its own proportional registration requirement from non-IRP state carriers and, as a result, per mile payment to the state by the two types of foreign carriers are similar (Table 1).

Carriers from IRP member states should have been found to pay higher user charges to other IRP member states than carriers from nonmember states. This expectation was borne out (Table 1). In 1976, Tennessee and Virginia were IRP members. Both states received more from carriers domiciled in IRP states than from other foreign-domiciled carriers. The explanation for the Tennessee minimal differential was discussed above.

Note that, in Table 1 carriers from IRP states, although they paid higher user tax rates to member states than did non-IRP carriers, they paid lower user tax rates to nonmember states. This result was true for each nonmember state. For instance, although Georgia collected 2.19 cents/mile from foreign-domiciled carriers based in non-IRP states, it collected only 1.66 cents/mile from similar carriers domiciled in IRP states. This payment just covers the carriers' motor-fuel tax liabilities, which are not subject to reciprocity. This result reflects the tendency for IRP-state-based carriers to apportion more of their line-haul equipment. Thus, nonmember states receive even less in registration fees. This finding suggests that, the more widespread IRP membership becomes, the greater the adverse revenue impact on nonmember states and thus the greater political and economic pressure to join.

Table 1 also shows what resident carriers paid to their home states. There were enough carriers to give statistically significant results in two states, Tennessee and Virginia. As would be expected, road-user-tax payments per mile by resident carriers were significantly higher than payments by the two nonresident classes. In Tennessee, resident carriers paid 20 percent more per mile in road user charges, and in Virginia, resident carriers paid 54 percent more than foreign IRP carriers. The Tennessee proportional registration requirement again explains the narrower differential.

We noted earlier that IRP membership should lower collections of state user taxes from resident carriers. Data limitations permitted us to test this hypothesis only for Virginia. In 1973, the same sample of resident carriers was found to have paid 5.43 cents/mile to Virginia in user charges (6, p. 15), and a foreign sample was estimated to have paid 2.42 cents/mile. Although resident carriers in 1973 were estimated to have paid 124 percent more in road user taxes per mile than non-resident carriers, by

Table 3. Allocated costs and total user tax payments to Virginia by carrier class.

Class and Carrier Type	1976 Federal and State User Payments per Mile (¢)	1976 Federal- and State-Allocated Cost per Mile (¢)	Costs Covered (%)
All ICC-class I common carriers	5.96	8.57	70
Virginia resident, ICC common carrier	7.59	8.33	91
Nonresident, ICC common carrier from IRP state	5.78	8.66	67
Nonresident, ICC common carrier from non-IRP state	5.52	8.66	64

1976 (the first full year of IRP operation) this differential declined to 54 percent. This narrowing was the result of higher payments by IRP-foreign carriers and lower payments by resident carriers.

ESTIMATING ALLOCATED COSTS

Although estimation of allocated costs for the sampled carriers is beyond the scope of this paper, a brief comparison of costs and user revenues that relys on cost data developed elsewhere would put the above results in perspective (6). Because it has been the predominant method, allocated costs were estimated by using the incremental cost technique of the occasional cost method (7). Federal cost data (7) in 1964 dollars were used to generate Virginia costs. Then, indices were used to bring the results into 1976 dollars. Responsibilities for construction and maintenance costs by vehicle classification were calculated separately and summed.

To estimate Virginia cost responsibility per mile by type of motor carrier, estimates were made of the vehicle mix used by carriers of various domicile. ICC and Virginia data were used to estimate the vehicle mix. The estimated allocated cost per mile by carrier domicile is found in Table 3, second column. The highest Virginia cost responsibility is attributed to both IRP-member and non-IRP, foreign-domiciled carriers. This higher cost responsibility reflects their greater use of the largest tractor-semitrailer combinations. Total federal and Virginia road user tax payments are given in the first column of Table 3. The latter includes operating and capitalized payments.

From Table 3, Virginia-domiciled carriers had the highest coverage rate; user payments covered 91 percent of their allocated costs. This high coverage reflects that Virginia-domiciled carriers registered a disproportionate number of vehicles in their home state. Foreign-domiciled carriers from IRP-member states covered an estimated 67 percent of their allocated costs; foreign-domiciled carriers from non-IRP-member states covered 64 percent of their costs. Thus, in 1976, none of the carrier classes covered their allocated costs.

