1229

TRANSPORTATION RESEARCH RECORD

Economics, Finance, Planning, and Administration

TRANSPORTATION RESEARCH BOARD
NATIONAL RESEARCH COUNCIL
WASHINGTON, D.C. 1989

Transportation Research Record 1229
Price: $21.50

modes
1 highway transportation
2 public transit

subject areas
11 administration
12 planning
14 finance
15 socioeconomics

Printed in the United States of America

Library of Congress Cataloging-in-Publication Data
National Research Council. Transportation Research Board.

Economics, finance, planning, and administration.
p. cm.—(Transportation research record, ISSN 0361-1981 ; 1229)
Papers presented at the 68th Annual Meeting of the Transportation Research Board.
ISBN 0-309-04821-4
1. Transportation—Planning—Congresses.
2. Transportation—Finance—Congresses. I. National Research Council (U.S.).
Transportation Research Board. Meeting
(68th : 1989 : Washington, D.C.) II Series.
TE7.H5 no. 1229
[HE11]
388 s—dc20
[388'.068] 90-32507
CIP

Sponsorship of Transportation Research Record 1229

GROUP 1—TRANSPORTATION SYSTEMS PLANNING AND ADMINISTRATION
Chairman: Ronald F. Kirby, Metropolitan Washington Council of Governments

Management and Finance Section
Chairman: Barbara Thomas Harder, Philadelphia, Pennsylvania

Committee on Manpower Management and Productivity
Chairman: Kenneth S. Cucchiaro, New Jersey Department of Transportation
Chester J. Andres, Steven L. Butts, John F. DiRenzo, Grant S. Fairbanks, George E. Gray, William C. Grenke, Ken Hogue, Douglas L. Jonas, Bill M. McCall, William R. Moyer, Marvin E. Mundel, Subhash R. Mundle, David A. Schrier, Jay A. Smith, Jr., Elden G. Spier, Anthony R. Tomazinis, William B. Werther, Jr., Sharon S. Wright

Committee on Local Transportation Finance
Chairman: David J. Forkenbrock, University of Iowa
Kenneth J. Dueker, Donald J. Emerson, Terry L. Gotts, Randall Halvorson, Janet L. Jones, Michael A. Kemp, Douglass B. Lee, Robert D. Owens, Wayne B. Placide, David J. Plazak, Arturo L. Politano, Suzanne H. Sale, Kumares C. Sinha, Marilyn Skolnick, Frank J. Smith, William L. Volk, Erskine S. Walther, Mark J. Wolfgram, Norman H. Wuestefeld

Committee on Strategic Management
Chairman: Kathleen E. Stein-Hudson, Howard/Stein-Hudson Associates
Terry L. Adams, John W. Barker, John W. Bates, Linda Bohlinger, Ian C. Campbell, Lawrence F. Cunningham, Sidney Davis, Aadel H. El Dib, Lannetta Finnegan, James W. Guenther, Irving Hand, Mark P. Howard, Sheila A. Keller, George T. Lathrop, Kenneth J. Leonard, Robert G. Maher, Ronald D. McCready, Edwin G. McKeever, James P. Redeker, Noreen Roberts, Aad Ruhl, Peter L. Shaw, Janet Bell Stromberg, Darwin G. Stuart, Bruce D. McDowell

Freight Transportation Section
Chairman: Richard A. Staley, Richard A. Staley Consulting

Committee on Inland Water Transportation
Chairman: Michael S. Bronzini, The Pennsylvania State University
Secretary: I. Bernard Jacobson, Temple Barker & Sloane
George Antle, Kenneth C. Bush, Joedy W. Cambridge, Gary N. Dicer, Gerrit Gort, Lowell D. Hill, Anatoly Hochstein, Kevin H. Horn, William F. Huneke, Marvin L. Jacobs, William F. McFarland, Howard E. Olson, R. Barry Palmer, Craig E. Philip, Larry J. Prather, Miles H. Sonstegaard, Robert N. Stearns, Martin Toyen, Edward F. Tralka

Transportation Data, Economics, and Forecasting Section
Chairman: Edward Weiner, U.S. Department of Transportation

Committee on Application of Economic Analysis to Transportation Problems
Chairman: Antoine G. Hobeika, Virginia Polytechnic Institute and State University
Gary R. Allen, Jan L. Botha, Stewart E. Butler, Kenneth John Button, Ralph C. Erickson, Z. Andrew Farkas, Walter E. Gazda, Jr., David Geltner, Curtis M. Grimm, Loyd R. Henion, Peter M. Lima, William F. McFarland, Douglas S. McLeod, Jeffery L. Memmott, Alan D. Pearman, Kunwar Rajendra, Gabriel J. Roth, Aad Ruhl, Ralph D. Sandler, Guillaume Shearin, Wayne K. Talley, C. Michael Walton, Robert J. Zuelsdorf

Specialized and Rural Transportation Services Section
Chairman: Robert T. Goble, Carter Goble Associates, Inc.

Committee on Intercity Bus Transportation
Chairman: Frederic D. Fravel, Ecosometrics, Inc.
John S. Andrews, Lawrence F. Cunningham, Donald L. Dean, Mary R. Kihl, Theodore C. Knappen, Harold E. Morgan, Jerome J. Rudnick, Robert E. Stammer, Jr., Eileen S. Stommes, Thomas Urbanik II

Statewide Modal Planning Section
Chairman: Kevin E. Heanue, Federal Highway Administration

Committee on Transportation Programming, Planning, and Systems Evaluation
Chairman: Thomas F. Humphrey, Massachusetts Institute of Technology Center for Transportation Studies
Secretary: Kumares C. Sinha, Purdue University
James H. Banks, Edward A. Beimborn, Priscilla S. Cornelio, Joel P. Ettinger, William H. Goldstein, Harvey Haack, W. M. Hilliard, Dale A. Janik, Steen Leleur, Cletus R. Mercier, Monty C. Murphy, Lance A. Neumann, Norman G. Paulhus, Jr., Alan D. Pearman, Kant Rao, Robert E. Royer, Louis A. Schmitt, Robert E. Stammer, Jr., William G. Stringfellow, Darwin G. Stuart

Kenneth E. Cook, Transportation Research Board staff

Sponsorship is indicated by a footnote at the end of each paper. The organizational units, officers, and members are as of December 31, 1988.

Transportation Research Record 1229

Contents

Foreword v

Technology Transfer: Strategy for Innovation Adoption at the Washington State Department of Transportation 1
G. Scott Rutherford and Rhonda L. Brooks

Personnel Scheduling Management System Investigation and Proposal 11
Margaret E. Blau

Evaluation of Strategic Management at Caltrans 25
Noreen Roberts

Strategic Planning Process for Transit Properties 35
Z. Andrew Farkas, Moges Ayele, Seifu Kerse, and Legesse Negash

Regional Economic Impact Model for Highway Systems (REIMHS) 43
Arturo L. Politano and Carol J. Roadifer

Legal Aspects of Competitive Construction Market Behavior—An Assessment in Support of VDOT's Antitrust Monitoring and Detection Effort 53
Gary R. Allen and Donald Culkin

Predicting Financial Impacts on Rural Roads of Potential Rail Line Abandonments 62
Kenneth L. Casavant and J. C. Lenzi

Economic Framework for Understanding Collusive Market Behavior: Assessment in Support of VDOT's Antitrust Monitoring and Detection Unit 71
Gary R. Allen and Cheryl Mills

On the Concept of Total Highway Management 79
Kumares C. Sinha and Tien F. Fwa

Dredged Material: Its Potential for Ice Control Sand Replacement 89
M. William Newstrand

Intercity Bus Stops: Essential Connectors for a Viable Rural System 92
Mary Kihl

Application of California Bus Accident Data in the Study of Intercity Bus Passenger Safety 100
Joan Al-Kazily

A Step-by-Step Procedure for Roadway Network Improvement Priority Setting 108
Fazil T. Najafi

Socioeconomic Methodology for Rural Road Construction 118
J. Greenstein, L. Berger, and H. Bonjack

Local Option Motor Fuel Taxes 127
Thomas W. Cooper and Judith A. DePasquale

Adapting HDM3 User-Cost Model to Saskatchewan Pavement Management Information System 137
Peter Bein

Foreword

This Record deals with a wide variety of transportation planning and administration topics, including economic analysis, finance, and transportation planning and programming.

In the first paper, Rutherford and Brooks provide a review of the current literature on technology transfer. Their work became the basis for a new technology transfer model used by the Washington State Department of Transportation (DOT). Blau, also working for the Washington State DOT, proposes a unified personnel scheduling management system that uses patterns already in existence in the field offices.

In her paper, Roberts describes and evaluates the California DOT's annual strategic management process and discusses its problems. Farkas et al. also discuss the strategic planning process. After reviewing the strategic planning methodology, they describe the results of case studies in the transit industry.

Although it is generally agreed that improvements in transportation systems affect regional economic development, the relationship has been difficult to measure. Politano and Roadifer describe a model that has been developed to measure the regional economic impacts of highway projects.

Allen and Culkin describe aspects of antitrust law, as well as experiences with bid rigging and detecting anticompetitive market behavior, in their study of the Virginia highway construction industry. The paper by Allen and Mills also involves understanding collusive market behavior. The authors set forth key market characteristics that may indicate collusion and then suggest methods for deterring collusive practices in highway construction.

Railroad rail line abandonments result in a transfer of freight to highways. Casavant and Lenzi develop a procedure to predict the road damage caused by rail line abandonment before the occurrence.

Within transportation agencies, a number of separate systems are used to manage the individual operations necessary to design, construct, maintain, and operate highway networks. Sinha and Fwa suggest an integrated total highway management process that would coordinate subfunctions and provide a clear understanding of overall system requirements.

The use and disposal of material dredged from rivers and ports during ship channel maintenance is a continuing problem. Newstrand analyzes the acceptability, costs, and benefits of using the disposal materials for snow and ice control on highways.

Kihl emphasizes the importance of bus stations in efforts to increase bus ridership in rural areas. She asserts that reliable, secure bus stops are essential to both maintaining existing ridership and enticing new riders. Another consideration for intercity bus transportation is the lack of seat belts or other passenger restraints on buses. In her paper, Al-Kazily considers the effectiveness of lap belts on intercity buses.

With limited resources, it is important that transportation agencies have a rational, formalized method for identifying and ranking highway improvement projects. Najafi describes a process for priority programming of projects that has been used in Gainesville, Florida.

Greenstein et al. assert that road improvements in developing countries in South America could increase agricultural production and substantially reduce costs. Substantial benefits could be gained if transportation systems were adequate to get perishable produce to markets or processing plants.

Additional revenues are needed by both state and local government transportation programs. Cooper and DePasquale suggest that the use of local option motor fuel taxes could be an attractive source of revenue and describe the substantial use of such local option taxes in Florida.

The final paper, by Bein, describes the application of World Bank's HDM3 User-Cost Model to the Saskatchewan Pavement Management Information System.

Technology Transfer: Strategy for Innovation Adoption at the Washington State Department of Transportation

G. SCOTT RUTHERFORD AND RHONDA L. BROOKS

The current literature regarding technology transfer is first reviewed in this paper to provide a context for a detailed consideration of the Washington State Department of Transportation (WSDOT's) technology transfer program. Interviews were conducted with WSDOT managers to gather information on existing practices and thoughts on improvements. Information from the literature review and interviews provides the basis for a new model of technology transfer for the WSDOT.

In 1984, the Washington State Department of Transportation (WSDOT) began developing a long-range "strategic plan." In order to define the issues the strategic plan would address, executive managers participated in a seminar to discuss conditions in 1995 and beyond that might affect the state's transportation system. These managers then evaluated the present functions of the WSDOT and identified immediate actions that would give it the capability to meet those future conditions.

WSDOT executive managers generally agreed that in the next two decades a number of changes will occur that will have a major impact on the amount and type of required transportation facilities and services. Among the conclusions they reached was that WSDOT will need to continuously evaluate the way in which it does business in order to fully use rapidly advancing technology and innovation in the transportation field (*1*).

In light of these forecasted conditions, the managers evaluated the department's present ability to meet future transportation challenges and needs. Seven major objectives were identified that required immediate actions by the department. One of these seven objectives dealt with technology transfer and was stated as follows: "provide a program of research and development that integrates technological innovations, methods, and techniques into the activities of the department" (*2*).

Management then developed strategies to accomplish each of the objectives. One strategy identified for the objective just described was to "develop a program of coordinated technology transfer" (*2*).

G. S. Rutherford, Washington State Transportation Center (TRAC), 4507 University Way, N.E., Suite 204, University of Washington, Seattle, Wash. 98105. R. L. Brooks, Washington State Department of Transportation, Olympia, Wash. 98504.

In this paper the authors report on an effort to study technology transfer practices at the WSDOT to

- Determine the state-of-the-art in technology transfer;
- Identify the current technology transfer practices at the WSDOT;
- Assess the current practices and determine whether any coordination of activities is necessary;
- Recommend resources, procedures, and activities required to enhance technology transfer practices; and
- Provide an implementation plan if a coordinated technology transfer program is required.

TECHNOLOGY TRANSFER PRACTICES IN INDUSTRY AND GOVERNMENT

Literature Search and Interviews

The subject of technology transfer is not new or unique to the transportation field. Discussions of technology transfer, innovation adoption, and other related subjects are found in literature from the fields of public and business administration, research use, social sciences, and communications. A review of this literature provided definitions of technology transfer, identified important principles of the process, and showed the state of knowledge in technology transfer.

Technology transfer is also practiced by many private- and public-sector organizations. Interviews with technology transfer specialists and a review of the literature regarding these programs is provided to demonstrate the experiences, techniques, and practices of other organizations.

Department Interviews

Current WSDOT technology transfer practices were identified through a survey of 32 work units in all WSDOT divisions and districts. The survey method consisted of interviewing one or more managers from each work unit. The interview format was borrowed from ethnographic research and, thereby, encouraged managers to express their ideas and definitions on the subject of technology transfer.

An inventory of the existing technology transfer practices that each work unit provided was obtained. The managers identified technology transfer practices that WSDOT employees participated in but that were provided by sources outside the unit. They also discussed organizational constraints that presented barriers to technology transfer in the work unit.

Technology Transfer Model

A review of the literature on the subject of technology transfer is necessary to understand the definitions of technology transfer and some of the organizational issues that influence the process. The literature also shows a trend in technology transfer research. Earlier studies on the process of technology transfer focused on the ability of an individual to adopt innovations. More recently, research has begun to examine issues that affect an organization's ability to produce or adopt innovations.

Technology transfer is practiced by several diverse groups, including government policy makers, business executives, and academic researchers. An examination of technology transfer programs that exist demonstrates the variety of their use by different organizations.

Since the 1950s, many professionals have been writing about technology transfer. A review of books, journals, and articles shows that most authors begin discussing technology transfer by providing a basic model of the process. The popular illustration shown in Figure 1 is used to describe technology transfer by many experts.

Three significant groups are identified in the process of technology transfer: source, user, and transfer mechanism. The identities of these groups are described as follows:

- *Source*—the sources of knowledge created from scientific research, experimentation, and human experience;
- *User*—the person or group who adapts or adopts the knowledge produced by a source; and
- *Transfer mechanism*—the method used to bring innovation from the source to the user.

Stated simply, the process by which a source produces or modifies a technology, how it gets communicated to a potential user, and whether the user adopts such innovation consists of dynamic linkages between these groups.

Social Process

E. Rogers (*3*), one of the early authors on the subject of technology transfer, concentrated on the diffusion of innovation as a social process. Rogers described five stages involved in the process of individuals adopting an innovation:

1. Individuals become aware of the innovation.
2. There is interest or a need for the innovation.
3. An evaluation takes place that weighs the risks against the benefits.
4. The user must have the capability to try the innovation.
5. The individual adopts the innovation when the trial of the innovation produces a significant improvement over the current practice or method.

In early 1980, researchers from the University of Wisconsin produced a more refined description of the characteristics that influence potential users in the technology transfer process. Their work focused on practitioners in the transportation field. These authors identified the following stages of the technology transfer process (*4–6*):

1. *Adaptation*—the altering of innovation and the new setting to enhance the "fit" of the new innovation;
2. *Adoption*—the testing of the innovation, which leads to the implementation, modification, or abandonment of the innovation;
3. *Implementation*—the long-term incorporation of the innovation; and
4. *Diffusion*—the dispersion (both internal and external) of the results.

Organizational Acceptance

Almost a decade after Rogers published his first book on the diffusion of innovation, he coauthored a book that identified certain factors, in addition to costs, that affect the degree of acceptability of an innovation in the organization (*7*). These are:

- *Relative advantage*—the degree to which an innovation is perceived as being better than the idea it supersedes;
- *Compatibility*—the degree to which the innovation is consistent with past experiences, values, and present needs of the organization;
- *Complexity*—the ease at which potential adopters can understand the innovation;
- *Trialability*—the extent to which experimentation or limited testing is possible; and
- *Observability*—the degree to which the results of the innovation are easily visible and communicated to others.

The attitudes of individual organizations were recognized in the late 1970s as an important influence on the adoption of innovation. Three major organizational characteristics that affect adoption are (*8*)

- *Risk-taking climate*—the general willingness of a firm to undertake new ventures that have a potential for failure;
- *Regulatory framework*—the extent to which others (legislature) can intervene (either positively or negatively) in the decisions of an organization by placing requirements on procedures and programs; and
- *Labor reaction*—the likely reaction of unions and employee groups to an innovation.

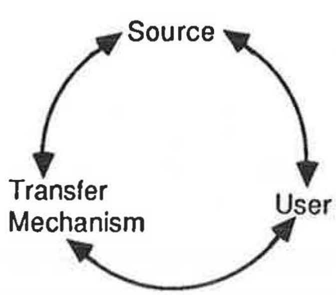


FIGURE 1 Technology transfer model.

Innovation in Corporations

By the 1980s, the subject of innovation became an important topic to business leaders. Increased market competition, rapidly developing technology (particularly in the computer field), a changing work force, and the economic climate were conditions that influenced managers to evaluate the way in which their organizations produced or adopted innovation. The analysis focused on not only the companies' ability to produce new products and technologies but also to adopt or adapt those that were being rapidly developed in the marketplace.

In a major study of American corporations, R. M. Kanter (*9*) selected 10 companies to determine the significant elements that contributed to their ability to be innovative. She defined innovation as "the process of bringing new problem-solving ideas into use. This process involves the generation, acceptance, and implementation of new ideas. Innovation occurs in any part of the organization and can involve creative use as well as an original invention."

Kanter found that innovation was the result of companies who practiced integrative management and problem solving. "Integrative (management) is the willingness to move beyond received wisdom, to combine ideas from unconnected sources, and to embrace changes as an opportunity to test limits." The contrasting management style and structure is "anti-change oriented and prevents innovation." Kanter called this "segmentalism" because "it is concerned with compartmentalizing actions, events, and problems and keeping each piece isolated from the others." Companies who have segmental operations find it difficult to innovate or to handle change.