SUMMARY

This paper examined the 1976 operating user taxes paid to five states by a sample of 98 ICC-certificated, class I, common motor freight carriers. With one exception, effective tax collections by the sampled states were in the same order as nominal tax rates. Because of registration reciprocity, foreign carriers paid less in each state than did resident carriers. IRP membership was found to lower the disparity between payments made by resident and foreign carriers to a state. Carriers from IRP states paid lower user taxes to the non-IRP states in which they traveled than did carriers from non-IRP states. This finding suggests that non-IRP member states will come under increasing financial pressure to join. When estimated allocated costs by carrier domicile for 1976 were compared with Virginia and federal user tax payments, no carrier class was found to cover its allocated costs.

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Critical Evaluation of AASHTO's Manual on User Benefit Analysis of Highway and Bus-Transit Improvements, 1977

ANDRE KIMBOKO AND LOYD HENION

The changing nature of transportation systems and services puts a burden on decision makers. Decision makers are usually presented with alternative uses of scarce resources. To choose among transportation improvement alternatives properly, investment decisions should be based on a process that meets efficiency criteria. Over the last few decades, interest in such a process has generated extensive literature. A Manual On User Benefit Analysis of Highway and Bus-Transit Improvements is one in this series. The book is intended to help to determine "whether the benefits from reduced highway and transit user costs (operating costs, fares, travel time values, and accident costs) exceed the highway or bus system costs required to produce the benefits." The manual presents a methodology and cost factors to estimate these system costs and user benefits. The methodology can be applied to most types of highway and bus-transit improvements. The technique and background information are significant contributions to the literature on economic analysis of transportation improvements. Although it assists in the selection of efficient transportation improvements, several factors reduce its practical utility for the average person involved in the early stages of transportation investment planning. This paper reviews the subject matter, stated purpose, and format of the manual. A summary critical evaluation of the manual is provided.

The problem of choosing among transportation improvement alternatives is fundamental to transportation capital investment planning. The literature on this subject demonstrates widespread interest in such a process. The complex nature of the problem has spawned an extensive collection of articles and books that deal with specific aspects of it.

The American Association of State Highway and Transportation Officials' (AASHTO) A Manual on User Benefit Analysis of Highway and Bus-Transit Improvements, 1977 (1) is one of these specialized references. It is intended to help the reader determine (1, p. 1), "Whether the benefits from reduced highway and transit user costs (operating costs, fares, travel time values, and accident costs) exceed the highway or bus system costs required to produce the benefits."

Economic analysis and cost factors are used to determine the economic desirability of highway- or bus-transit-improvement alternatives by estimating benefits that might be accrued to the users. This methodology excludes consideration of the nonuser social, economic, and environmental effects of highway or bus-transit improvements (1, pp. 1-2).

Most types of highway and bus-transit improvements, including curve elimination, widening or adding of lanes, grade changes, new road construction, installation of traffic control devices, dedication of lanes for buses, and changes in bus routes or schedules, may be analyzed by using this methodology. Chapters 6 and 7 (1) provide examples for this purpose.

The manual is an update, extension, and replacement of the 1960 AASHTO report, Road User Benefit Analyses for Highway Improvements (2), and a replacement for the National Cooperative Highway Research Program (NCHRP) Report 133 (3). It provides (1, p. 1) "short-cut procedures" to deal with problems referenced in NCHRP Reports 96, 122, and 146 (4-6).

The manual is organized into four major components:

1. Methodology, reduced to eight steps;
2. Project description;
3. Cost definitions and cost factors; and
4. Examples to illustrate the applicability of the proposed methodology and cost factors.

These are presented in seven chapters. A discussion of the economic analysis of transportation improvements is introduced in chapter 1. Chapter 2 presents the proposed methodology (eight steps) for analyzing the economy of highway and bus-transit improvements, and project description and project costs are treated in chapter 3. Chapter 4 deals with unit highway-user costs in terms of basic section, accident, transition, and delay costs. Section transition and intersection delay costs are the subject of chapter 5. Chapters 6 and 7 serve to illustrate the applicability of the proposed methodology and cost factors for highway and bus-transit improvements. Tables of compound interest factors, motor-vehicle running cost-factor tables, method for updating cost factors, decision rules for selecting sets of projects and establishing priorities, and research project summary of findings (NCHRP Project 2-12) constitute appendices A-D.

The manual requires that the reader have a basic familiarity with some tools of economic analysis, both theory and quantitative methods.

EVALUATION

Strengths

The main strengths of the manual are its integrated treatment of the economic analysis of user benefits of highway and bus-transit improvements and decision rules for the selection of sets of projects and the establishment of priorities (1, appendix C). These may be viewed as a major contribution to the literature on economic analysis of transportation improvements.

A few innovative ideas are introduced in the manual (e.g., bus-transit improvements, simplified decision rules, and logically sequenced, but cumbersome, methodological procedures).

Weaknesses

Organization

The manual does not read well. It contains too much detail and excessive background information. Numerous tables and figures distract the reader. Some figures are reduced to a size that makes them difficult to read. These figures and tables could have been consolidated and presented at the end of the appropriate chapter or a change could have been made in the manual's format to accommodate them. The organization and layout of the manual contribute a great deal to this distraction. Chapters start at the middle of pages. The flow of the text is often interrupted by pages of figures (1, pp. 50-61) and tables (1, pp. 126-135).

The methodology that is provided could have been more concise, with necessary detailed and relevant explanation (reduced to a minimum) referenced in the appendices, as in the cases of procedures for updating cost factors (appendix B), decision rules for selection of sets of projects (appendix C), and research project (appendix D). The manual does not contain an index to facilitate references to the major subject areas dealt with in the text. An index is a very useful device, especially for inexperienced practitioners.

The inclusion in the main body of the text of contradictory statements that justify the limitation of the book to user benefits and costs only and of a lengthy discussion regarding consumers' surplus and its controversial adaptation to explain induced and diverted traffic does little to improve the readability of the manual and to enhance the understanding of the principles of cost/benefit analysis for the average analyst. Indeed, in some cases, it creates confusion.

These difficulties may reduce the usefulness of the manual to many practitioners who are relatively inexperienced in transportation economic analysis (7). More than 60 percent of the states prefer a simple but accurate methodology to assist them in their transportation investment programs (7).

Concepts and Approaches

In general, the manual deals thoroughly with major theoretical concepts that underlie transportation economic analysis and presents logical approaches for applying them. In a few instances, statements are made that are questionable and contradictory and approaches are taken that do not totally reflect today's transportation conditions. For instance, in defining the scope of the manual, it is stated that (1, p. 2), "For developed countries, the economic elements of the SEE trilogy--social, economic, and environmental impacts--is largely covered by highway and transit user impacts." This is offered as the basis for focusing on the effects of highway and transit improvements on transportation costs. According to the book, this practice is consistent with (1, p. 2) "current economic theory."

The statement referenced above is true only as long as all of the SEE costs, including all of the transportation costs, are internalized by the highway and bus-transit users. This is not the case in today's transportation system. This is indirectly recognized by the authors for the case of SEE, since in the next paragraph the reader is reminded of the "crucial importance" of the SEE trilogy, and later the exclusion of SEE is cited as one of the manual's limitations (1, p. 176).

Another justification given for restricting the manual's scope to the user economic effects is that (1, p. 2) "...such analysis is limited to readily costable benefits and costs." However, the authors readily adapt the concept of consumers' surplus to explain the inclusion of induced and diverted traffic. The concept of consumers' surplus is basically derived from "willingness-to-pay", which is a value that is not readily measurable. Such statements, although few are dealing with fundamental concepts, may create misunderstanding and confusion among practitioners--the very persons that the manual is trying to assist.

For the analysis of improvement costs for highways and bus systems, the authors present only a listing of types of project cost estimates (1, pp. 37-40) and brief discussions on analysis period (1, p. 20) and residual value (1, p. 29) of the improvements. These are not only loosely connected but are presented as separate components conceptually as well as organizationally.

A more comprehensive discussion, similar to the discussions about user costs (1, pp. 40-75), that involves these three components would have provided the reader with useful insights into the highway and bus system improvement costs (project costs) and the interdependence of these three components. For example, lifetime or service life of a highway facility is a determinant of residual value of the facility. The analysis period may very well be influenced by the surfacing design life option. Project cost estimates depend on the design alternatives adopted, and this in turn impacts the cost of a project.

Major policy issues in transportation investment planning evolve around these components. The development of strategies for pavement management is one of them. These strategies cannot be properly developed without a good understanding of the interdependence of these components and the various alternatives based on current conditions (e.g., changing vehicle mix or increasing axle load). These alternatives determine the project cost estimates, including maintenance costs. The development of these alternatives includes determination of design life alternatives, coupled with the economic analysis of each alternative and its effect on the highway system.

Such a comprehensive, but concise, discussion would provide the decision maker with potential options from which to develop pavement-management strategies based on current conditions. Improvement projects could then be evaluated, by using cost/benefit analysis, based on these strategies.

Most of the available strategies were established under conditions and policies that prevailed 20 years ago or longer. Some of these conditions have changed, or at least are operating in a different direction from the one assumed previously. For example, nationally, registration of heavy vehicles (buses and trucks) increased at much higher rates than registration of passenger cars. Between 1970 and 1977, registration of heavy vehicles grew by about 57 percent, but the increase for passenger cars was only 27 percent during the same period. For the same period, the vehicle miles of travel for heavy vehicles rose by about 51 percent as opposed to about 26 percent for passenger cars (8). Moreover, the axle load of heavy vehicles has been steadily increasing for the past decade.