Kanter made important recommendations to managers for providing innovation in an organization. These are summarized as follows:

- Encourage an innovative culture in the organization by highlighting the achievements of its employees. This culture is established by providing rewards, introducing innovations to different areas in the organization, and letting the people who discover or produce the innovation be the marketers of the product or method.
- Provide employees with greater access to a responsive system by establishing multidiscipline committees that review and support proposals for innovation.
- Improve lateral communications by bringing people from different departments together. Allow greater horizontal mobility for employees by allowing work groups or teams to work on projects.
- Create cross-functional links, even overlaps in functions, so that teams of people are responsible for the same end product.
- Reduce the layers of hierarchy that produce barriers to resources. Push decision making downward, making it possible for people to directly pursue what they need. Allow employees to share information and provide quick intelligence about external and internal affairs.
- Reduce secrecy about the organization by providing employees more information about the company's plans. Avoid surprising employees with new plans by involving them in the development of such plans.
- Give people at lower levels in the organization a chance to contribute their ideas by involving them in task forces and problem-solving groups or through more open-ended, change-oriented assignments, with room for the employee to determine the approach.
- Establish an organizational structure for change that is parallel to the existing organization. Provide recognition of the change structure to employees.

Another important observation that Kanter made was that "top executives need at least some of the qualities of corporate entrepreneurs in order to support this capacity at lower levels in the organization." In other words, executive managers must not only support innovation within the organization, they must be innovative leaders.

INNOVATION IN PUBLIC ORGANIZATIONS

P. Drucker (*10*), an author of many books on management, entrepreneurship, and organizational excellence defined innovation as the "effort to create purposeful, focused change in an enterprise's economic or social potential. The success of an organization is based on its ability to adopt change and to provide a work environment that induces employees to be innovative."

According to Drucker, most innovations in public agencies are imposed by outside sources or catastrophes. He explained that for many organizations the belief is that "if you invent a better mousetrap, the world will beat a path to your door." But what managers fail to consider is, what makes the mousetrap "better," and for whom?

Drucker proposed that the vehicle for a change in attitudes, values, and behavior is a "technology" called management. He sets forth principles for managing innovation that include analyzing the opportunities for innovation by looking, asking, listening, and introducing simple focused changes on a small scale.

Drucker explained why innovative enterprises are difficult for a public agency. His reasons are summarized as follows:

- Operations are based on a "budget" rather than results.
- Innovation in the public sector must please many constituents, rather than just the customer.
- Change can be a threat to a public agency's existence, beliefs, and values.

Drucker recommended policies for organizations to establish that would provide a climate for innovation:

- Establish a clear definition of the department's mission;
- Develop a realistic statement of goals;
- View failure to achieve objectives as an indication that the objective is wrong;
- Instill a constant search for innovative opportunities through policies and practices; and
- Allow opportunities for lower-echelon employees to participate in the process of innovation.

Barriers to Innovation

J. B. Quinn (*11*, p. 34), author of books on strategic management and technological innovation, explained that innovative organizations must "recognize that the random, chaotic nature of technological change cuts across organizational and institutional lines, laps into a multitude of outside resources and user groups." Quinn described the bureaucratic barriers in an organization that affect its ability to innovate as follows:

- Executive managers have little contact with workers who might influence their thinking about technological innovations.
- People who go outside the chain of command are viewed as "fanatics, troublemakers, or nonteam players."
- Executive managers have expectations for immediate quantifiable results.
- The costs of assessing direct, indirect, overhead, overtime, and service costs against a project add to development costs; big projects often become political targets.
- Managers who want innovation to occur only through formal research and documented results rationalize excessively.
- In the name of efficiency, the organizational structure can require many approvals; it can take a chain of "yeses" to approve a project and only one "no."
- Reward and control systems are designed to minimize surprise, yet innovation is full of surprises that can disrupt plans and control systems.

Technology transfer is practiced by several diverse groups including government policy makers, business executives, and academic researchers. The following examples of technology transfer are provided to demonstrate the various technology transfer programs in other organizations.

U.S. Department of Agriculture

Since 1914, the U.S. Department of Agriculture (USDA) has funded cooperative extension services at universities around the country. As universities generated new knowledge through research, it soon became apparent that there was a need for technology transfer to teach the results of the research to practitioners in the field. The present-day cooperative extension service centers were established in most states through a cooperative effort by the USDA, universities, and local governments.

The cooperative extension's mission is to assist people in making informed decisions through research and experience based on educational programs; improve agriculture and natural resource management; improve the capabilities of individuals and families; aid communities in developing and adapting to changing conditions; and provide developmental opportunities for youth (*12*).

Cooperative extension "agents" link the needs and problems of people and communities with rapidly developing technology. Extension service centers practice technology transfer by teaching; distributing publications, newsletters, and brochures; arranging demonstrations, workshops, and seminars; and providing one-to-one technical advice and problem solving.

FHWA

The FHWA developed the Rural Technical Assistant Program, commonly called RTAP, in 1982. This technology transfer program focuses on rural roads, bridges, and public transportation. "Rural" in this program means counties, small cities, and towns that are not part of urbanized areas. Around the nation, 41 technology transfer (T2) centers assist local transportation agencies in receiving the training and new technology they need. The T2 centers provide materials to local agencies, distribute newsletters on the latest technology, conduct training, and evaluate programs. Most of these T2 centers are coordinated from a university, although some are administered from a state transportation agency. Under this program the latest in technology, as developed by research, industry and other sources, is transferred to a network of local transportation agencies.

International Organizations

Technology transfer is practiced globally by the U.S. State Department and other federal and privately funded agencies to introduce new technology and knowledge to developing nations. Unique considerations in international technology transfer include geography, language, and culture. The United States transfers knowledge to other countries about agricultural technology, population control, space technology, and weapons (*13*).

Summary

Research on the technology transfer process began with examinations of the factors that influence individuals to adopt innovation. Today, technology transfer is analyzed in the context of organizations because the organization determines whether the individual seeks out and uses innovation in the work environment. Another reason that the focus of technology transfer research is now on organizations is that managers recognize the individual as an important source of innovation. Organizations must have the ability to capture innovation that is created or discovered by employees.

Programs of technology transfer play important roles in the functions of many different organizations. Educating farmers about new agricultural technology, transferring population control methods to developing nations, and bringing new products and methods to rural transportation workers are examples of the technology transfer process. Successful technology transfer is important to an organization because more knowledge, better use of resources, progress, and the elimination of inefficiencies are all feasible outcomes. Technology transfer is important to individuals and communities for the same reasons.

CURRENT WSDOT TECHNOLOGY TRANSFER PRACTICES

Technology transfer is practiced in all WSDOT divisions and districts through a variety of methods and techniques. The techniques or "transfer mechanisms" that individuals and work units use to introduce sources of knowledge to potential users are categorized for the purpose of discussing the current practices in WSDOT.

Many external organizations and groups, such as the U.S. Department of Transportation and private industry, also provide technology transfer.

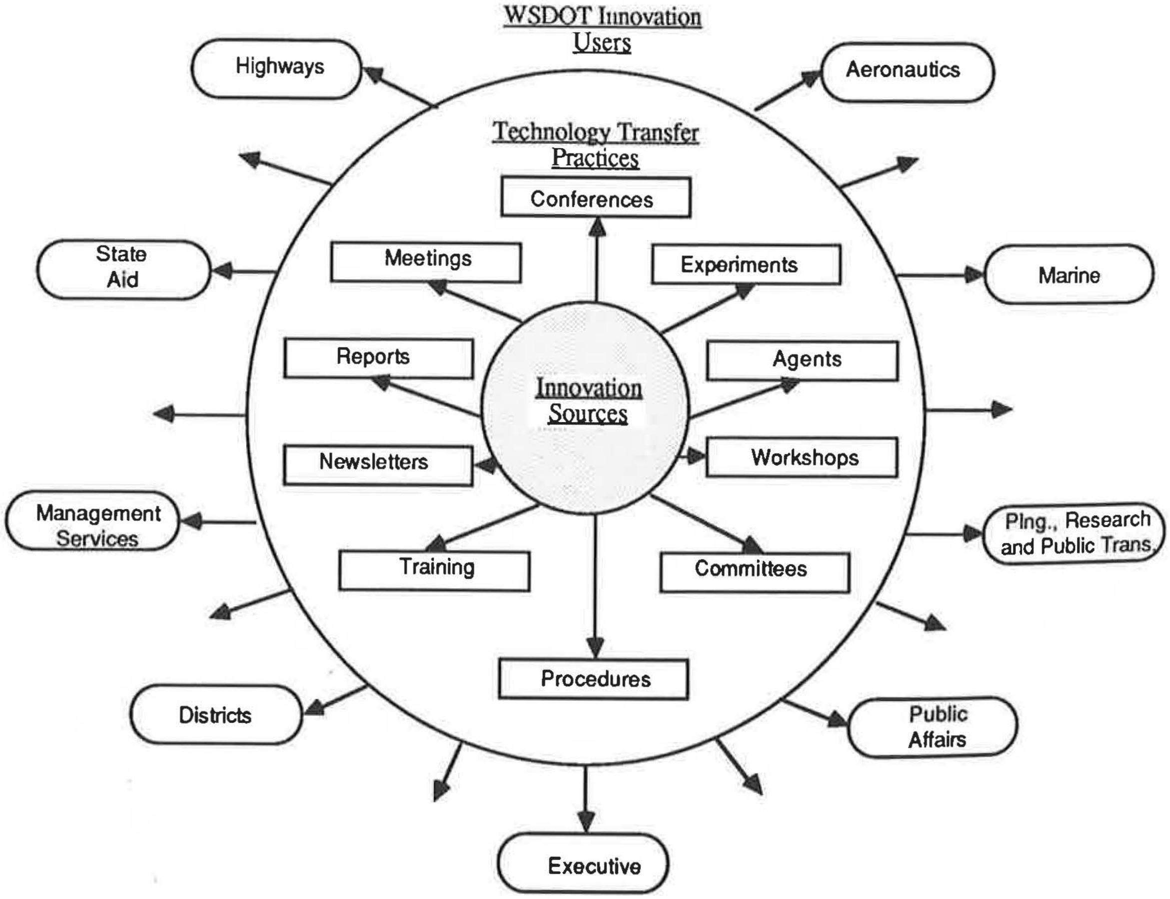


FIGURE 2 Current technology transfer practices at WSDOT.

Figure 2 illustrates how innovation is transferred through conferences, meetings, reports and so on into WSDOT divisions and districts. Technology transfer is clearly practiced within each district or division but with no recognized connection between different sources, WSDOT offices, or functions, so that much information simply never reaches appropriate users.

An overview of the technology transfer practices of each work unit that participated in the study is provided in a matrix (Table 1). This information was collected from interviews with WSDOT managers from 32 work units.

The following sections describe how each activity is used for technology transfer. Data gathered by the survey interviews provide specific examples for each practice. Relevant issues pertaining to the practice are also discussed.

Conferences

Many formal and informal opportunities for technology transfer occur at conferences. Displays, presentations, workshops, demonstrations, and papers are all technology transfer mechanisms that can be part of a conference program and used to introduce innovation to potential users. Conferences provide an opportunity for attendees to gain knowledge about events that are external to their own organization. More important, conferences provide attendees opportunities for face-to-face contact with peers and other professionals. Important contacts for future activities and problem solving can be made at conferences.

Although conferences are an excellent technique for providing technology transfer, the number of employees who attend is limited by budget constraints and out-of-state travel restrictions. Opportunities for attending conferences in WSDOT are provided to executive managers and some employees from middle management levels. Therefore, it is important that managers who do attend conferences communicate their experiences to other members of the organization. Some managers accomplish this by conducting staff briefings on conference events. Other managers file "trip reports," which are distributed to other executive managers.

Workshops

Workshops can be a technology transfer practice because they give attendees an opportunity for first-hand experience with a new product or procedure, usually in a "working session." Workshop topics are specific in nature and provide an opportunity for the attendees to discuss their experience with each other. WSDOT's Management Information Systems office conducts workshops on new software packages with informal groups of employees. WSDOT participates in workshops sponsored by the FHWA and private industry.

TABLE 1 OVERVIEW OF WSDOT TECHNOLOGY TRANSFER PRACTICES

Group	Confer-ences	Work-shops	Train-ing	Demon-stration	Exper-iment	Agent/ Liaison	Reports	News-letter	Proce-dures	Research	Commitee	Annual Meeting	Assoc-iations
Staff Development	—	AC	C Crd	C	—	—	PR	—	F	Y	Y	Y	Y
Public Affairs	S	—	ACS	S	—	—	PR	PR	—	Y	Y	—	Y
Aeronautic	ACS	AC	AC	AC	C	—	PR	PR	—	Y	Y	Y	Y
Highways													
Resource	—	—	C	—	—	Carr	—	—	I	—	Y	—	—
Bridge	ACS	AC	AC	AC	C	Henley	PR	R	F	Y	Y	Y	Y
Location/Design	A	AC	AC	AC	C	Gripne	PR	R	F	Y	Y	Y	Y
Construction	A	AC	AC	AC	C	—	PR	R	F	Y	Y	Y	Y
Materials	A	AC	AC	AC	C	Anderson	PR	R	F	Y	Y	—	Y
Maintenance	A	AC	AC	AC	C	Williams/Kesseck	R	PR	F	Y	Y	Y	Y
Traffic	A	A	AC	AC	C	C. Mansfield	PR	R	F	Y	Y	Y	Y
Support	A	AC	AC	AC	C	—	PR	R	F	Y	Y	—	Y
Management Services													
Administration	AS	AC	AC	AC	C	—	PR	PR	F	—	Y	Y	Y
MIS	A	AC	AC	AC	C	Area Reps	PR	PR	F	Y	Y	Y	Y
Mgmt./Oper.	A	—	—	—	—	—	—	—	—	—	—	—	—
Library	—	—	ACS	—	—	Russo	RD	R	I	Y	Y	—	Y
Methods/Procedures	—	—	—	—	—	—	—	F	F	—	—	—	—
Marine Division	A	A	AC	AC	C	—	R	PR	F	Y	Y	Y	Y
PRPT													
Research	A	SC	A	C	C	—	PRD	PR	F	Y	Y	Y	Y
Public Trans.	AC	AC	AC	C	—	—	PRD	PR	I	Y	Y	Y	Y
State Aid	A	AC	AC	—	—	—	PR	R	F	Y	Y	Y	—
T2 Center	AC	AC	AC	AC	—	Crommes	PRD	PR	I	Y	Y	Y	Y
Districts													
1	A	AC	AC	C	C	Jacobson	PR	PR	F	Y	Y	Y	Y
2	A	A	AC	AC	C	Senn	PR	R	F	Y	Y	Y	Y
3	A	A	AC	A	—	George	PR	PR	F	—	Y	Y	Y
4	A	AC	AC	AC	—	Coffman	PR	PR	F	—	Y	Y	Y
5	A	A	AC	A	—	McNeil	R	PR	F	—	Y	Y	Y
6	A	AC	AC	AC	C	Larson	PR	PR	F	Y	Y	Y	Y

Key: A = Attend; D = Conduct; Crd = Coordinate; D = Disseminate; F = Formal; I = Informal; P = Publish; R = Receive; S = Support; Y = Yes; — = Not identifed

Training

Once someone has proved that an innovation will benefit the department, a training activity is developed for adopting the innovation on a larger scale. Training is a mechanism of technology transfer when the training activity introduces new skills, products, or methods, rather than instructing employees on established practices of the organization. Technology transfer training is concerned with more than just informing the participant of the existence of new methods or products; the training is intended to help the participant adopt the innovation. For this reason, technology transfer training is most effective when it uses multiple communication methods and provides an interactive learning experience.

Employees in all divisions and districts attend training of some type, as required by statutes concerning human resource development and the requirements of certain job classifications. However, this training is concerned with employee development. Technology transfer training is more oriented toward organizational development because it strengthens knowledge and skills that are identified by the organizations' needs, rather than the individual employees' needs.

Technology transfer training is often part of contracts with private industry vendors who supply WSDOT with new products or equipment. For example, after WSDOT purchases a new product, the vendor may be required to provide training on its use.

Demonstrations

Demonstrations are a technology transfer practice because they provide potential users an opportunity to witness or experience innovation in action. People are more likely to adopt or adapt a product or method when its use has been demonstrated. Demonstrations are conducted informally by various employees in WSDOT when a new product or method has been discovered.

Demonstrations that give employees first-hand information on innovations are also conducted at conferences and meetings. An example at a conference or meeting might be a demonstration of a new traffic control device that operates on light intensities. The inventor of the device might set up a booth at a conference and provide attendees an opportunity to witness the traffic signal's response to varying light intensities.

WSDOT employees also attend demonstrations of new products, equipment, and technology that are provided by private industries. These demonstrations are conducted when vendors contact field offices directly to introduce new products and arrange demonstrations. In many instances, local transportation or public works agencies arrange to attend these local demonstrations.

The FHWA develops demonstration projects from the results of research conducted by transportation organizations. WSDOT participates in these demonstrations sponsored by FHWA.

Experiments

Experiments can produce knowledge that requires a technology transfer practice in order for a user to adopt the innovation. The experiments that are included in WSDOT's technology transfer practices are tests conducted by various offices without a formal connection to the WSDOT research program. These experiments are conducted by employees and work units outside the research office and tend to be more informal than formal scientific experimentation. The successful or failed results of experiments should be communicated to other work units and employees in order for WSDOT to benefit fully.

Agent-Liaison

Technology transfer "agents" are persons whose job responsibilities include keeping apprised of innovative developments in their fields and transferring the innovation to other users through various techniques. Agents also have credibility with users because they are usually at the same peer level as many others in the work unit. In WSDOT there are a few examples of employees who are designated "agents." Examples of some of the technology transfer practices the agent provides are development of proposals for incorporating new technology into bridge construction and maintenance, review of published reports on innovations and consideration of their application in the work unit, and maintenance of a network with peers in other states with bridge operations.

Not every program or work unit in WSDOT has a designated agent or liaison who can be used for technology transfer. In these instances, technology transfer practices occur more randomly and are more difficult to quantify.

Reports

Reports are a practice of technology transfer because they provide information about innovations from a source of knowledge to a potential user.

The WSDOT library, located in WSDOT's headquarters building, catalogs and maintains reports and other printed documents published by WSDOT and other organizations and persons. The WSDOT library is also linked to a regional library system for accessing collections stored in the state and university library systems. The library publishes a regular listing of new acquisitions of interest to transportation officials. This list is distributed throughout WSDOT divisions and districts.