Without these strategies, the reduced costs for highway users due to improvements may be short-lived. In fact, the rapid deterioration of much of the highway system and the increasing costs of resurfacing, rehabilitation, restoration, and reconstruction may be partly viewed as a direct result of the current lack of such sets of strategies.

Concepts and Illustrations

In general, the manual gives complete and detailed suggestions, guidelines, and examples. However, some of these suggestions and guidelines (rules of thumb) are offered with no explanation or reason, and in certain cases they are ambiguous and inappropriate and perhaps they should not be followed (or at least they should have been presented as optional) due in part to the set of assumptions implicit with their use.

For instance, in relation to the user cost factors, the book recommends updating them (1, p. 14) "when the relevant price levels...change by more than 20 percent." Why 20 percent and not 10 or 15 percent? The currentness of cost factors is sought, in part, to account for the effect of inflation on price levels (including the relevant ones) as reflected by the change in the consumer price index (CPI) or other price level change indicators. The market rate of interest and the current dollar discount rate (the market or nominal rate of interest used to discount future streams of benefits and costs expressed in current dollars) are subject to inflation. The market rate of interest is one of the components of the CPI. CPI and interest rate change at different rates and not necessarily at the same time.

There is a direct relationship between market rate of interest and change in relevant price levels (e.g., an increase in interest rate would be reflected in higher cost of an automobile). When outdated cost factors are used to calculate future user benefits and costs in current dollars, the projected user benefits and costs would be underestimated by an amount, in percentage, approximately equal to the percentage change in the relevant price levels.

The decision to keep cost factors current is then a function of how much underestimation of user benefit and cost the analyst or decision maker is willing to allow. A rule of thumb that emphasizes the relation between relevant changes in price level and the market-rate-of-interest, on the one hand, and the amount of the underestimation of future user benefits and costs on the other hand, would be more helpful than a mere specific figure of relevant price level change. Such a suggestion might read as follows: When relevant price levels change at a higher rate than that of the market-rate-of-interest, efforts should be made to update cost factors unless the analyst or decision maker decides otherwise.

Similar suggestions are made with respect to (a) vehicle mix (1, p. 42), (b) changes in highway user costs due to change in bus-transit patronage (1, pp. 102-103), and (c) others [e.g., residual value (1, p. 29) highway section definition, variations in volume/capacity ratios (1, p. 35), calculation of present values of benefits and costs, and accurate calculation versus practical applications (1, p. 20 and p. 30)]. Only the first two are considered here.

Regarding the vehicle mix, the book states (1, p. 42), "If the percentage of trucks in the traffic stream is relatively small (less than 5 percent), basic section costs may be calculated as if the entire stream consists of passenger cars." This statement, specifically the less than 5 percent, is misleading and does not reflect the complete picture of vehicle mix when considered in conjunction with the design standard (design life), and construction and maintenance costs of certain improvements (e.g., curve elimination as given in the book on page 78).

For example, take a basic section that has an average hourly traffic of 1000 vehicles. First, assume, as in the manual, that the entire stream consists of passenger cars that weigh about 3800 lb each. This is equal to about 500 equivalent single-axle load (ESAL). Second, assume that the vehicle mix is made up of 95 percent passenger cars and 5 percent trucks. There would be 950 passenger cars and 50 trucks (29 trucks of typical 18-wheeler 3-S2 configuration that weigh about 54 000 lb each and 21 single-unit trucks that weigh 12 000 lb each). This vehicle mix amounts to about 21 700 ESAL (475 for passenger cars plus 21 225 for trucks).

With the homogeneous stream, only passenger cars, the ESAL is 500 as opposed to 21 700 ESAL for the heterogeneous stream. This is a ratio of 43:1. The variation in the construction and maintenance cost may be significant; thus, the variation in cost/benefit results of the improvement. The variation in maintenance cost may be translated into shorter life of the improvement due to the increased ESAL. This may become crucial for those states that have an increasing proportion of 3-S2 trucks or segments of the road heavily traveled by 3-S2 trucks.

Vehicle mix is never assumed to consist entirely of passenger cars, regardless of truck proportion, in the design and in the estimates of construction and maintenance costs of an improvement. A possible exception would be bus-transit exclusive roadway improvement. There is no apparent reason to do so when calculating basic section costs.

The manual defines annual user benefits of bus-transit improvements as the reduction in transit user costs and highway user costs. For the highway user costs, these include changes in vehicle running (operating) costs and travel time. The manual asserts (1, p. 103), "These changes are typically a small fraction of total motor vehicle costs and travel time, yet, they are often worth considering when a sizeable change, say over 10 percent, is caused in the vehicular traffic...."

This 10 percent figure is probably intended as a shortcut suggestion. It is inappropriate. A more comprehensive method should have been provided to deal with the analysis of these changes regardless of the amount of reduction in the highway user costs.

The economic analysis of bus-transit improvements may be sought for reasons other than reduction in the highway user costs; although it is to be recognized that reduction in these costs is important, so is the cost reduction in maintenance of highway facilities. The limitations placed by this figure will truncate the availability of additional information that may be acquired about the proposed bus-transit improvements, especially when they are independent of highway improvements or proposed as alternatives to highway improvements.

These considerations, although cited in the manual, are not dealt with appropriately. The manual could have provided examples that deal with bus-transit improvements as alternatives to highway improvements, as well as cases that show relationships between number of buses needed to serve additional person trips, operating axle weight of the needed buses, and additional maintenance and construction costs of the city streets due to buses. These would have enhanced the understanding of much of the literature on bus-transit improvements and increased the usefulness of the manual to its intended users.

CONCLUSION

Although the narrowness of the manual's scope is perhaps justifiable, given the complexity of the problem of selecting among transportation-improvement alternatives, the reason that is advanced for limiting the scope of the manual is not theoretically rigorous.

The book does provide usable tools in the form of procedures to evaluate user benefits and costs. These may be useful to transportation-investment analysts and policymakers. Several illustrations and shortcuts should be viewed as optional and some should not be followed in certain instances. The analyst finds little assistance from the book in dealing with some aspects of bus-transit improvements and improvement cost estimation.

The manual can be a valuable reference document for analysts who are familiar with economic and traffic engineering principles. However, the fundamentals found in elementary textbooks on principles of economics or traffic engineering are lacking.

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The views expressed in this paper are ours and do not necessarily reflect those of the Policy and Planning Section or the Oregon Department of Transportation.

Discussions

Douglas S. McLeod

Kimboko and Henion's critical evaluation of AASHTO's A Manual on User Benefit Analysis of Highway and Bus-Transit Improvements (1) is well based and timely. To a lesser degree, I concur in nearly all of their criticisms. The authors, however, do not present many of the manual's strengths and major weaknesses. The paper is timely because it provides useful comments and further exposure to the most-widely accepted highway and bus-transit economic-analysis methodology. My comments will address Kimboko and Henion's evaluations and will further discuss strengths and weaknesses of the manual.

The authors state four strengths of the manual:

1. Integrated treatment of economic analysis of user benefits of highway and bus-transit improvements,
2. Decision rules for the selection of projects,
3. Establishment of priorities, and
4. Thorough treatment of major theoretical concepts that underlie transportation economic analysis and a logical approach to apply them.

I agree with the authors' assessment of these four strengths. However, other aspects of the manual also contribute significantly to transportation economics literature. First, simply because it is the AASHTO guide, the manual's assumptions and methodology are elevated to the standard to base economic analyses. Second, the manual fulfills one of its major purposes by providing users a means for updating cost factors over time. The updating procedure is comprehensive and relatively easy to implement. Third, the manual is comprehensive and covers greatly diverse highway projects. From personal experience, the methodology has been useful on such a great scale as a large highway network analysis (9), a safety study, and to a lesser extent, on a bus study.

The manual makes two positive breaks with conventional transportation economic analysis. First, the methodology is based on a willingness-to-pay approach (1, p. 154), rather than a conservation-of-resources approach [i.e., 10)]. However, as pointed out by the authors, the manual at times philosophically deviates from the willingness-to-pay approach. Second, the manual recommends a 4-5 percent discount rate (1, p. 15) rather than more traditional higher rates. As stated in the manual, these higher rates inappropriately reflect inflation.

Further positive aspects of the manual are that it is based on well-researched data. Although, as pointed out by Kimboko and Henion, the methodology at times is cumbersome, there are numerous cross references (i.e., 1, p. 12 and in the examples). Finally, the manual is truly a guide for economic analysts rather than a cookbook approach to be followed. Data and basic steps are provided, but significant decisions are left to the economic analysts or decision makers.

Numerous weaknesses of the manual's organization are addressed. Although I agree with each point made, none of them should seriously limit the manual's effectiveness. An index would be useful to inexperienced practitioners, but at least as stated above, there are numerous cross references. My major concern about many of the manual's figures is not where they lie in the text, but their small size. Values obtained are subject to too much error due to the figures' small scale. Larger-scale figures should be provided, or at least be available, for order.

Kimboko and Henion point out convincingly the questionable and contradictory statements concerning

1. The relation between highway and transit user impacts with social, economic, and environmental impacts and
2. The willingness-to-pay approach.