Reports are a passive technology transfer practice because they rely solely on the reader's understanding of the material presented for the method, idea, or product to be applied. The reader does not have the opportunity to ask questions or to communicate with the source of the innovation. Furthermore, research reports are often so technical that the potential user cannot understand the application of the research results. In many cases, research reports are written for other researchers. Brief, concise summaries of the research result or report topic must be produced in order for employees to consider using the information.

Newsletters

Newsletters are a communication tool that, by relating developments and advancements in various fields, can spark ideas in WSDOT employees. Newsletters are also a method to recognize the accomplishments and contributions of employees.

Research

The WSDOT research program operates under a formal Research Council that includes members from the Washington State Transportation Commission, WSDOT executive managers, representatives from the state's two research universities, FHWA staff, and people from private industry. One important aspect of research use is the involvement of potential users in the definition of the problem and the creation of the solution. This is a practice of technology transfer because the process brings researchers and potential users together.

Department Committees

Committees provide an opportunity for technology transfer to occur because members usually represent different organizations, work units, disciplines, and levels of authority. The committee methods of management, decision making, problem solving, and operation provide different perspectives. Committee members introduce innovations and the dynamics of the committee usually provide a vehicle for others to obtain political support for their application.

Procedures

Procedures are used in the practice of technology transfer when WSDOT officially adopts an innovation that has departmentwide impact. When innovations become a procedure, a change or addition to the published WSDOT manual is required. Formal procedures are published for many of the department's functions including highway maintenance, construction, design, administration, and traffic engineering. The manuals describe the accepted standards, specifications, practices or methods of the department. WSDOT manuals go to WSDOT employees, local agencies, and private contractors.

Formal procedures can impede technology transfer because they discourage employees from trying different procedures or deviating from established practice. Legal liabilities and tort claims make changes in proven methods or standards riskier for the WSDOT. For these reasons, changes to formal procedures are carefully reviewed and tried before WSDOT adopts them. Furthermore, much time can pass between acceptance of a new procedure and the publication and distribution of the new procedure to manual holders.

Meetings

Technology transfer is practiced at meetings where peers discuss mutual issues and topics, share information, and communicate with employees who share similar job responsibilities. Annual meetings are held by professional groups in WSDOT, such as the traffic engineers, location engineers, construction engineers, project engineers, and maintenance supervisors. Quarterly meetings are held by WSDOT professionals, including the safety officers, personnel officers, and marine engineers. Most work units hold staff meetings on varying schedules.

The safety meetings are about the only opportunity for field employees to meet in one location. Safety topics are presented by district safety officers, and the employees provide feedback on various equipment and operations. These meetings also provide an opportunity for field employees to discuss work matters with their peers and supervisors.

Meetings, particularly the annual meetings, which are well attended by most professionals in WSDOT, provide many technology transfer opportunities. Workshops, demonstrations, presentations, and displays are sometimes provided at these annual events. The annual meetings provide an opportunity for peers to informally discuss projects and work topics and allow employees to establish and maintain networks within WSDOT.

Professional Associations

Professional associations support technology transfer by providing materials, meetings, publications, newsletters, and networks for employees. Associations also conduct research that produces innovations and report on the latest developments in their professional field.

SUGGESTED PROGRAM OF TECHNOLOGY TRANSFER

Technology transfer is and should be a decentralized process because innovation adoption is more likely if the mechanisms used to introduce innovations are generated and conducted from the users' work areas. Each division and district conducts some type of technology transfer practice, and employees participate in technology transfer provided by external sources.

The various technology transfer practices identified in this study should continue in each of WSDOT's functional areas. However, there must be a concerted effort to reduce departmentwide barriers to innovation adoption.

Kanter (*9*) suggests three elements that must be integrated into an organization in order for employees to be innovative and for innovation to be adopted. These "basic commodities" are

- Information (data, technical knowledge, political intelligence, and expertise);
- Resources (funds, materials, space, and time); and
- Support (endorsement, backing, approval, and legitimacy).

In some areas, staff and time are only available through a predetermined budget, information only flows through the identified chain of command, and legitimacy is available only through the formal authority vested in specific areas, with no support available for consideration of innovations in work methods.

Kanter would call this a segmented organization because each piece is separated from the other in terms of information, resources, and support. Technology transfer requires a more integrative management style because, typically, the creation or adoption of innovation requires a search for information, resources, and support from a variety of functions and work units in an organization.

Coordinating technology transfer requires connecting people from different organizational boundaries as well as sharing information, resources, and support from a variety of groups. Support is obtained for the adoption of innovation through peer groups and management. Strategies for innovation adoption can be more effective if existing resources can be shared and borrowed. Kanter (*9*) describes three organizational operatives that are necessary to create an integrative management environment. These operatives should be part of a coordinated technology transfer program:

- Open communication system so that employees can locate information that they can use to shape and sell a project;
- Network forming arrangements that can help employees with innovative ideas build a coalition of supporters; and
- Sharing and borrowing of resources to get technology transfer mobilized into action.

Development of a coordinated technology transfer program requires an integrative management to have these operatives. Coordinating does not mean control or centralization of these activities; rather, coordination provides information, resources, and support for technology transfer in an organization.

These three elements—resources, information, and support for innovation—are important to an organization's ability to use state-of-the-art technology and innovations in its work methods and operations. Resources exist within an organization that can be more effectively used if managers are able to share them to the benefit of the whole organization and not just the specific work unit. Information from sources outside the immediate work unit provides workers with broader perspectives of the field, and support from peers and management helps facilitate the adoption of innovation.

In WSDOT's case, resources in technology tranfer are expended to benefit external organizations, communities, and the public. WSDOT employees also participate in technology transfer practices that are conducted by WSDOT transfer agents, federal agencies, associations, and private industry. However, more attention is needed to provide technology transfer activities by WSDOT for the WSDOT work force.

The inventory of existing technology transfer practices indicates that there are many opportunities for employees to learn about innovative ideas, methods, and technologies. However, the conclusion cannot be drawn that the knowledge that employees are obtaining from participating in these technology transfer practices is actually being applied to their work methods and activities. Certainly, there has been some impact, considering the improvements and innovations that have been made in the transportation field in recent years. However,

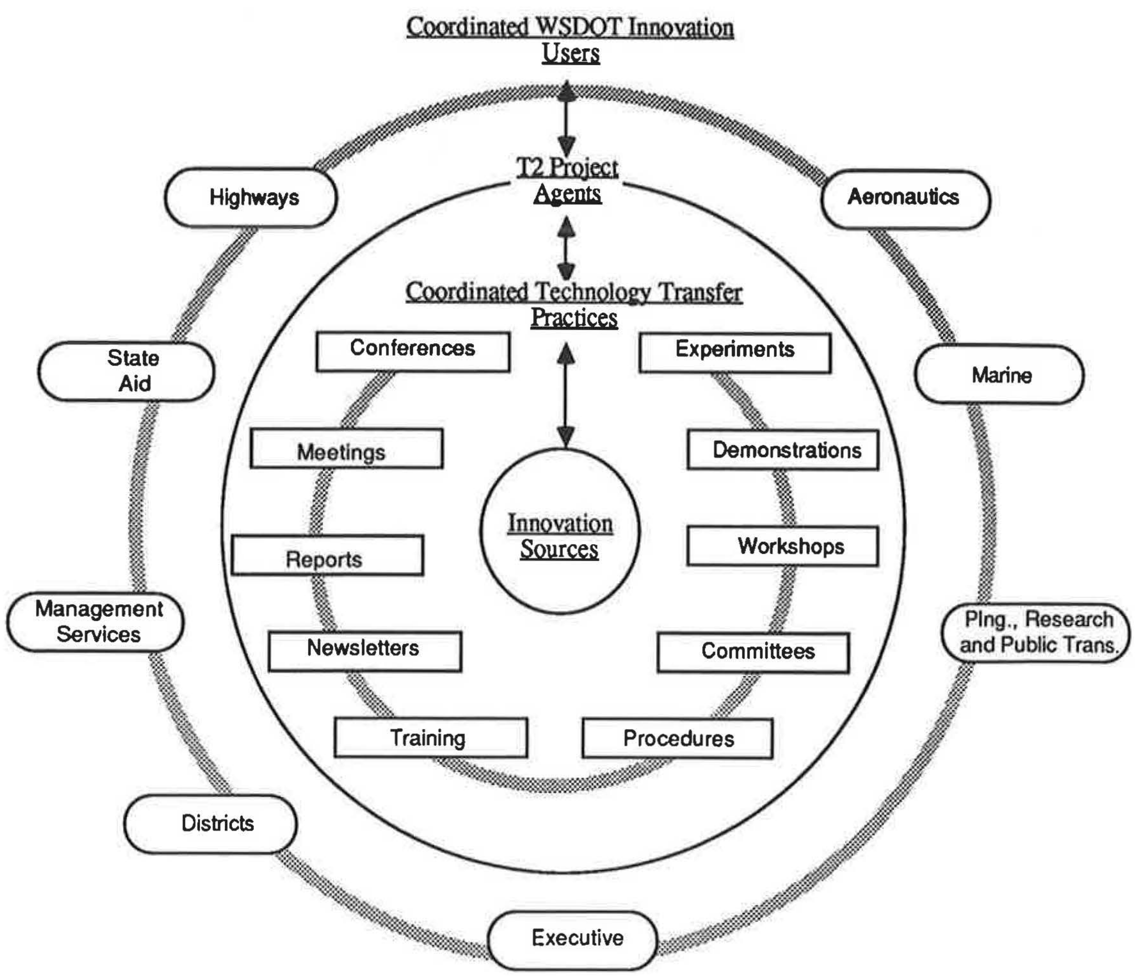


FIGURE 3 Proposed coordinated technology transfer program that parallels current WSDOT program.

there is no certainty that the organization is capturing the most knowledge possible from its employees or using the latest innovation as a result of specific technology transfer practices. Examples of innovation adoption exist, but there is no clear explanation of how the innovation was discovered, how it was adopted, and whether its integration into work methods has had positive or negative effects. It also cannot be concluded that the majority of the work force is receiving information about new technology or that the innovations they are creating are being shared with other work units.

One purpose of this study was to determine whether any coordination of technology transfer is necessary to enhance the process of integrating innovation into WSDOT. The conclusion of this study, based on information from literature and WSDOT employees, is that a coordinated technology transfer program can be one strategy for enhancing WSDOT's ability to adapt and adopt innovation. Figure 3 illustrates a coordinated technology transfer program in which resources, information, and support are shared by different work groups in WSDOT.

Consider the following advantages of coordinating WSDOT's technology transfer practices:

- Resources would be more effectively used in technology transfer practices.
- Opportunities for technology transfer to occur in WSDOT's existing programs and activities would increase.
- More employees would be involved in the existing technology transfer practices.
- Technology transfer practices would be evaluated to improve practices and to provide management with information on their impacts.
- New technology transfer practices would be developed in areas where a need was identified by changing conditions or work groups.

The proposed technology transfer program relies on a strong network of technology transfer agents dispersed throughout the organization. These agents occupy space with their target client groups but communicate with other technology transfer agents to trade techniques and provide encouragement. One primary activity of technology transfer agents is to document innovative adoption successes to provide management with feedback on the status of the process.

In a world of shrinking resources, state departments of transportation must continually seek more cost-effective practices. An institutionalized technology transfer process is a necessary activity in every large organization.

REFERENCES

1. *1995 Plan, Summary of Interviews.* Washington State Department of Transportation Staff Report. Olympia, Nov. 19, 1985.
2. *Strategic Objectives: 1985–1987.* Washington State Department of Transportation, Olympia, 1985.
3. E. M. Rogers. *Diffusion of Innovations.* Free Press, New York, 1962.
4. E. A. Beimborn and R. P. Schmitt. *User Perspectives on the Use of Urban Transportation Research.* Center for Urban Transportation Studies, University of Wisconsin, Milwaukee, Jan. 1981.
5. E. A. Beimborn, R. P. Schmitt, and M. J. Mulroy. *Technology Transfer Primer.* Office of Statewide Transportation Programs, University of Wisconsin, Milwaukee, Aug. 1984.
6. E. A. Beimborn, R. P. Schmitt, and M. J. Mulroy. *Methods of Effective Transfer and Implementation of Highway Maintenance Technology.* FHWA-RD-84-501. FHWA, U.S. Department of Transportation, July 1984.
7. E. M. Rogers and F. I. Shoemaker. *Communication of Innovation.* Free Press, New York, 1971.
8. J. Ettlie and D. Vellenga. The Adoption Time Period for Some Transportation Innovations. *Management Science,* Vol. 25, No. 5, May 1979, pp. 429–443.
9. R. M. Kanter. *The Change Masters: Innovation and Entrepreneurship in the American Corporation,* Simon & Schuster, Inc., New York, 1984.
10. P. F. Drucker. *Innovation and Entrepreneurship: Practice and Principles,* Harper & Row Publishers, Inc., New York, 1985.
11. J. B. Quinn. Managing Innovation: Controlled Chaos. *Harvard Business Review,* Vol. 63, No. 3, May–June 1985, pp. 73–84.
12. *Cooperative Extension: Its Mission, Organization and Programs.* College of Agriculture and Home Economics, Washington State University, Pullman; U.S. Department of Agriculture, Feb. 1985.
13. C. A. Samli. *Technology Transfer.* Greenwood Press, London, 1985.

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

Personnel Scheduling Management System Investigation and Proposal

MARGARET E. BLAU

The focus of this study is the current state of personnel scheduling management systems in the Washington State Department of Transportation construction field offices. It is assumed that, although all of the field offices use some level of scheduling, there could be more effective and systematic and less reactive ways of doing personnel scheduling at this level. The study finds that the project engineers are scheduling under a variety of constraints and concerns that directly affect their ability to do long-range planning and respond quickly to short-range scheduling changes. In response to the findings, a unified personnel scheduling management system has been conceived, using patterns of scheduling already in existence at the field offices. Three design approaches are suggested that would fit into many of the field offices. Recommendations for implementation are also made, which are intended to ease the changeover into these proposed systems.

The Washington State Department of Transportation (WSDOT) is a state governmental agency that has been mandated to provide a multimodal transportation system that meets the social and economic needs of the state (*1*, p. 2). To fulfill the mandate, WSDOT designs, constructs, and maintains various facilities statewide, such as roadways and alternate transportation modes.

The department's construction section oversees the building of new facilities and the replacement of older facilities to the best known standards and specifications. The responsibility for maintaining these standards in construction lies in the on-site inspection of the various projects, which are handled through small units called construction field offices (also called project offices and field offices).

Headed by a project engineer, each field office is responsible for administering the contracts by ensuring that the contractors properly construct departmentally designed projects within a district. All aspects of construction management, including finances (to a certain degree), inspection, testing, and records are included within this office. As part of this, the project engineer must be able to balance all of the projects assigned to him or her with all of the resources given him or her in a cost-effective and timely manner. To do this, the project engineer must undertake what can be termed personnel management.

Personnel management at the construction field office level is, both currently and historically, a significant concern. No uniform personnel scheduling management system is available to the project offices, and personnel management methods as well as schedule controls are lacking. Project engineers need to handle constant schedule changes that involve altering or adjusting personnel schedules and that are generated by contractors, the public, the department, employees and others (see, for example, the internal document *Report to the Secretary of Transportation on the Construction Project Engineer Study*, WSDOT, January 1986).

Frequently, the project office develops a method of dealing with scheduling that resembles crisis management, here called reactive management. Scheduling is handled in immediate reaction to a situation rather than as an anticipated and planned response. When this type of method develops in an office, the project engineers appear to come to expect that they must operate in a reactive manner, neglecting planning.

This study was done to establish

- An understanding of the current state of personnel scheduling in the WSDOT construction field offices;
- An understanding of the problems that the construction field office project engineers face in personnel scheduling;
- An assessment of the methods used to deal with personnel scheduling; and
- Preliminary designs of systems that could help field office project engineers manage personnel scheduling in a more effective and systematic and less reactive manner.

The problems encountered by field offices will not disappear. Indications are that they will worsen with simultaneous shortages of funds and deteriorating highways. Response to these problems must be more effective, cost-conscious, and timely.

STUDY ASSUMPTIONS AND METHODOLOGY

To describe the study accurately, a listing of the assumptions on which it was based and a brief description of the methodology used are helpful. The following assumptions were formulated for the study:

- A more uniform personnel scheduling management system would be able to relieve the project engineer of some of the time-consuming aspects of personnel scheduling and, thus, free him or her for more direct contract administration.
- The personnel scheduling management system employs two types of scheduling: planning and operational, functioning simultaneously in the field office.
- The current state-of-the-art of personnel scheduling management at the construction field office level is based more on reactive management than on a treatment of the whole system based on foreknowledge and assessment.

Washington State Department of Transportation, District 1, Environmental Section—M.S. 138, 15325 S.E. 30th Place, Bellevue, Wash. 98007.

- The reactive response is one of the root causes for the lack of a personnel scheduling management system.
- It is possible to improve procedures and systems for planning and managing resources (personnel, time, equipment, and funds) so that an adequate response to scheduling changes can be formulated and acted on quickly and effectively.
- The system could be designed to fit into the current levels of scheduling found at the department.
- Systems currently in place, or simpler systems implemented from this study, can be upgraded as the construction field office gradually increases its sophistication in personnel scheduling.
- An improved system would increase productivity, decrease engineering cost overruns through earlier identification of them, and improve office morale and communications.

The methodology used to develop the final personnel scheduling management system concept consisted of an investigation that included sending a questionnaire to and interviewing project engineers. This established an understanding of how personnel scheduling is done currently. As part of the investigation, the structural placement of projects, personnel, and the construction field office itself within the department was established; interrelationships were identified; and a model of scheduling for the construction field offices was developed. Then a comparison was made of current personnel scheduling management practices and the model. From this comparison, problems and constraints operating within the current system were identified.

Based on these investigations, a unified personnel scheduling management system was outlined. This system would need to include the ability to do both planning and operations scheduling (explained later in this paper), interconnecting the two. Three approaches to further design and implement this system were proposed, one manual and two computerized. All of the approaches used the steps to scheduling found in the conceptual exploration of the system, many of which were already in place in the construction field offices.

CONSTRUCTION FIELD OFFICES AND SCHEDULING ISSUES

Organizational Structure

WSDOT is organized as a hierarchical structure. Headquarters is concerned with the general administration of all aspects of the department, formulating policies for the department, and setting district goals. Districts, of which there are six, are concerned with specific project and personnel management issues. Construction field offices, which are also hierarchical, are a specific type of office in the district that administers assigned contracts through a variety of tasks including inspection, testing materials, and keeping records, using a variety of permanent and temporary staff members.

Project Cycles

Projects at WSDOT go through five phases from start to finish: conception, definition, production, operations, and divestment (*2*). Two distinct project subcycles exist within WSDOT. The first is exclusively a design cycle and encompasses the first three project phases, whereas the second is exclusively a construction cycle involving the last two project phases. The dividing point between the two phases is the ad date, which for design is the date the project is expected to be complete for advertisement and which for construction marks the beginning of contract administration.

Conception is a complex interaction between headquarters, the districts, the Transportation Commission, and the legislature, which results in the prioritization and programming of projects. After a project is programmed, the district defines it by creating the Design Report, which includes the design concept, recommendations for design alternatives, and various special studies required by the project's scope. After the Design Report is completed and headquarters has approved it, the district produces the plans, specifications, and estimates (PS&E), which include the drawings and other information used by the contractors to construct the project. The construction field office is not expected to be involved in these phases, although PS&E theoretically would be reviewed by a construction field office beginning about 2 months before the ad dates.

The construction phase begins with operations, which is project inspection as construction is done; staffing levels for each project change in response to contractor needs as construction progresses. The final phase, divestment, is the completion of the final estimates (required at headquarters 45 days after the contractor finishes) and final records (required as soon as possible after the project closes).

Personnel Scheduling

Most projects are ready to construct when the field office receives them, and personnel with a variety of skills in inspection are available to ensure timely construction to specifications. To match the personnel and projects required for construction requires the generation of a balanced personnel schedule. Here, a generic model of scheduling is developed and is used as a focal point for discussion.

Elements of Scheduling

Scheduling combines and balances three elements: personnel, projects, and time. The typical approach to creating a complete personnel schedule includes

- Projects fixed in time based on ad date and duration;
- Office personnel assigned to projects; and
- Combining these to assess how personnel are used over time.

Optimizing the schedule is done by controlling the occurrence of projects in time and the assignment of personnel to projects.

Model of Personnel Scheduling

Figure 1 illustrates the concepts presented as elements of scheduling. Projects and human resources are apportioned to the field office from other departmental levels. The project engineer assigns his or her available resources to the office's projects, resulting in a personnel schedule.

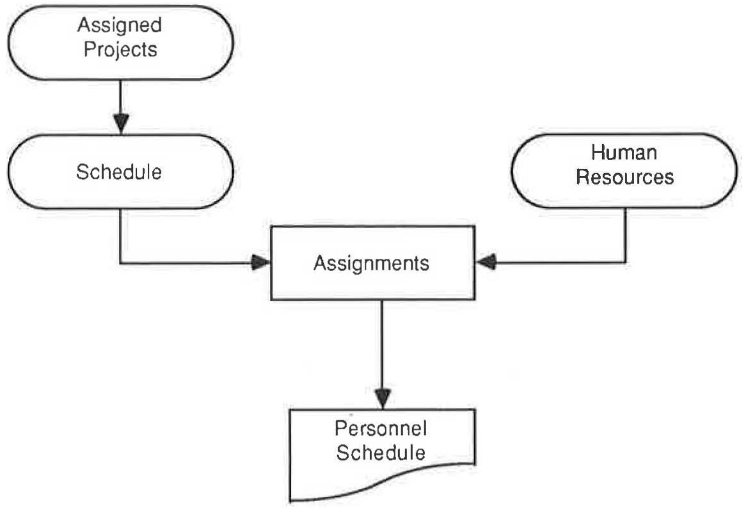


FIGURE 1 General diagram of personnel scheduling within field office.

Figure 2 presents a more refined picture of the project office process, which reflects both planning and operational considerations. In planning, expected future projects and anticipated human resources are assigned together over a range of time and balanced with the use of available information. If a balance is not achieved on the first iteration, all the elements are open to alteration. The expected final result is the preliminary personnel schedule.

Operations scheduling is used when projects are under way and is a dynamic, constant balancing of personnel assignments. Continual reassessment is necessary as project schedules and available personnel change over the short term. During this assessment, or monitoring, the type of change taking place is established, and appropriate adjustments are made.

Methods for Creating a Personnel Schedule

On the basis of these dimensional elements, the two phases of personnel scheduling and what the project engineer perceives as his or her need for a personnel schedule, the project engineer chooses one of four general levels of "scheduling" identified by Shawcroft (*3*) to create the best balanced match between people, projects, and time. The following descriptions are based on how each level characteristically handles the phases and the elements of personnel scheduling. Whether the first two levels (informal and "to do" lists) can truly be scheduling is questionable because they do not use all three elements of scheduling.

- *Informal*—mental. The project engineer associates personnel and projects in his or her mind to generate the field office's personnel work load. Written forms of schedules of any kind are rare and reliance is placed on the project engineer's memory. Formalized longer-range scheduling is rare.
- *"To do" list*—formalized list of projects or tasks. Listed items are usually unrelated to each other. Key personnel may be assigned to a project or task. Time may be involved, but only informally.
- *Bar chart*—time added to the list of projects or tasks. Time is considered essential to the schedule, and projects and personnel are assigned on a time line. The charts created are generally static and cover fairly long periods. Project tasks are not related to each other, and updating is difficult.
- *Network*—relationships between tasks added. The effects of changes on one task can automatically propagate changes in following tasks related to the first task. Resource demand, because it is interconnected with tasks, also changes automatically as tasks change. Time is dynamic, so that both longer- and shorter-range scheduling are important. Updating is one of the keys to maintaining this level of scheduling.

CURRENT FIELD OFFICE PRACTICES

Data Collection Methodology

The methodology used to examine the issues of personnel scheduling management in construction field offices involved, first, a literature search to discover what previous experience might have been. This search unearthed much indirectly related material, but nothing that could direct the research.

Second, the methodology involved sending a questionnaire to and interviewing the field office project engineers. The objectives of the questionnaire and interviews were to

- Determine existing personnel scheduling practices and procedures;
- Identify scheduling problems and constraints; and
- Obtain suggestions for what would be useful in a personnel scheduling management system.

Other states were also interviewed to compare WSDOT's personnel scheduling management techniques to theirs and possibly gain suggestions for potential solutions to the problems encountered. Detailed information was included in a technical report.

Levels of Scheduling

According to the information from the questionnaires and interviews, almost all the responding engineers and members of their staff were involved in some form of preliminary per-

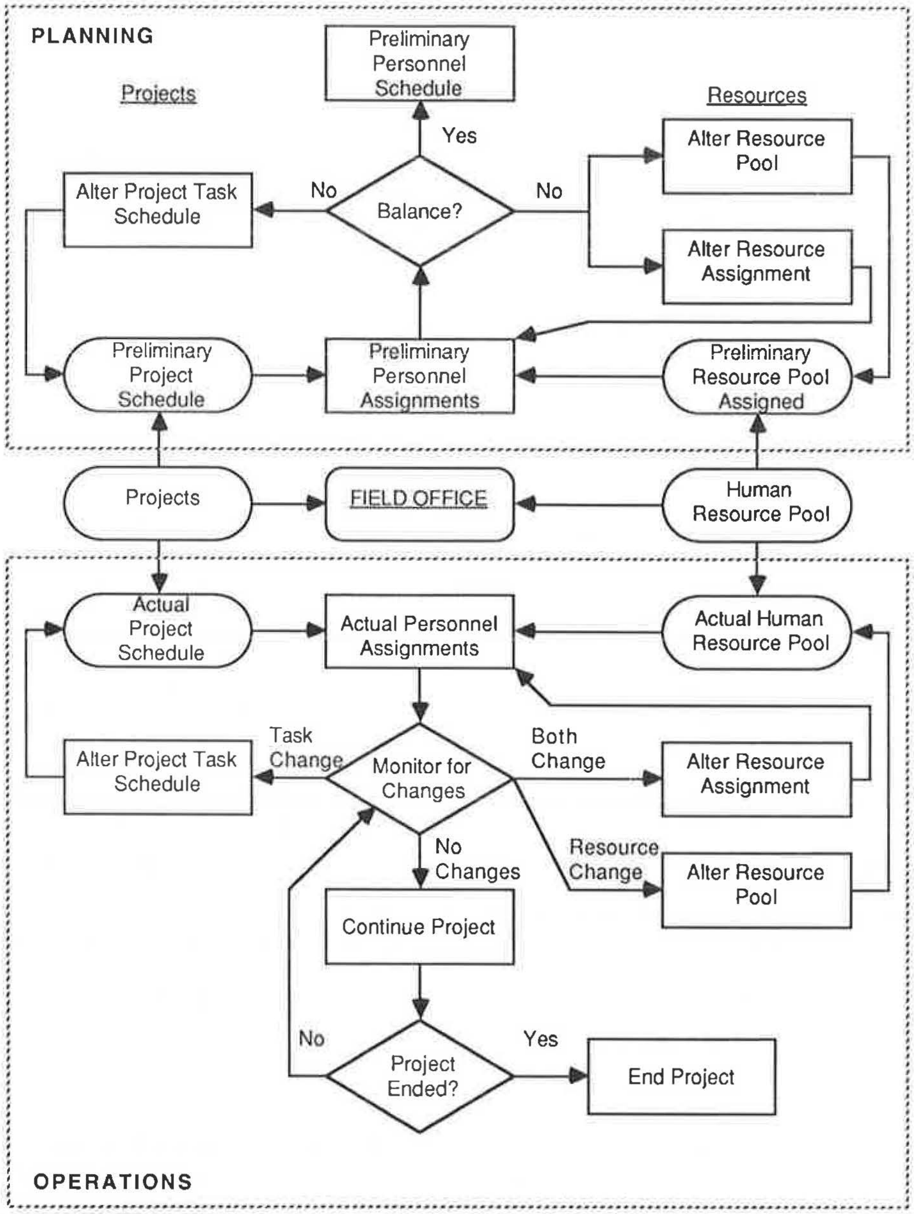


FIGURE 2 Flowchart of planning and operations personnel scheduling.

sonnel scheduling (or planning), and virtually all of them attempted some form of operational personnel scheduling. Though usually informal, the operations phase also included some type of monitoring. Of the four levels of scheduling, 13 percent of the project engineers use informal levels, 44 percent use "to do" lists, 37 percent use bar charts, and 6 percent use networks.

Planning

Generally, if the project engineers plan, they do so to determine the adequacy of personnel and equipment and to schedule people with projects. Planning schedules were done mostly at grosser detail levels, such as months or no time periods, gross task schedules, and key personnel assignments only.

Problems they encountered that they perceive as limiting the effectiveness of planning included the uncertainty of start dates, uncertainty of when project tasks would actually occur, and lack of detailed project schedules. These problems all focus on the project dimension of scheduling, and the data required to alleviate them must come from outside the field office. Areas such as lack of procedures for scheduling were not considered problems because the project engineers feel they can control them.

Operations

Like planning, operations schedules were done at a fairly gross level of detail, with less documentation (only about a third write down an operations schedule). Those who document, however, used a greater level of time (weeks and months). About two-thirds of the project engineers also monitored all projects, usually to update schedules.

As with planning, problems such as lack of detailed, updated, and reliable contractors' schedules; uncertainty of project activities' timing; and lack of response time were important in limiting the use of personnel evenly over a year. Much of the data for these concerns are not under the project engineer's control. Those that the project engineer could control were not considered problems.

To solve the problems encountered in operations, project engineers generally use solutions that alter the resource pool (such as adding temporary employees, instituting overtime, or borrowing crew) or the assignments. Fewer than half of the project engineers ask the contractor to adjust his or her schedule, the only nonresource-altering solution mentioned.

CURRENT STATE OF PERSONNEL SCHEDULING MANAGEMENT

Systems of Scheduling at WSDOT

The project engineers do carry out purposeful personnel scheduling management at WSDOT. Characteristics common to all the systems found at the department include the

- Delegation of day-to-day scheduling to the chief inspector or the project inspector, unless a crew change is required, at which point the project engineer becomes directly involved in the process;
- High level of distrust of the contractor's progress schedule and the written updates received; and
- Reluctance of almost all project engineers to ask the contractor to alter his or her schedule.

Table 1 compares the typical system features and characteristics of the four systems mentioned as they are found at WSDOT (note that CPM is "Critical Path Method").

Limitations of Current Systems

Two major restrictions limit the project engineer's ability to do personnel scheduling management. The first, and most important, restriction is that the project engineer is severely limited in his or her ability to balance the system. As illustrated by Figure 3, the project engineer cannot take advantage of the balancing techniques offered by the left side of the scheduling model, which concerns the ability to alter project

TABLE 1 ELEMENTS OF PERSONNEL SCHEDULING SYSTEMS AT WSDOT

Typical System Features / Type of System	Attitudes	Planning	Operations	Treatment of Elements (time, people, projects)	System Advantages	System Disadvantages
Informal	Lack of interest in • time • paper • planning Don't need to plan Personnel most important "Gut feel" scheduling	Reluctant to plan No balancing Considered unreliable Mental	Started after contractor begins work Reactive to situations Informal monitoring Mental	Mental process Attention on personnel Assignments fluid Operational timeline a mental process	Little paperwork Project Engineer available to solve problems Project completion is goal	Less flexible as design centralization comes in Lack of historic records Difficult for anyone to take over Not true scheduling (unwritten)
"To do" List	Unconcerned about "missing pieces" in schedule Some mistrust of computers "Gut feel" scheduling with a little planning	Done readily Some balancing attempted Not connected to operations No timeline Update by adding project to list	No time line People and projects matched Monitoring by verbal update and personal visit	Time missing Projects, people in list at gross level (whole projects, key people)	Documentation exists Simplicity Anyone can understand lists Secondary task list possible	Not true scheduling (no time element) Inability to anticipate change
Bar Chart	Challenged to control problems	At least a season to a calendar year is planned Balancing is integral part Time line with some project divisions Updating useful and common	Highly detailed (if on computer) Contractors' progress is monitored and connected to office schedule Use computer programs: • Microsoft Project • Lotus 1-2-3	Chart covers all elements Engineering costs tracked often Project tracking done Procedures tailored to office needs	Able to do resource leveling (histograms available) Realistic attitude toward planning All elements involved Computer easily incorporated	Lack of time for update Information may be missing Manual chart slow to update System set up is time consuming and complex
Network	Planning key to operations Crew needs as much information as possible as soon possible Prefer contractors to hand in CPM	Essential Key to operations Preliminary schedule leads to operations schedule	Daily schedule Use several computer programs: • Microsoft Project • Lotus 1-2-3 • SPF	Detailed preliminary schedule Detailed operations schedule Engineering costs tracking essential	Resource leveling, balancing Combines planning and operations (unified system) Track contractor easily System enhanced easily Updates more easily Schedule available quickly	Setup time is long Level of detail and accuracy is affected by uncertainty of activity start dates

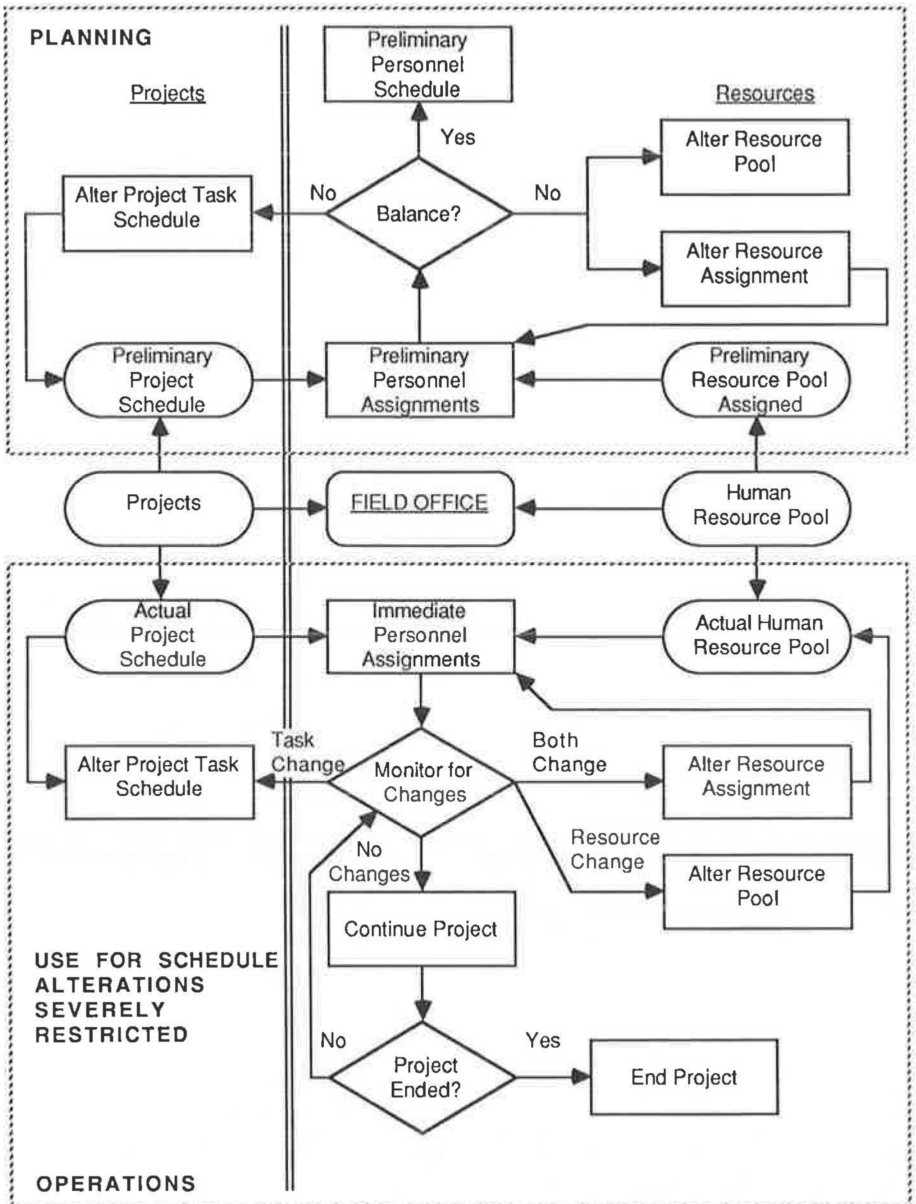


FIGURE 3 Model of scheduling: limitations on the construction field office.

task schedules. Control of the schedules used by the project engineer for planning and operations is in the hands of the design section of the department and the contractor. The second restriction, affecting the resource pool, consists of difficulties in communication and perceptions about departmental policies.

Project Schedule Limitations

Resource Leveling For the field office, resource leveling, an important aspect of scheduling, is essential for two reasons:

- Highs and lows caused by the seasonality of the construction process for contractors also affect the construction field office schedules; and
- The department limits each field office to a certain level of permanent staff somewhere between the peaks and valleys.

The following major limitations affect resource leveling for projects:

- The construction field office does not know for certain about a project's assignment until 2 months (maximum, frequently less) before the ad date, leaving little time for the leveling, which begins to be required at least a year in advance.
- The field office does not control the ad or start date, both of which change frequently, quickly, and with little prior notice, making resource leveling for more than in-house projects a futile exercise.
- Project engineers do not control contractors' progress schedules and so only guess the task schedule for resource leveling.