They are correct in stating that the manual's statements dealing with these fundamental economic concepts may create confusion among the manual's users.

Kimboko and Henion in their daily work are obviously very concerned about design aspects of highways and more specifically the interrelationship between heavy vehicles and pavement-management strategies. They criticize the manual for not devoting adequate attention to project costs. I find the manual's discussion on project costs quite adequate. Nevertheless, project costs are important and the manual's final form reflects considerable improvements on this subject compared with initial drafts. Most users who view the manual as a guide for conducting detailed economic studies have probably wished for more-detailed or less-detailed treatments in certain areas under study. From my own experience, I have needed more detail in such areas as initial bus costs, bus salvage values, and highway type-traffic speed relationships. On the other hand, for highway network analyses, a simplified method to aggregate costs of intersection delay was desired. However, after other sources were consulted and professional judgments made, the analyses proceeded. Certainly, I prefer to have guidance from the manual in these important areas; however, given the scope of the manual and wide range of projects to which it can be applied, I cannot find fault with the document for not including these items that were important to me. The manual relies heavily on its users' judgments for determining appropriate considerations in a study. Kimboko and Henion make a strong case for the importance of increased attention to vehicle-mix and pavement-management strategies; however, I do not find fault with the manual for lack of a detailed analysis in this area.

The authors criticize the manual for suggestions and guidelines (rules of thumb) that they feel are inappropriate and ambiguous at times. They point to the manual's treatment of changes in price levels, vehicle mixes, and the reduction of transit user costs and highway user costs from bus-transit improvements. I agree with all three of their assessments; I update costs at the beginning of each study and use appropriate vehicle mixes. However, I do not find fault with the manual for presenting such shortcut methods to users who feel they are reasonable for the type of study they are conducting.

I disagree with the authors' position that the manual's examples are complete and detailed. Quite the opposite, I find the examples replete with simplifying assumptions and no example reflects a majority of the manual's methodology. Note, however, that the manual stated that the examples reflect only specific parts of the methodology (1, p. 78).

Though I agree with the authors' concept of user benefits and costs subject to underevaluation due to inflation, I find their presentation confusing. The interchanging of market-rate-of-interest and discount rate, and the use of current costs throughout the discussion lead to the confusion and the inappropriateness of their possible suggestion for cost updating. I prefer to obtain updated user costs and project costs at the same time to reduce the underestimation of one type of cost versus the other. In any case, the manual's 20 percent price-level-change criterion is too great. A 10 percent level appears more reasonable, and this underestimation will at least be partly offset by lagging project cost estimates. The Florida Department of Transportation updates values yearly but allows analysts the option of updating at any time if desired.

Many weaknesses of the manual were not pointed out by Kimboko and Henion. In my opinion, the two most significant weaknesses of the manual's methodology to its users are the number of calculations required by its users and probable inconsistencies of simplifying assumptions (9). The immense amount of hand calculations for a complex project greatly increases the probability of a computational error. To reduce the probability of error, the manual's methodology needs to be computerized. This need was recognized in the manual (1, p. 176). Florida (9) and Colorado (11) have already developed computer programs based on the manual's methodology. Thus, this weakness is at least being partly corrected.

The second major weakness stems from two of the manual's major strengths. Because the manual covers small-to-immense projects and is a guide rather than cookbook approach methodology, results may be subject to great variability according to what assumptions are made. For instance, one analyst may use the manual's 4 percent discount rate, and another may use the U.S. Office of Management and Budget's 10 percent rate; users may use significantly different accident cost values; or, for a large network study, costs for intersection delay may be included or treated in a general way. Groups of users, say by states, should define more precisely what major assumptions will be used in order to obtain greater uniformity of results.

In addition to the suggested improvements sited by Kimboko and Henion and those above, further improvements to the manual should be made. First, Figure 3 (1, p. 24), which deals with peak-hour traffic characteristics, is inappropriate for all of the manual's examples. The 30th and 100th peak traffic hours are important design parameters but are not relevant to the manual. For example, by using the example on page 24 (and assumptions on page 23) of the manual, there would be 618 one-way peak hours and 1236 two-way peak hours. To use the 30th peak-hour misrepresents traffic peaking characteristics. An hourly curve closer to 618 should be used. As an improvement, hourly traffic curves well beyond the 100th hour should appear in Figure 3.

Further improvements include the following:

1. Change the calculation of a present-worth factor for a stream of benefits (1, p. 31) to a present-worth factor for a stream of costs that involve a specific cost component (9);
2. Change the inaccurate definition of discount rate on page 7 to reflect the appropriate discussions on pages 7, 14, and 15; and
3. Bring back all values to the time of decision (year 0) rather than to the year construction is completed (1, p. 20).