To partially solve this problem, the focus must shift from a concentration on projects to the resource pool. Also, a secondary task schedule not necessarily dependent on particular projects can be planned for slack times.

Lack of Communication The construction field office is seldom fully informed about the project it will be inspecting until approximately 2 months before the ad date. This tends to limit the project office's planning to notifying headquarters of what the field office believes (guesses) it needs in the way of personnel and equipment for the next season. Many of the project engineers limit their view of planning deliberately to avoid having to deal with as many changes as are expected.

The solution to this problem may lie in a greater attention to the valid concerns of construction inspectors by design teams. The design team must become aware of the advantages of involving the construction personnel much earlier in the design process, perhaps at the Design Report stage.

The Contractor's Progress Schedule Project schedules for operations within the field office are often partially based on the contractor's progress schedule. The contractor's progress schedule is supposed to tell what the contractor intends to do, approximately when in work days, and what the critical work items are. However, many contractors' progress schedules are not detailed or accurate, and updates are infrequent. The inaccuracy of these schedules limits the field office's ability to create reliable schedules and the techniques available for adjusting the personnel schedule.

The solution to this problem will include holding more strictly to the contractor's progress schedule specifications, which require accuracy and weekly updates. Enforcement of these specifications will require support from upper-level construction personnel.

Resource Pool Limitations

Resource pool limitations are generally caused by two problems: communication difficulties between district construction organizations and perceptions about departmental policies. The communication difficulties were not found statewide and were generally influenced by rivalries, egocentricities, and position-protection attitudes. Policies perceived as restricting the project engineer's ability to schedule include design centralization (which takes away work during slower seasons), cutbacks in permanent staff (which cause lower inspection standards), and contractor accommodation as the main purpose for scheduling (which can strain the resource pool).

Solutions to these problems most likely lie outside the field office, through reestablishment of trust by greater communication at all levels. The initial movement would come from upper levels of management.

PRELIMINARY DESIGN CONCEPTS

System Objectives

Five major objectives for improving personnel scheduling management surface when the scheduling model is used to explore the current personnel scheduling systems of the construction field office:

- *Improve personnel needs projects* by upgrading planning scheduling by incorporating minimal levels of project detail and personnel demand while keeping the system relatively easy to use and maintain.
- *Minimize reactive management* by upgrading operations scheduling by incorporating ways to see clearly the complete day-to-day tasks and available personnel in the short term.
- *Maintain efficient use of resources* by upgrading resource scheduling to eliminate unnecessary resource peaks and valleys.
- *Improve documentation* by maintaining records that chronicle the relationship between project progress and personnel assignments and use.
- *Create ease of use* by establishing methods of data collection, processing, and reprinting that are understandable.

All of these objectives build on data, procedures, and products already in use at field offices.

Essential System Requirements

System Products

The basic system objectives could be met through the production of three standard reports:

- Personnel Projections Schedule;
- Quarterly Personnel Summary; and
- Daily Personnel Assignments Schedule.

The first two would be specifically planning reports and the last would be an operational report.

Personnel Projections Schedule Figure 4 illustrates the general format of the Personnel Projections Schedule. The scales would be at a low level of detail: time in weeks (or quarter-months) over a 2-year period, personnel in crews and classification levels, and projects at gross level of tasks. The 2-year term has been chosen to represent the biennium unit used for much of the department's planning. The four sections are as follows:

- *Section 1*—the bar chart, which would be the main schedule overview.
- *Section 2*—a summary of the number of crews required for each time period.
- *Section 3*—a table of the classification levels that make up each crew.
- *Section 4*—a projection of the number of personnel needed in each classification level.

Quarterly Personnel Summary The Quarterly Personnel Summary is a summary of the Personnel Projections Schedule specifically for district personnel planning. Figure 5 illustrates the Quarterly Personnel Summary report, which indicates the projected person-months needed in the field office for construction, location, and administration.

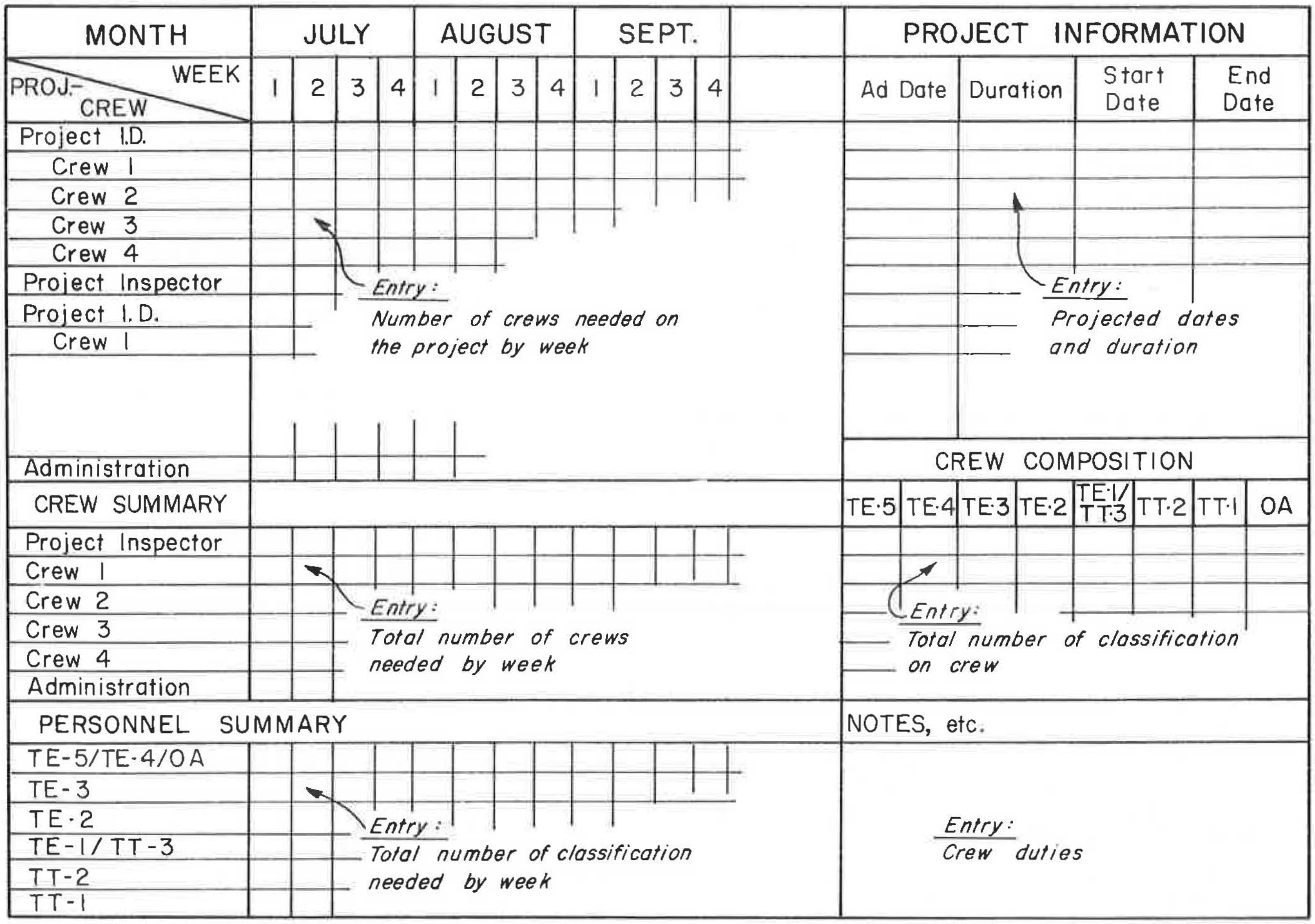


FIGURE 4 Personnel Projections Schedule.

PROJECT ENGINEER

	REPORT PERIOD ______												
MAN MONTHS REQUIRED	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	
LOCATION													
CONSTRUCTION													
ADMINISTRATION P.E. Assist. Office Engr. Secretary													
OFFICE TOTAL													

EMPLOYEE ROSTER

______ PERMANENT

______ ON LOAN TO

______ BORROWED FROM

______ IN TRAINING

______ TEMPORARY

______ TOTAL

NOTE: REQUIRED PERSONNEL SHOULD INCLUDE 10% TO COVER ANNUAL AND SICK LEAVE

SURVEY & MATERIALS INSPECTION TO BE INCLUDED IN LOCATION OR CONSTRUCTION

FIGURE 5 Quarterly Personnel Summary.

Daily Personnel Assignments Schedule Figure 6 illustrates the general format of the Daily Personnel Assignments Schedule, a bar chart showing how each person is scheduled over 4 weeks. The scales would be at a fine level: time in days covering a 4-week period, personnel by individual names and classification level, and projects broken into tasks at each point where the size or type of crew changes. Below the bar chart would be the project summary, which would list each project's tasks and total the number of personnel assigned daily to each task. Creation of the bar chart would require creation of two side reports, which are then combined into the main schedule.

System Processing Overview

Planning Steps Summary Figure 7 is a flowchart illustrating the process required to achieve both the Personnel Projections Schedule and the Quarterly Personnel Summary. The proposed system is not intended to cover specific individuals or highly detailed project tasks and must allow for two types of flexibility. The first is easily adjustable start and end dates that incorporate new information as it becomes available. The second is flexibility in producing the two reports, of which the second report is dependent on the first. Furthermore, the system must recognize variations in types of data available

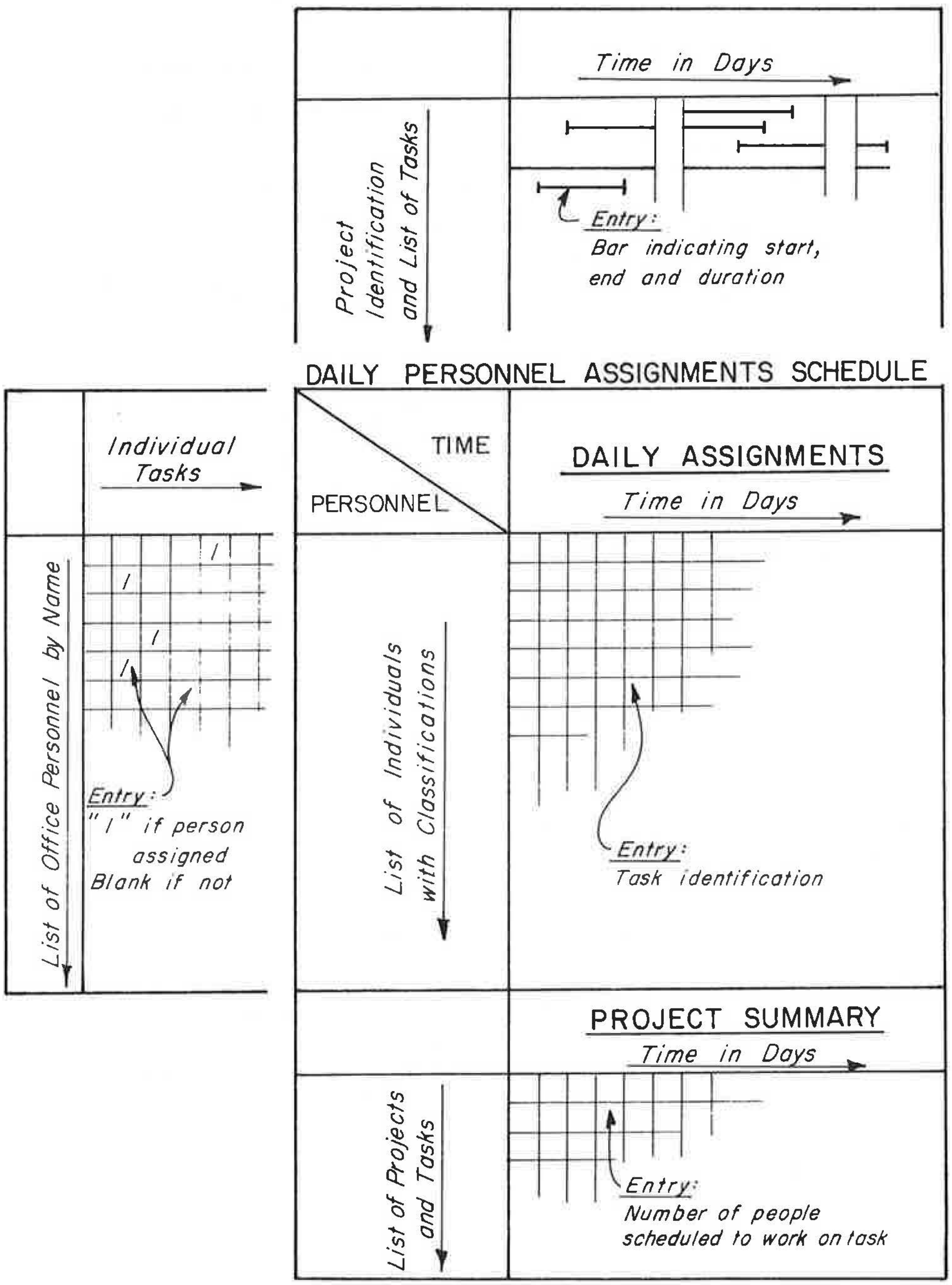


FIGURE 6 Daily Personnel Assignment Schedule.

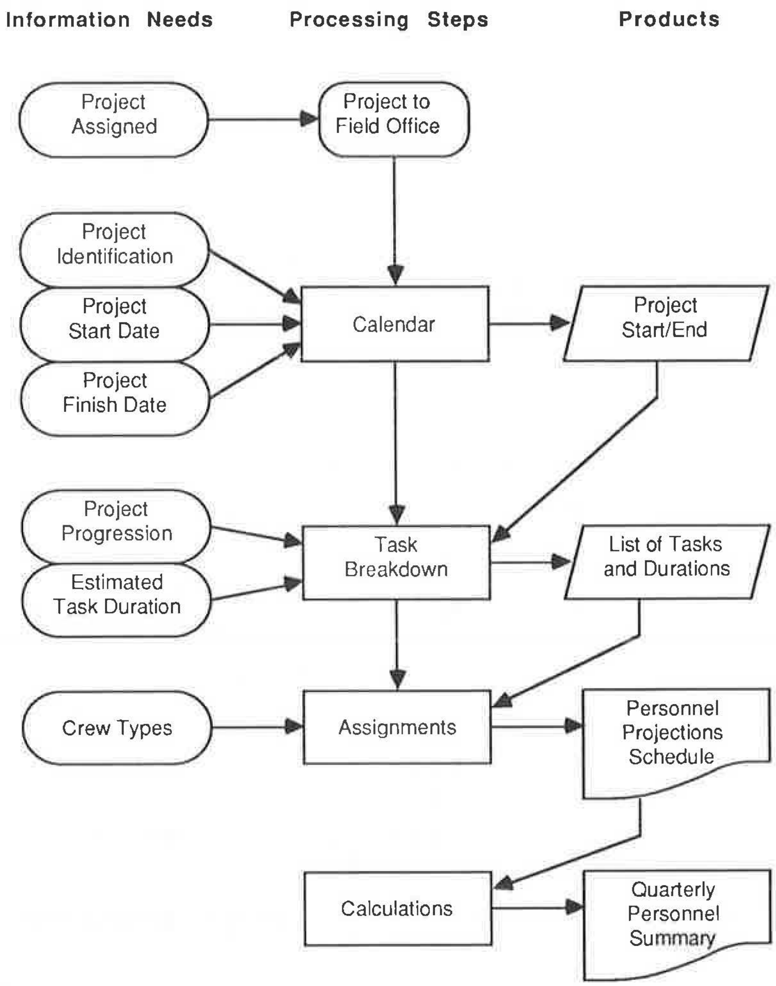


FIGURE 7 Flowchart for Personnel Projections Schedule and Quarterly Personnel Summary.

and permit the project engineers to use their own judgment in assessing future total crew needs for project tasks.

The process to achieve these schedules is initiated by the assignment of the project to the field office. Steps include

1. *Calendar step.* Place the project onto a master calendar, using a project identifier, the first date anyone in the office was expected to begin work on the project, and a date for the project's completion. The information could be calculated from the ad date.
2. *Task breakdown step.* Break the project into tasks that different crews would perform using the probable project progression and the estimated duration of the tasks estimated from the first step.
3. *Assignments step.* Determine crew demand by project using information from the first two steps. Partial weeks are acceptable.
4. *Reports step.* Calculate the remainder of the Personnel Planning Schedule and the Quarterly Personnel Summary. Generation of the demand by time period by crew type, the crew summary of Figure 4, would be done first. Extending the crew type out by the number of persons per crew would lead to person-demand by week, termed the personnel summary. The Quarterly Personnel Summary would be generated from information located on the Personnel Projections Schedule. The personnel summary section would be an estimate of the number of personnel by classification by week (or quarter-month) required in the field office. The monthly average of personnel by classification could be calculated and added together for the office totals required on the Quarterly Personnel Summary.

Operations Steps Summary Figure 8 illustrates the process required to create and maintain the Daily Personnel Assignments Schedule. The proposed system is expected to cover specific individuals in daily detail over short time periods. It must be flexible enough to allow constant adjustment of individual assignments as new information becomes available, while maintaining a slightly longer view on upcoming changes. This schedule is expected to be updated at least weekly, to maintain as high a level of accuracy as possible.

The system's steps are as follows:

1. *Project task schedule step.* Convert the project into crew-related tasks and associate these with a daily calendar that covers a maximum time period of 4 weeks. Task duration

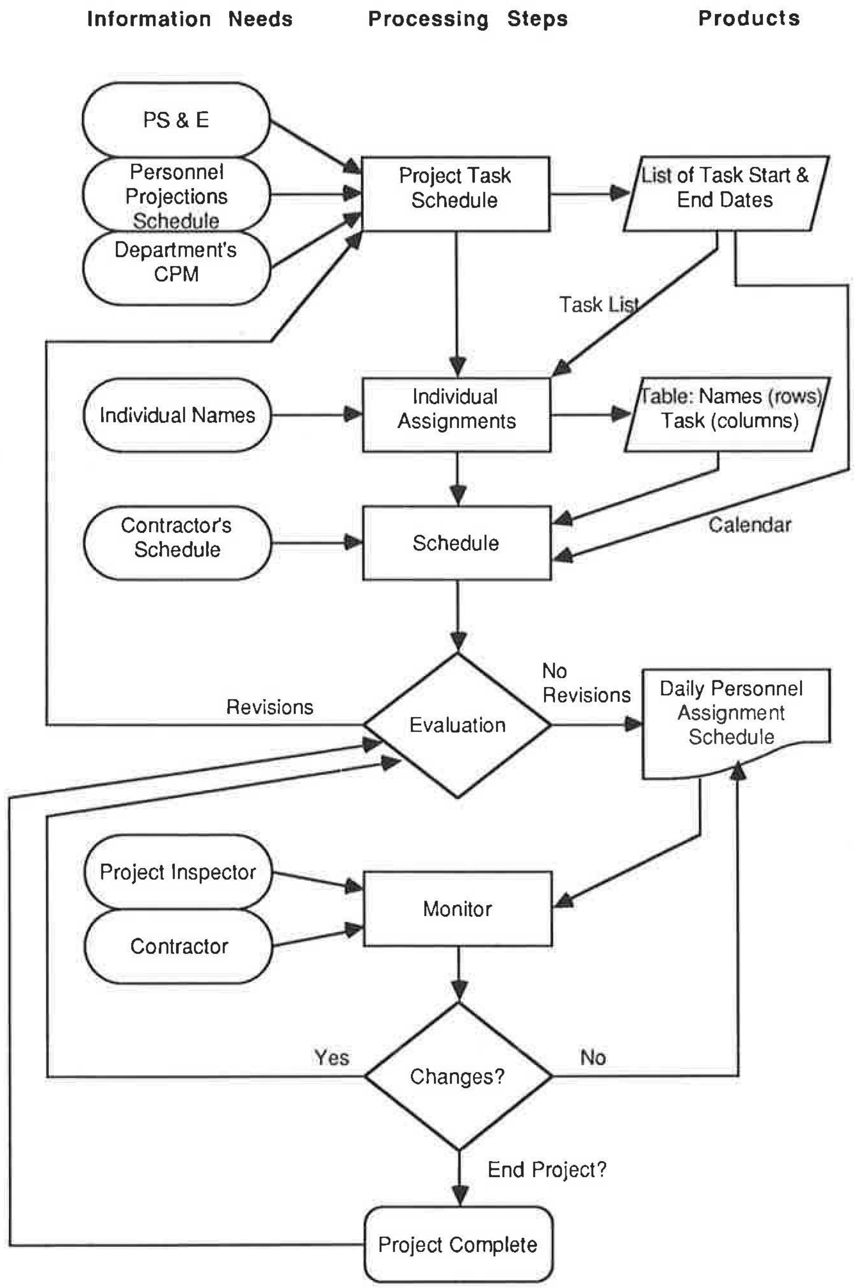


FIGURE 8 Flowchart for Daily Personnel Assignments Schedule.

would depend on a crew size or type change. Information required to do the task breakdown would include the project identification, the project plans, the ad or construction start date (or both), and total project duration.

2. *Individual assignments step*. Assign individuals by name to each defined project task. The information required for this matching would be a list of all members of the office staff and their classification levels and the list of tasks and durations developed above. Determine at this time whether overtime or per diem would be required. The result would be a table with columns listing project tasks and rows listing individuals; entries at the junction of the columns and rows would indicate when the individual was assigned to a task.

3. *Schedule step*. Combine the information from the first two steps and create the proposed operations schedule with the daily task assignments for each person over the next 4 weeks, as well as the project summary, which outlines tasks and summarizes crew totals by task.

4. *Evaluation step*. Evaluate the schedule for whether all project tasks were adequately staffed and whether all personnel were committed at, or close to, 100 percent time throughout the period. If adjustments were not necessary, a usable schedule would exist; if adjustments were required, revisions would be made.

5. *Monitoring step*. Continue to collect the best information available on task start and end changes and personnel adjustments, ideally updating the schedule weekly. Two basic sources, the project inspector and the contractor, would be available for this information. Continue to evaluate the schedule for reasonable staffing levels and resource use.

Component Interaction

The planning and operations components of the system are expected to interact in two ways. First, the planning schedule could be used as the initial project task schedule for operations, refined as necessary to meet the detail requirements of operations. Second, current operations information on projects in progress would be periodically incorporated into the Personnel Projections Schedule. This process would be done at least quarterly and would result in easier scheduling methods and better foresight into potential scheduling problems.

SYSTEM DESIGN APPROACHES

Manual System Approach

The manual implementation of these procedures would closely resemble the lists, tables, and charts used in the conceptual system. Each of the reports, the Personnel Projections Schedule, the Quarterly Personnel Summary, and the Daily Personnel Assignments Schedule, would become a form to fill in. Tables and charts, used to create the final reports, would also be fill-in forms. The steps would be done manually to process the information into the reports.

The only advantage to this approach would be that a standardized procedure for scheduling would be available. For field offices lacking formal scheduling capabilities, these procedures would result in documented personnel schedules. The major disadvantage of the approach is that it is time-consuming to use, causing three system objectives to be compromised. Constant recalculation and redrawing would not encourage ease of use; the monitoring aspect, which would allow the system to minimize reactive management, would require swift responses; and when creating a schedule becomes so time-consuming, the effective use of personnel fails. Consequently, this system is not recommended for implementation except in limited circumstances.

Spreadsheet System Approach

Implementing the outlined system on a spreadsheet program is a reasonable alternative. All field offices currently have access to at least one spreadsheet program, Lotus 1-2-3, which would allow the direct implementation of the proposed reports and procedures. The degree to which the overall system was automated could vary, depending on the extent to which the designer wished to use various program capabilities. Planning and operations schedules would be completed separately in a spreadsheet system. Implementation of the schedules would closely parallel the procedures outlined earlier and would produce the final form of the reports as described.

Advantages are as follows:

- Many of the manual calculations would be removed from report production, offering flexibility.
- Sections pertinent to each final report could be printed directly from the spreadsheet, with forms similar to the products described earlier.
- The graphics extension capability would be used to visualize resource distribution.

The disadvantage would be the time required to set up this system. Each report section would need to allow for the addition and deletion of projects, project tasks, and personnel and for the recalculation of the summaries. Familiarity with spreadsheet programs and the macro programming language would be necessary for the designer to accomplish the task.

Network System Approach

The third approach, also a reasonable one, would incorporate the use of network-based project management software. Programs such as Microsoft Project, which is supported by WSDOT, are thought to fit naturally into the context of any type of project management environment. Although they use a different method of input and report production, these programs still encompass scheduling and use of resources in a process much the same as the steps presented earlier in the description of the required system procedures.

Advantages to using a network program are as follows:

- All calculations that are necessary to scheduling are already built in and no system development is required.
- Updating is easy for both task start and end dates and classification/crew and individual resource files.
- Master files with static information can be created.
- Planned schedules can be compared with actual schedules.

Disadvantages are as follows:

- Some time is required to understand completely the advantageous use of the program.
- The reports are not in the same format as the conceptual system has envisioned.
- The systems are based on traditional resource leveling methodology, which is not applicable to the construction field offices.
- Data for the Quarterly Personnel Summary are not able to be extracted automatically, at least from Microsoft Project.
- Operations schedules may be better used as interactive screens rather than being constantly reprinted.

Approach Assessments

Three approaches to implementing the personnel scheduling management system have been suggested. Although the manual system is not recommended for use in the construction field offices, it still might be useful. At least partial implementation of the manual form, perhaps simplified or in conjunction with some already in use, would help field offices that do not have any documented system. Adding features from the proposed manual system to existing manual systems also would make true schedules out of levels of scheduling that are missing certain essential elements.

The two computer-based systems each have different focuses and strengths that could be advantageous to a field office, depending on the focus of the personnel scheduling system manager. It is also possible that a combination of the two computer-based systems would work best for an office. The spreadsheet system is focused on the end products, the reports.

The process is defined in terms of what the output should be like, and the system would be established to furnish the products. System design would be more difficult to do initially, but the end product would offer more flexibility, especially because the information could be presented in the proposed conceptual forms.

The network approach is focused on the process involved, the dynamics of the system. The system is already defined, and the user would employ the system to access the outputs that met the personnel scheduling needs. There would be less work in programming, but more in establishing the best way to access the system for the information required.

Both computer-based systems would require some manual operations. The spreadsheet would require at least manual entry and updating of start and end dates and resource assignments, as well as initial spreadsheet set-up information, which would be office-specific. Depending on the amount of automation through macros and cell formulas, more manual operations might be required. The network system would require that at least start dates and durations, task breakdowns, and resources be manually entered. Once the network was operating, updating would be performed manually. The Quarterly Personnel Summary would also have to be extracted manually from data provided by the program or sent to the spreadsheet for automatic calculations.

CONCLUSIONS

Given the findings that have been summarized, the following conclusions are drawn:

- The constraints that are operating will continue to restrict any personnel scheduling management system in the construction field offices.
- The system proposed here in conceptual form is expected, when implemented, to improve personnel scheduling management and decisions by standardizing and, in some cases, automating procedures, thus alleviating some of the stresses associated with reactive management.
- The three approaches fulfill the system objectives to varying degrees. The manual system can be implemented without requiring additional expertise but, because of time constraints, is severely limited in its ability to be easy to use, minimize reactive management, and effectively use personnel. The spreadsheet system minimizes the manual calculations required in scheduling and has less time constraints, but it requires a greater set-up time and more expertise for the designer. The network system requires little physical system development and offers the easiest updating methods, but the programs can be time-consuming in learning applications especially because the reports from this system are conceptually different than the proposed approach.

RECOMMENDATIONS

At the conclusion of the study, recommendations were formulated for implementation that could help the construction field offices better manage their personnel scheduling. These recommendations are divided into those that can be implemented by the construction field office directly and those that are dependent on outside actions for implementation.

Inside the construction field office, it is recommended that

- One or more construction field offices design and implement one or more of the proposed systems;
- Implementation of the proposed systems be done in coordination with the technical support personnel available at WSDOT, with both construction field office and technical staff involved rather than only one or the other;
- After the various system approaches have been designed and tested, they be installed in any interested field office; and
- Construction field office personnel experienced in the use of any of the systems help work out formal training sessions to teach both the system concepts and practical experience in system implementation and use.

Outside the construction field office, it is recommended that

- A study be done to establish whether exclusive assignment of a micro to the project engineers for use in scheduling would be the best way to encourage implementation of a scheduling system;
- Steps be taken to alleviate the problem related to construction personnel input into design, which input is not now available in a timely manner; such steps could include, but not be limited to inviting
  - — construction inspectors with some experience to design team meetings when project scope or design is being discussed;
  - — input from the tentatively assigned construction field office when alternatives have been chosen for constructability of the designs; and
  - — construction field office input into special designs for constructability and understandability of the plans.
- Training in critical path method scheduling be more widely available to the entire field office system;
- Encouragement and support by headquarters and district management be given to the project engineers in enforcing the Standard Specifications and Special Provisions where contractors' progress schedules are concerned (*4,5*);
- Contractors' progress schedules and updates be required to be more uniform as well as more readily available to the construction field office; and
- Project costs be related more directly to personnel schedules through a revised method of estimating project costs.

ACKNOWLEDGMENTS

This research was done for the Washington State Transportation Commission, Department of Transportation, in cooperation with the U.S. Department of Transportation, FHWA. Their sponsorship is gratefully acknowledged.

REFERENCES

1. Managers Set Strategic Objectives. *Interchange*. Washington State Department of Transportation, Bellevue, Sept. 1987.
2. H. Kerzner. *Project Management: A Systems Approach to Plan-*

ning, Scheduling and Controlling, 2nd ed. Van Nostrand Reinhold, New York, 1984.
3. R. G. Shawcroft and C. E. Barb. *Critical Path Method Scheduling: Basic*. Washington State Department of Transportation, Seattle, Wash., 1986.
4. *1988 Standard Specifications for Road, Bridge, and Municipal Construction*. American Public Works Association, Washington State Chapter; Washington State Department of Transportation, Olympia.
5. *Construction Manual 1984*. Washington State Department of Transportation, Olympia, 1984 with revisions through June 1987.

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

Evaluation of Strategic Management at Caltrans

NOREEN ROBERTS

The California Department of Transportation (Caltrans) has completed the first two cycles of an annual strategic management process. In this report, the author documents and evaluates the process through these cycles. First, a background review of the need for this type of management tool is covered. The process, schedule of events, and products that were developed to provide department management with a means for more effective decision making are then outlined. An evaluation of the process at the end of the second cycle includes a discussion of the problems encountered and of where the process fell short in delivering anticipated improvements. This evaluation also includes the benefits derived from the process to date. Finally, the proposed modifications to the process for the start of the third cycle, including changes to the content of the resulting products, are covered.

Strategic management is a proven and valuable management tool. It can be applied effectively in a large, complex public-sector organization, such as a state transportation agency, with substantial benefits.

Outlined in this discussion paper is the strategic management process developed at the California Department of Transportation (Caltrans). The steps in the process, how they evolved, and the products produced are reviewed. The problems encountered in implementing the process during the first two annual cycles are looked at, as well as the iterative nature of development and the benefits to date. The need for flexibility with a change in top management and the change in management style that results are examined. Finally, a new approach to meet the needs of current management and the process and products proposed for the third cycle are presented.

BACKGROUND

Caltrans has a history of almost 100 years of evolution and change. It began in 1895 as a state highway department charged with developing a network of roads to link centers of population with agricultural, timber, and mining areas. It became a large division of highways that built an extensive and world-famous freeway system. It has become a department of transportation that has seen that system aging and being used to capacity in urban areas. Over time, the culture of the organization also evolved, incorporating a professional pride and a sense of accomplishment in providing the kind of highway system that Californians wanted and needed.

It came as somewhat of a cultural shock, then, when in the 1970s some California cities said "No more freeways, at least not here." The resulting slowdown in highway improvements and the emphasis placed on alternative forms of transportation meant a transition in the role of the department and a change in its culture. With time, it became apparent that the excess capacity built into the highway system in the 1950s and 1960s was being used up and that alternative forms of transportation, although taking some pressure off the highway system, were not the total solution.

Economic activity was expanding, population was growing primarily through in-migration, vehicle ownership was increasing faster than population growth, and vehicle-miles of travel were growing at the fastest rate of all. Population was moving to the suburbs and suburban fringe areas, and business and industry were following. The transportation system that had been developed to serve a radial commute pattern of suburb to central city was operating at or near capacity and was not adequate to address the evolving suburb-to-suburb commute. Nor were the local street networks designed to handle this rapidly growing commuter traffic. Traditional forms of public transit had limited application in a suburb-to-suburb commute pattern, and ridesharing by vanpool or carpool, although effective in the radial system in some areas, did not have widespread application or appeal in developing areas.

At the same time, the department was coming under increasing criticism for not having anticipated these problems, for not providing leadership at the state level, and for not having continued the state highway building program back when land was still available for rights-of-way at a manageable cost.

Under a new state administration, and in response to these criticisms, the department increased its state highway improvements. At the same time, concerns began to surface on the adequacy of resources to address both current and future transportation needs. Although there had been a recent increase in both state and federal gasoline taxes, these increases were primarily in response to the decreasing buying power of existing transportation funding and did not respond to the need for an increase in facilities and services to meet the current and projected growth in economic activity and population.

Thus, the department was faced with increasing pressure to provide both improvements to the state highway system and leadership to address concurrent problems, under the additional constraint of decreasing resources. Further, the department was still struggling to adjust to a recent requirement for legislative budgeting after decades of relative autonomy in administering the constitutionally protected "trust fund" program.

Recognizing this decrease in state level resources, and in response to increasing urban congestion and its perceived effect on the economy of California, local jurisdictions and

Office of Strategic Management and Policy Analysis, Division of Transportation Planning, California Department of Transportation, 1130 K Street, Sacramento, Calif. 95814.

the private sector have increased their contributions to state and local transportation financing. County initiatives have been proposed to voters to increase the sales tax. Such increases are earmarked to fund improvements to specific state highway routes or transportation corridors. Further, land developers have voluntarily, or through mitigation requirements of local jurisdictions, contributed funds for improvements to the state highway system. The resulting combination of local initiative financing and developer funding has exerted a significant measure of external influence over the scope and timing of improvements to the state highway system.

This external influence, in addition to the necessity of providing added improvements within constrained state resources, the need to effect cost cutting and to implement extensive efficiencies in program delivery, and the need to justify each budget request for new or redirected resources, produced many more complexities for top management.

Heretofore, an annual budget development exercise had been sufficient to set the direction of the department for the coming fiscal year. However, the department no longer had just one clear and simple directive, to maintain and improve the state highway system. It no longer had a single, predictable, and steadily growing source of funding. It no longer had a stable, homogeneous, and engineering-oriented work force. Probably of equal significance, it no longer seemed to be respected as a professional organization. Decisions were being criticized, programs were being questioned, and suggestions were made that the department no longer knew where it was going or what its responsibilities were.

The department had implemented a form of "zero based budgeting" and "management by objectives." Both of these approaches had generated benefits. But there was a nagging belief that something else was needed, something to provide an overall direction plus a framework within which this new direction could be administered.

STRATEGIC MANAGEMENT AT CALTRANS

Why Strategic Management?

The concept of strategic management has been adopted and adapted by public-sector organizations from a process in use by the private sector for some 30 years. Other state transportation departments have successfully implemented strategic management in response to similar complex management problems. The experiences of private business firms in using the process are well documented and some adaptations in the public sector have also been reviewed and reported. It appeared to top management that initiating a strategic management process within the department might provide the form of direction setting and administrative framework necessary to address the increasing complexities they were facing.

Windows of Opportunity

The first step taken by the department was to create an Office of Strategic Management in the Director's Office and to hire a consultant. A series of management level committees was set up and discussions held on critical issues that needed to be resolved. It was decided that congestion on the state's urban freeways was one of the more pressing concerns. In most urban areas, adding capacity to the existing system or expanding the system was out of the question. The social, economic, and environmental costs were simply too great. A small ad hoc task force was established to investigate advances in new technology that might provide a long-term solution to the problem.

The task force concluded that this was a promising approach, that some new technology was being or had been developed, that some innovative systems could be adopted and tried in limited pilot projects, and that further research in this area could have significant benefits. An Office of Advance Technology was created and directed to continue research into possible applications.

Thus, this early application of strategic management was to select a series of "windows of opportunity" by identifying key issues, to explore potential solutions, and to demonstrate the effectiveness of "strategic thinking" in addressing critical problems. This approach provided valuable insight by focusing on the need for key issue identification. It also demonstrated the usefulness of a task force to explore alternative strategies to resolve such problems. However, this application did not directly address the need for overall direction setting nor did it provide the framework for administering this direction, two specific management requirements.

A More Traditional Process

While retaining the issue-identification/task-force approach as an integral part of the process, the department's management requested that a direction-setting process be established. Relying heavily on the experiences of other public-sector organizations and, particularly, on the experiences of other state transportation agencies, the department adopted a more traditional strategic management process.

The department has completed two annual cycles of this form of continuing strategic management. It seems timely, therefore, to evaluate how effective the process has been to date and to examine what modifications have been proposed for the third cycle.