In conclusion, Kimboko and Henion point out valid weaknesses of the AASHTO manual. An understanding of these weaknesses will assist the manual's users. Additional weaknesses are presented, the most significant of which is the number of hand calculations required and the inconsistency of results among users. Positive aspects of the manual also are addressed in this discussion. Despite the weaknesses presented above, the manual is a most important and useful tool to economic analysts and administrators.

Willard D. Weiss

The authors have provided a comprehensive and useful critique of the publication, A Manual on User Benefit Analysis of Highway and Bus-Transit Improvements. A number of their criticisms, however, deserve further comment. Three of these are discussed below.

SEE IMPACTS

The authors apparently take exception to the manual's assertion that (1) "current economic theory" concludes that "for developed countries, the economic element of the SEE trilogy--social, economic, and environmental impacts--is largely covered by highway and transit user impacts". The authors state that it "is not the case in today's transportation system" that all the SEE costs "are internalized by the highway and bus-transit users."

As a general statement, either position could be argued, but what is more important is whether or not for any specific project evaluation the SEE impacts are adequately included in the user cost analysis. To the extent that the SEE impacts of a given improvement are reflected in induced or diverted traffic, those impacts should be measured by the consumer surplus approach presented in the manual. This measure, however, may be quite inaccurate if the induced traffic benefit represents a large share of the total user benefit (i.e., if triangle KLM in Figure 4 of the manual represents a large portion of trapezoid U_oKLU_1).

Thus, in some situations, the procedures in the manual may be adequate for measuring SEE impacts but may be quite inadequate in others. It is currently up to the analyst to decide whether additional SEE analysis is required for any given project. A useful addition to the manual may be some guidelines for making this determination. This could be presented as an appendix, which outlines specific SEE impacts with an indication of the adequacy of their measurement by the procedures given in the manual.

ALTERNATIVE PROJECT DESIGNS

The authors have suggested inclusion in the manual of a discussion of the interdependence of project design (initial cost), service life, and residual value. An example was given for alternative pavement designs, which generate different values of initial cost, annual maintenance cost, and service life. They suggested that procedures be included in the manual for developing pavement management strategies and similar facility designs on an optimum basis.

Determination of the optimum design of a given project is a process highly amenable to application of engineering economy. However, a set of working procedures for optimization of highway design would be necessarily extensive and its inclusion in this manual would probably not be feasible. It may be more suitable as a separate, companion document.

In any case, the evaluation of alternate designs for a given project can, of course, be done by using the manual, by considering each design as a separate, mutually exclusive alternative. The procedure is given in appendix C of the manual.

EFFECT OF VEHICLE MIX ON USER COSTS

As an alternative to estimating user costs separately for different vehicle types, the manual suggests (1): "If the percentage of trucks in the traffic stream is relatively small (less than 5 percent), basic section costs may be calculated as if the entire stream consists of passenger cars." The authors have objected to this simplification and demonstrated that the effect of a small percentage of trucks on roadway construction and maintenance costs may be significant.

The authors may have misinterpreted the term, "basic section costs," in the above quotation. These are defined in the manual as the time value and unit running costs on the analysis section and do not include construction or maintenance costs. Hence, the simplification suggested applies only to the calculation of these user costs and are not intended to be applied to construction and maintenance costs, as the authors have implied. For calculating the basic section costs, the small error introduced by this simplification would appear to be acceptable.

Apart from these comments on the authors' evaluation of the manual, a separate criticism of the manual itself may be raised: The manual does not suggest a procedure for ensuring optimum timing of a project even if its benefit/cost ratio is favorable. Sometimes, especially in a situation where a high traffic-growth rate is projected, even though the total (present-worth) benefits exceed costs, the benefits for the initial year are low and a postponement of the project implementation proves to be more economical than immediate implementation. This may be determined by considering different project timings to be mutually exclusive alternatives (e.g., alternative A is the basic project constructed in year 1; alternative B is the same project constructed in year 2; and so on), and evaluating the alternatives as described in appendix C of the manual.

A simpler approach, which is usually as accurate, is the so-called first-year-benefit analysis. The basis of this analysis is that the economic effect of postponement of the project by one year is represented by the loss of the first year's benefit plus the gain due to the foregone interest for one year on the capital investment. The foregone interest is simply the investment times the interest (or discount) rate. Thus, successive postponements can be tested until the initial year's benefit is reached that just exceeds this foregone interest. That point in time represents the optimum timing; that is, implementation at that time will be more economical than implementation any time earlier (or later).

Determination of the optimum timing of a project does not necessarily ensure a favorable overall benefit/cost ratio for the project, depending on the nature of the future benefit stream. However, for continuously increasing benefits it usually does, and this fact permits another useful application of the first-year-benefit analysis: evaluation of projects in which future benefits are difficult to assess because of traffic congestion conditions. This conceptual problem was addressed in the manual (1, chapter 4 and example 4 in chapter 6), but the solution suggested is somewhat arbitrary and inexact.

An alternate approach is to apply the first-year-benefit criterion and when the optimum timing is determined (which may be immediate implementation), it is generally true that the project is economically feasible as well (favorable benefit/cost ratio). Exceptions to this rule can occur, but only if the traffic growth rate is small, in which case the congestion problem is not likely to arise anyway.

Authors' Closure

Our paper and the subsequent reviews of it by Douglas S. McLeod and Willard D. Weiss should provide the users of the AASHTO manual with insights as to its major strengths and weaknesses. That was and still is our intent.

We appreciate the efforts of the discussants in this process, who, in their reviews of our paper, pointed out additional strengths and potential weakness of the manual. Certainly, some users may also find (if they have not already) many other strengths and weaknesses in the manual.

In general, we concur with the results of the discussants, McLeod and Weiss. However, several areas of their review deserve further comment on our part. We will address: (a) discount rate, interest rate, and related expressions; (b) basic section costs and vehicle mix; (c) shortcut methods; (d) SEE impacts; and (e) interdependence of residual value, analysis period, and cost of improvements.

The proper use of expressions such as market rate of interest, market or nominal rate of return, current and real costs is partly explained on pages 14-15 of the manual (1). A relatively simple definition of discount rate is provided on page 7 of the manual. We disagree with McLeod's assertion that this definition is inaccurate. The manual's definition of discount rate is sufficient and conveys the basic notion of the discount rate, in that money has a time value. A borrower of money (capital) pays interest and a lender of money (capital) expects a return.

Expressions used in our discussion of changes in price level are consistent with the manual's use of these expressions. The effect of change in price level on the interest or discount rate is easily understood. The purpose of our discussion is to suggest an alternative to the 20 percent figure. This alternative would be partly based on the intrinsic characteristics of CPI rather than on an arbitrary figure.

We do not consider the manual's recommendation of a 4-5 percent discount rate to be "a positive break with conventional transportation economic analysis", as reported by McLeod. However, the discussion provided by the manual about what a discount rate ought to represent is important. This discussion leads to the distinction between market or nominal rate of return and rate of return that represents solely the real cost of capital.

As noted in the manual (1, pp. 14-15), the discount rate, which represents solely the real cost of capital (to be used when discounting future benefits and costs estimated in constant dollars), is generally lower (between 4 and 5 percent) than the current market rate of interest (to be used when discounting future benefits and costs projected in inflated or current dollars). The manual notes that this latter rate (i.e., current market) commonly ranges between 8 and 12 percent in recent economic studies of public projects. The discount rate of 10 percent suggested by the U.S. Office of Management and Budget is within that range. The definitional distinction between these two types of discount rate is more important than the mere order of magnitude of these figures.

The complete definition of the expression basic section costs is provided in the manual (1, p. 40). The manual defines it as "consisting of the unit cost (time value and vehicle running costs) associated with vehicle flow and the basic geometrics (grades and curves) of the analysis section". The association is clear in our discussion of this subject. The vehicle mix is used in the estimation of basic section costs as well as in the calculation of project costs of certain improvements (e.g., construction of new freeways or expressways, widening of existing roads or reconstruction to higher geometric standards, straightening or eliminating curves, and grade changes). For a given analysis section the same vehicle mix figure ought to be used in both instances in order to minimize the overestimation of benefits by underestimating the costs.

A case was made by McLeod that the users of the methodology provided in the manual may encounter numerous hand calculations. This, he contends, constitutes a significant weakness of the manual. The large number of hand calculations is not as significant a weakness as is the use of shortcuts suggested in the manual. These shortcuts, with implied assumptions, may lead to inconsistent and varied results, even if the hand calculations are replaced by computer calculations. These shortcuts should be carefully assessed.

With respect to SEE impacts, we reiterate that it is quite inaccurate to assume that SEE impacts are covered by highway and transit user impact if all the transportation costs are not internalized by the transportation users.

Finally, the discussants disagreed with our discussion regarding the need for inclusion in the manual of the interdependence of analysis period, residual value, and cost of improvements (and subsequent reference to the development of pavement management strategies). We still contend that the manual should have addressed these issues or at least alluded to them. Several states have shown interest in these issues. A review of the NCHRP Report 215 (12) [and to some extent NCHRP Report 58 (13)] may provide some insights into the essence of our discussion of these issues.

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