THE FIRST TWO CYCLES

Overview

The experiences of other public-sector organizations in implementing a strategic management process stress several key features of successful application. Strategic management should

- Be specifically designed to apply to a particular organization;
- Influence the annual budgeting process;
- Be flexible;
- Foster vision and "strategic thinking" throughout all levels in an organization; and
- Be used to convey, both within and outside the organization, a multiyear direction and purpose.

The strategic management process adopted by Caltrans addressed each of these key features. Further, it was implemented in such a way that it

- Was built on existing functions, so that it was relatively easy to implement because many of the components were already in place;

- Was not necessary to create an elaborate new organizational structure but only to redirect what was already available so that it required few new resources; and
- Has already led to improved internal and external understanding of the department's long-term direction, primarily through distribution of an annual Policy Direction Statement.

Organization and Decision Making Responsibilities

Currently, decision making within Caltrans may be categorized as executive, staff, and line responsibilities. The department is organized into a headquarters office and 12 district offices (Figure 1). Management of the district offices is the responsibility of the district directors, who report to the director of the department, and of their deputy district directors, who have line responsibility within each district for major functional or program areas of departmental operations (for example, maintenance, traffic operations, project development, construction, right of way, planning, and administration).

Executive management of the department is the responsibility of the director of the department, the deputy directors, and the assistant directors. The headquarters office is organized into divisions headed by a division chief who has staff responsibility (i.e., policy, standards, and technical expertise) for a functional or program area of departmental operations. These division chiefs report to their appropriate deputy director.

The division chiefs, with functional responsibility for major program areas, prepare and annually update strategic management plans for their program, in coordination with the other division chiefs, the functional area deputy district directors, and the district directors. These plans are reviewed by the appropriate deputy director. This same management group jointly prepares annual work plans detailing the mutually agreed upon scope of the work to be accomplished during any 1 year, based on the multiyear strategic management plans. From these work plans, resource estimates are developed that result in the department's proposed annual budget. The division chiefs and the district directors also jointly develop performance criteria for each functional area to enable performance evaluations throughout the year, which form the critical feedback loop.

Components of the Process

The key components of the current strategic management process at Caltrans and their interrelationship are shown in Figure 2. These components are discussed in the next sections.

Trends Affecting Caltrans

The first component is a documentation of the results of a scan of the external environment. It provides a broad, general overview of trends and events affecting, or likely to affect, transportation in California and, therefore, the department's policies and programs. Within a short- and long-term time frame, general trends, forecasts, and projections are discussed as they relate to the department. These include population increases, demographics, changes in life style, economic growth including any new trends in key economic sectors, land development patterns, facilities/system trends, advances in new technology or automation, environmental factors, political/legislative actions, and other similar indicators. Also included is an analysis of "stakeholder" concerns and expectations, as well as information resulting from the "internal" scan.

The concept of "stakeholders" in strategic management has been used to denote one element of the external environment that must be considered. Just as the private sector considers the concerns and interests of its stakeholders (i.e., its customers, its board of directors, and its stockholders), so a public-sector organization must consider the stakeholders to whom it is responsible in providing a public service. In the department's case, such stakeholders include the state administration; the legislature; the FHWA; the California Transportation Commission; the Departmental Transportation Advisory Committee; state, regional, and local agencies; special interest groups; and highway user groups.

In addition to addressing the external influences on Caltrans, strategies must be developed to address the department's internal capabilities, its strengths and weaknesses, and the resources it can deploy now and in the future.

This Trends Affecting Caltrans document provides a common base of assumptions for departmentwide direction setting and for individual program direction.

Policy Direction Statement

The annual Policy Direction Statement is the "vision" statement, by the director, of the long-term direction of the department, a statement of where the department is heading in consideration of the trends and events described in the Trends Affecting Caltrans document. The Policy Direction Statement provides the framework within which both departmental and program direction and decision making are developed, and it states the goals and objectives the department has adopted to support its future direction. Thus, it provides a means to convey this "vision" of future direction to those inside and outside the department.

Strategic Management Plans

Strategic management plans for each major program area include the programs' objectives, strategies, and performance measures. These documents are prepared jointly by the division chiefs and the district directors to describe the objectives and the strategies they have developed for each major program area to implement the goals and objectives contained in the Policy Direction Statement. In addition, these plans provide a program-by-program look at trends and events as they may affect individual program areas.

Performance Measures

Proposed performance measures are an essential part of each program area's strategic management plan. Evaluation of the effectiveness of strategies in reaching specific objectives is a key element in the cycle, both from a program development standpoint and from an effective management one. A form

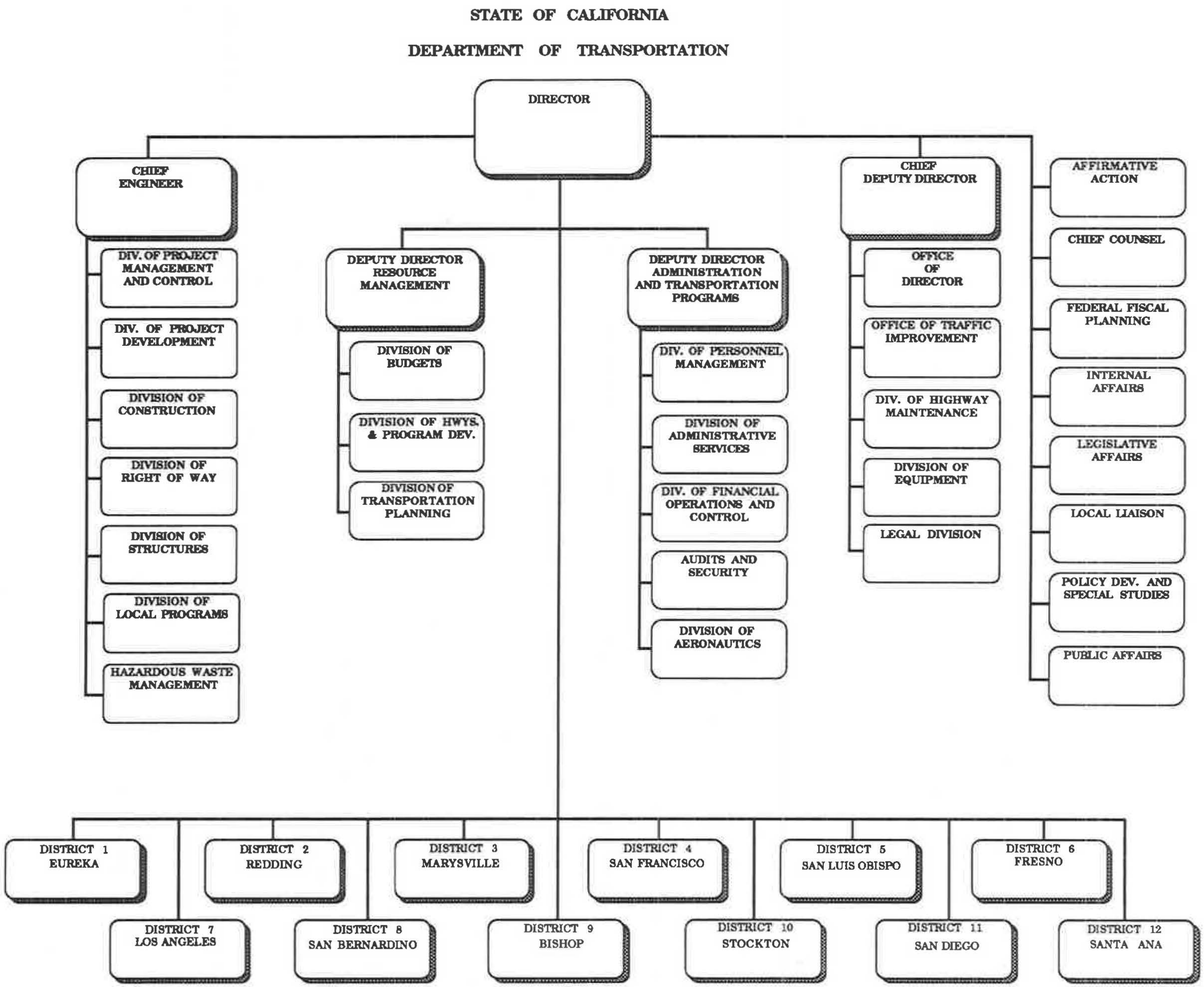


FIGURE 1 Organization.

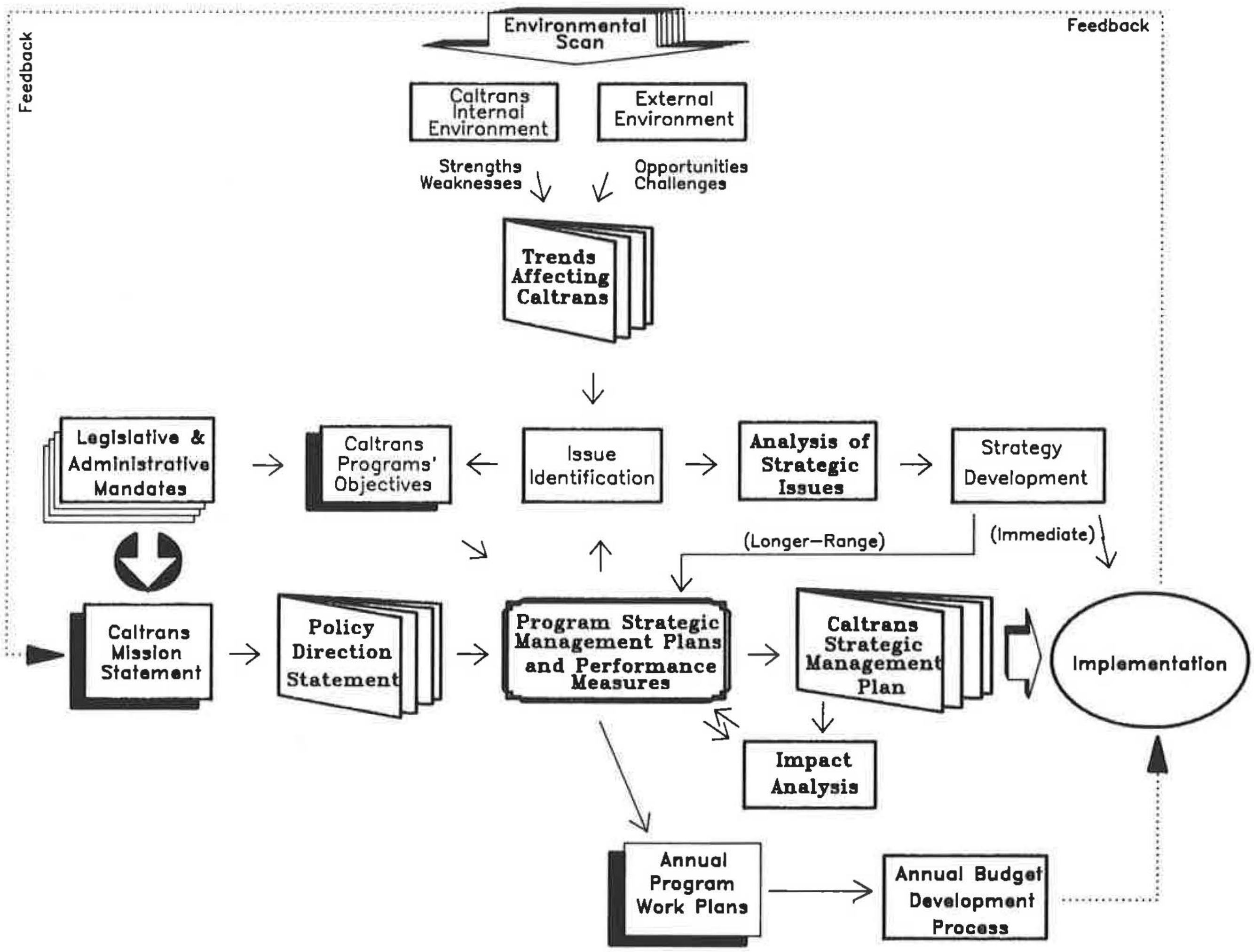


FIGURE 2 Caltrans' strategic management process.

of pilot project or demonstration project may be an effective tool in evaluation, particularly when implementation on a statewide basis could be costly in terms of resources. However, the functional managers, at both the division chief and district level, are usually the best judges of appropriate performance measures and methods. Evaluating the effectiveness of the existing program, or at least documenting results of prior evaluations, is also desirable when recommending new strategies that may take resources from the existing program or when augmentation is requested. This feedback loop is critical in evaluating the effectiveness of the strategic management plans and provides the necessary input to make updates to the plans meaningful management tools.

Caltrans Strategic Management Plan

The individual strategic management plans are the key to implementing the future policy direction of the department and, when aggregated into the Caltrans Strategic Management Plan, provide the objectives and the strategies the department intends to employ to address the challenges of the future. The Caltrans Strategic Management Plan is one of the final documents in the annual strategic management cycle and, as such, incorporates a summary of the significant factors from each of the preceding components.

Issue Identification and Analysis

Issues of critical concern to the department may have been identified through trend analysis (i.e., the external/internal scan) or by the division chiefs and district directors in their Strategic Management Plans. If, in the opinion of department managers, such issues are indeed critical and need to be addressed, then a request is made for an analysis of the issue, the development of alternatives, and a recommendation for either program strategies or departmental policies to address these concerns.

Depending on the complexity of the issue, the analysis may be either relatively straightforward or fairly involved. If the issue affects only one program area, the analysis will likely be completed by the program area's staff. If it affects more than one program area, a small ad hoc task force formed across programs, as was described earlier, is more appropriate.

Although the above issue analysis process has implied sequential products, in practice the process is more likely to be a continuum with products (policies and strategies) feeding into the process when available or when appropriate.

Impact Analysis

The combined Impact/Issue Analysis Report is a companion document to the Caltrans Strategic Management Plan. It incorporates an identification of key issues from the trends document, plus those highlighted in the individual strategic management plans, with an identification of potential cross-program impacts from an analysis of the strategies proposed for each major program area.

Sequence of Events—Second Cycle

The time line shown in Figure 3 outlines the sequence of events and the products produced during the second cycle (FY 1987–88).

The cycle began with the preparation of the trend analysis report, or environmental scan, Trends Affecting Caltrans. During the first cycle a brief trend analysis report was prepared from information developed by planning program personnel for their ongoing strategic planning. Caltrans managers and staff indicated that such information was useful in developing program objectives and strategies and as a starting point for "brainstorming" discussions. As a result, for the second cycle a more comprehensive analysis was prepared.

An executive summary of this trend analysis was prepared and distributed to the department's deputy directors along with copies of the prior year's Policy Direction Statement (1987). An off-site meeting was scheduled with the deputy directors to discuss direction setting and to develop policies to guide the department's activities during FY 1987–1988. A draft of key policies and significant discussion points resulting from this off-site meeting was prepared for review by the deputies. After approval, this draft was circulated to the division chiefs and district directors for their review and comment. Appropriate suggestions were incorporated and a consensus obtained on a final draft, which was given to the deputy directors for approval.

Copies of the trend analysis and the draft policy direction statement were provided to the division chiefs, district directors, and key staff members as input to the preparation of strategic management plans for each major program area. These plans were prepared and presented along with annual work plans and budget proposals to the deputy directors. In addition, an impact analysis report was prepared, based on the strategic management plans, and also presented to the deputy directors.

Based on the presentations to the deputy directors of the plans along with the budget proposals, preliminary decisions

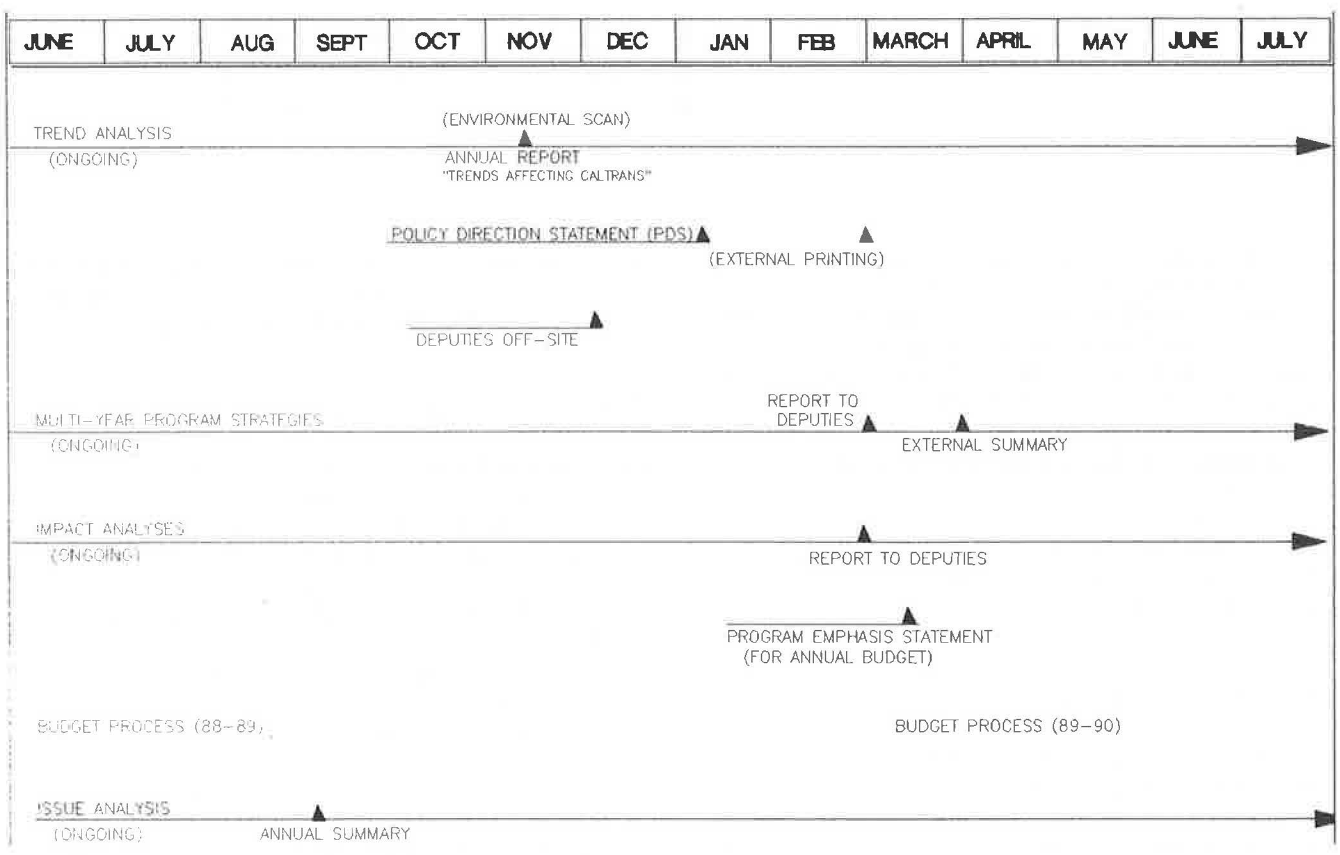


FIGURE 3 Caltrans' strategic management work plan (1987–1988 fiscal year).

were made on the forthcoming annual budget. From this point, the annual budget development process followed.

EVALUATION OF THE FIRST TWO CYCLES

There is a tendency when evaluating the effectiveness of a "new" management tool either to gloss over the problems of implementation or to become frustrated when the process does not produce all of the benefits that were anticipated. However, it must be remembered that change usually occurs slowly and incrementally, particularly in large public-sector organizations. One of the key attributes of the concept of strategic management is its flexibility. One of the key requirements for strategic management to be effective is that it fit within the existing organizational structure and meet the management needs of the individuals who will use it.

Problem Areas

One of the errors we made at Caltrans was trying to integrate too much of the process too quickly. Another related error was to link the strategic management process too closely with the annual budget development cycle.

At a series of scheduled meetings we had an opportunity to talk with each of the division chiefs responsible for developing a strategic management plan for a major program area. However, these discussions came too late in the sequence of events. In addition, the discussions became too complex when we tried to cover, not only a review of the concepts of strategic management and its benefits, but also the instructions for developing the plans and instructions for budget development, as well.

Although the managers had developed strategic management plans the previous year, the process had since been modified. These modifications were an attempt to address inconsistencies and were in response to a joint evaluation of the effectiveness of the prior year's effort. In addition, changes were made to the formats of the plans and to the budget development activities. All of these changes may have improved the process and products, but they added to the managers' workloads and to the complexity of the process. As a result, managers needed to develop their updated and longer-term strategic management plans at the same time that they were developing annual work plans and annual budget proposals. Understandably, the tendency in some cases was to incorporate and emphasize strategies or contingency plans linked to current or short-term budget resource needs, but not necessarily within the context of the longer-term program objectives.

Further, the presentations to executive management were complex, in that they combined the presentations of the updated strategic management plans with presentations of annual work plans and budget resource requirements. The combined presentations, although logical from a hierarchical sequence, were not effective.

Rather than making budget decisions within the context of the overall objectives of the program as described in the strategic management plans, budget decisions more often reflected and supported short-term strategies. Not that these budget decisions were necessarily in conflict with the longer-term program objectives, but it was apparent that strategic management was, at best, only indirectly contributing to the decision making process.

An additional "problem" occurred with the retirement of the director of the department. Until such time as a new director was appointed, it was difficult for the executive team to know what goals and objectives the new director would propose. As a result, the Policy Direction Statement was primarily a modification of the prior year's document, incorporating those policy changes enacted by the legislature and those specifically expressed by the state administration. However, it did not contain clear-cut goals and objectives for departmentwide direction.

Observations on the Process

For the most part, those managers responsible for preparing and updating strategic management plans have expressed a willingness and desire to continue the strategic management process, albeit with some significant modifications. Most managers decided that a formal presentation of their individual program's plans to the executive management group served no useful purpose as a lead-in (hierarchical sequence) to budget development and decision making. Rather, they propose discussing their long-term program objectives and strategies with their individual deputy directors outside and ahead of the budget development cycle.

Some managers expressed the view that, even if the strategic management plans and the process itself were not used directly for executive level decision making, they found the process and the products useful in managing their individual programs.

Some managers felt that the amount of work involved was not justified if it did not influence final decision making. It was pointed out by other managers that the influence was there, but indirect. Each manager was responsible for the degree to which his or her work plan and budget proposal implemented or contributed toward long-term program objectives. Further, decisions at the executive level on these work plans and budget proposals were, indirectly, decisions on the strategies and objectives in the strategic management plan for the program area, insofar as the individual manager had integrated them.

One of the more interesting observations to come from working with the department's managers in this area over the past 2 years was that many of them were already applying the concepts of strategic management and had been doing so for some time. The challenge came in assuring these managers that what we were proposing was not new, but rather a more formalized approach to their existing management style. In other instances where it appeared that the managers were not applying a strategic management approach, the challenge came in attempting to demonstrate that such an approach would be effective and was applicable to their program area. This was particularly true in the support area functions. These managers were providing a level of support that was determined by the level of workload in other program areas, or by statutory mandate, or executive order. While the question of "what was provided" was determined outside of their program area, "how it was provided" was very much their management responsibility, one that lent itself to a strategic management approach.

Benefits

The benefits of the process to date can be categorized into the three areas discussed in the next three sections.

Budget Development

Over the past two cycles there has been considerable improvement in the budget development process, in general, and the review of the department's budget by external agencies, in particular. The credit for these improvements is due primarily to the staff of the Budget Division and to those functional managers who are responsible for presentations and justifications for increases or changes in program resources. However, the strategic management process can be credited, in part, for fostering an increased awareness of the reasons behind the need for increased or reallocated resources. Working together with the district directors and their staffs to develop program objectives and the strategies necessary to reach those objectives and developing work plans and resource requirements needed to implement those strategies has provided the functional managers with logical and well-prepared background information and justifications.

Strategies To Address Key Issues

As mentioned earlier, the preliminary approach to strategic management resulted in the creation of an Office of Advance Technology. The continuing research of the staff of this office into potential applications has resulted in several significant benefits. They have been instrumental in creating a consortium to pursue studies and demonstration work in automated highways. The consortium consists of other state departments of transportation, the University of California, the FHWA, and the private sector, including automobile manufacturers.

In another example, the Maintenance Division and the Office of Advance Technology are working together to develop applications of robotics to the more dangerous or disruptive maintenance work.

Other key issues have been identified through the continuing strategic management process and strategies have been developed to address them. Two of these strategies, the Metropolitan Freeway Task Force and proactive planning, are discussed in the following paragraphs.

The Metropolitan Freeway Task Force was initially created to address the issue of the feasibility of changing design standards to reduce, or perhaps eliminate, the need for some maintenance activities on high-volume urban area freeways. The time period during which maintenance can be performed on metropolitan freeways without major disruption of traffic, that is the "window" for maintenance, is becoming smaller all the time. Maintenance Division personnel identified this as an issue during the second cycle development of their strategic management plan. They proposed an ad hoc task force involving staff from Design and Operations, as well as district maintenance staff, to address the issue. Preliminary work by the task force identified related issues, such as traffic management during lane closures for both maintenance and rehabilitation/reconstruction, and the charge to the task force was expanded accordingly. Further, the task force went into the field to interview district maintenance supervisors and crews. This resulted in an extensive set of pragmatic recommendations, as well as some innovative suggestions worthy of further investigation.

The task force is currently preparing its draft report proposing short- and long-term strategies to address current and future problem areas. In addition to demonstrating a strategic management approach to a major problem area, this task force provided an example of both a matrix organizational approach, albeit temporary, and an entrepreneurial opportunity for field personnel to become directly involved in developing strategies and policies for use departmentwide.

Proactive planning also evolved out of the strategic management process. The Planning Program's strategic management plan included a discussion of the issue of increasing the coordination between land use planning and transportation planning. While the Planning Program had been using a strategic planning approach for years, the annual strategic management plan provided them with an opportunity to develop support for additional resources to address this particular issue. This resulted in the ability to implement several demonstration projects, involving a cooperative effort with local and regional agencies in coordinating early planning for both land development and the transportation system needed to serve that development.

Improved Coordination and Communication

As mentioned previously, several of the managers had already prepared strategic management plans before the institution of the more structured annual cycles. Planning Program personnel obviously had a head start in this respect. They had fully involved the deputy district directors for planning in the development of strategies, through scheduled formal discussions at their biannual functional meetings and more informally throughout the year. In addition, the functional manager of the Planning Program incorporated the program's goals and objectives developed through this process as his own management objectives. Further, the program had twice been through a zero-base budget evaluation to demonstrate both the validity of the strategies and the need for resource augmentation. Thus, this program incorporated two of the ongoing management tools into the strategic management process.

The Maintenance Division had also developed its own long-range maintenance plan before the formal process, borrowing the environmental scanning material from the Planning Program.

In addition, the Operations Division had developed a long-range operations plan and had developed and implemented several of the resulting strategies to improve traffic operations on the existing highway system.

By discussing among themselves these strategic management plans along with those of other program areas, managers were able to communicate more readily with each other from both the district and division perspective. This improved their understanding of each other's problem areas and the strategies to address these problems and enabled them to be more aware of the potential impacts that a decision in one program area might have on other program areas. For example, the Operations Division's long-range plan called for the development of specific new and advanced traffic operations technology, and the Office of Advance Technology was able to, and continues to, assist in this research. The installation of new traffic operations high-tech equipment would require new and more sophisticated maintenance, which the Maintenance Division needed to incorporate into its program area plan. This operational strategy would also require personnel with different skills, which the Administration Divisions needed to incorporate in their training/retraining programs for existing staff and in their recruiting program.

THE THIRD CYCLE

In developing modifications to the strategic management process for the third cycle, we wanted to ensure that the department retained and built on the benefits derived during the first two annual cycles. Further, we wanted to retain those benefits derived from the issue-identification/task-force approach or "windows of opportunity," developed before the more formal traditional cycles. At the same time, there were several major problem areas that needed to be addressed to increase the effectiveness of the process and to reduce the work load on the managers.

The primary consideration, however, was to develop a process that met the management needs of the new director and provided him with opportunities to incorporate "front end" and "tops down" direction on major policy issues. We recognized that the strategic management process developed at Caltrans was tailored to the management style of the previous director and his executive team. With a new director and a somewhat different executive management style, the process needed to be modified. However, we felt it essential to retain some continuity to the process.

We had originally proposed to begin the cycle earlier in the calendar year to allow more time to elapse between the development of updates to the strategic management plans and the beginning of the budget development process. But with a change in the department's executive team, some time elapsed before the commitment to continue the strategic management process was clarified.

With this clarification and a firm expression by the new director of his support for management planning, plans and proposals for the third cycle could be developed.

The environmental scanning document Trends Affecting Caltrans has been updated and circulated to the division chiefs, district directors, and their staffs for review and comment.

The Policy Direction Statement will be changed to enable the director to outline his goals and objectives for the department. We hope to be able to work closely with the director to develop this document through a series of iterations until we capture his ideas to his satisfaction. We have set a target date of mid-January 1989 for a final document.

In addition to this Policy Direction Statement, the director has requested a document covering the department's ongoing policies. We have started to prepare such a report with a working title of Operational Policies. The director commented that the majority of Caltrans' employees are working on the department's ongoing activities and need a document they can relate to, one that spells out the policies they need to be familiar with in their day-to-day activities. They also need to know if there have been recent changes made to these policies, such as those changes related to increased efficiencies in the project development process, for example, or changes to maintenance procedures that might result from the Metropolitan Freeway Task Force study. Only a small percentage of Caltrans' staff, the director believes, can relate to the future direction of the department in their day-to-day work, or to its goals and objectives.

It is anticipated that the functional area managers and the district directors will develop objectives for each major program area that complement and expand on the director's departmentwide objectives and that they will develop strategies to attain these program objectives. It is also expected that they will jointly propose performance measures with which to determine progress of their strategies toward the program's objectives. We will request that these program level strategic management plans be brief, containing only the most critical program objectives with a few key strategies and performance measures for each objective.

Once the strategic management plans are prepared, they should be discussed with the appropriate deputy director and a firm consensus reached. After deputy approval of the program's strategic management plans, the division chiefs and the district directors would develop work plans for the coming fiscal year. These work plans should spell out in some detail the ongoing work of the department plus any new tasks to be undertaken to address the program areas' longer-range strategies. The budget development process follows the approval of the work plans.

The strategic management plans will be aggregated and summarized into Caltrans' Strategic Management Plan, incorporating the departmental goals and objectives from the Policy Direction Statement and the program objectives, strategies and performance measures from the individual strategic management plans.

Obviously, this is still a proposal and all of the usual caveats apply. However, one of the advantages of the concept of strategic management is its flexibility. The challenge will be to meet the needs of the director for an adequate and appropriate management planning process that fits his management style but, in order to incorporate some continuity with the prior process, to retain and build on those benefits already achieved.

CONCLUSIONS

After a little more than 4 years, Caltrans seems to be well on its way to institutionalizing a strategic management process. The process and its products may change over time to keep pace with changing management needs. However, there is a firm commitment of support from the new director and acceptance of the process by many of the division chiefs. Thus, the concept of strategic management should continue to be an integral part of management decision making.

The benefits to Caltrans of using this management tool could be substantial and cumulative. We have already seen benefits as a result of the identification of key issues from the environmental scan. The use of ad hoc task forces, with members selected from several program areas, has produced pragmatic and innovative strategies to address such issues.

In addition, improved communications among managers and their staffs have resulted from joint involvement in the process. This has provided a cohesiveness that seemed lacking in the past. The opportunity to review the objectives and strategies of other program areas has made managers more aware of the need to minimize the impacts of one program's strategies on another and to work more closely to develop joint or complementary strategies.

The complexities of the external environment and the broader role and responsibilities of the department point to the need for this type of management system, and the benefits to date seem to warrant further effort. The documents resulting from the process provide a means of communicating Caltrans' goals and objectives and give employees, as well as stakeholders, a sense of the department's future direction and the knowledge that there is a well-thought-out plan behind management decisions.

There are those who argue that strategic management cannot work in a large public-sector organization such as Caltrans. They believe that such organizations are constrained by the political process, by the short time frame of 2 to 4 years for political decisions, by the statutes and regulations governing the organization's duties and responsibilities, and by the need to meet resource requirements through a process of consensus building at local, state, and federal levels.

Although such conditions exist for most public-sector organizations, experience has shown that other organizations have successfully implemented an effective strategic management process that includes not only longer-term direction setting for the organization, but also strategies to address political constraints.

The statutory mandates governing Caltrans' roles and responsibilities are relatively broad and allow the department considerable flexibility in implementation. Consensus building is a part of the political process in which the department has had, and continues to develop, significant experience and success, particularly at the district level. The magnitude of the transportation problem at both the national and state levels is such that the political process can only address the issue of resources incrementally, within a longer-term framework of state and national goals and objectives.

It is seldom that the political process itself develops long-range goals, objectives, and strategies for a public-sector organization. This normally results from decisions of management professionals within the organization itself. They bring a strategic "vision" to the role and responsibilities of the organization because they have a professional commitment to these responsibilities that extends well beyond the political time frame.

It will be a continuing iterative and development task to institute a fully integrated strategic management process at Caltrans, one that provides the department's managers with the tools they want and need. However, with sufficient flexibility and adaptability as an inherent aspect of the process, strategic management should continue to change and evolve, as will Caltrans itself.

The contents of this report reflect the views of the author, who is responsible for the facts and accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the California Department of Transportation. This report does not constitute a standard, specification, or regulation.

Publication of this paper sponsored by Committee on Strategic Management.

Strategic Planning Process for Transit Properties

Z. ANDREW FARKAS, MOGES AYELE, SEIFU KERSE, AND LEGESSE NEGASH

Strategic planning is a management tool used to analyze fundamental issues and changes and to aid managers in effecting organizational response to change. Strategic planning has been implemented and refined by most major corporations and some public-sector organizations, including a few transit properties. The authors' objectives in this paper are to review the literature and explain how strategic planning works, to present the results of case studies of strategic planning in the transit industry, and to recommend a framework for strategic planning. The authors concentrate on the recognized steps or elements of strategic planning. The major findings are that (a) management must make an early and serious commitment of time and resources to the strategic planning effort; management must participate; (b) the situation audit should be the basis for establishment of mission, goals, and objectives; objectives should be measurable; (c) management should select the audit's appropriate depth; (d) the establishment of mission, goals, and objectives and development of strategy should have a marketing perspective; (e) there should be strong links between strategy implementation, program planning, and the budget cycle; implementors should have responsibilities, objectives, and incentives to implement; and (f) a planning staff should be selected early to monitor the progress of programs, agency performance, and environmental change.

Strategic planning is a management tool used to analyze fundamental issues and changes and aid managers in effecting organizational response to change. Although the strategic planning concept predates that of strategic management, most writers emphasize the interrelationship between them. David (*1*) describes strategic management as the formulation, implementation, and evaluation of actions that will enable an organization to achieve its objectives. According to Steiner (*2*), "Strategic planning is inextricably interwoven into the entire fabric of management; it is not something separate and distinct from the process of management." Strategic planning supports strategic management and is a function of all managers at all levels in an organization.

Strategic planning has been implemented and refined by most major for-profit corporations. But has strategic planning really worked? According to Marrus (*3*), academic research on the subject has identified many positive results. David (*1*) reviewed studies on strategic planning by small businesses and found that there were significant benefits for manufacturing and service-oriented firms.

Since the late 1970s, there have been several attempts to apply strategic planning concepts to the nonprofit and public sectors. Organizations in these sectors are under increasing public pressure and scrutiny and are facing increasing competition (*4*). Although several authors have argued over the merits of strategic planning in the public sector, a recent review concluded that strategic planning is becoming widespread as a tool for improving public-sector planning (*5*).

Meyer (*6*) outlines four major differences between strategic planning in the private sector and in the public sector:

- Public agencies are subject to public scrutiny and political pressures that private-sector organizations seldom experience.
- In public agencies the decision making process is not as direct as that found in private-sector organizations.
- In the public sector, agency objectives are often mandated by legislation and not subject to management prerogative.
- Implementation of actions can be much more difficult in the public sector because of the allocation of resources through the political process.

Meyer concludes that these very same problems make strategic planning in the public sector necessary.

A few transit properties were among the first public-sector organizations to apply strategic planning concepts. But because of strategic planning's relative novelty in the transit industry, little empirical information is available on its application and benefits. Given the generally positive experience of other organizations, it is reasonable to expect that the transit industry can also benefit from strategic planning.

OBJECTIVES AND METHODS

The authors' objectives in this paper are to

- Review the literature and explain how strategic planning works;
- Present the results of case studies of strategic planning efforts in the transit industry; and
- Make recommendations on a strategic planning process for transit properties.

The research methodology consists of two major components: (a) review of the strategic planning/management literature and (b) review of strategic transit plans and case studies of five transit properties' strategic planning efforts. The case studies involve in-depth evaluation of strategic plans and personal interviews of officials with strategic planning responsi-

Center for Transportation Studies, Morgan State University, Baltimore, Md. 21239.

bilities. The interviews took place between August 1987 and April 1988. The cases are Alameda/Contra Costa Transit (Oakland), New Jersey Transit, Port Authority of Allegheny County Transit (Pittsburgh), Seattle METRO Transit, and Utah Transit. These cases were selected using the following criteria: diversity in terms of size of fleet, geographic diversity, adherence to a strategic planning process, and involvement in the implementation phase of the process.

THE STRATEGIC PLANNING PROCESS

Although strategic planning processes vary among organizations, there are elements that are common to most strategic planning efforts. So (*7*) identifies the steps that appear to be common to strategic plans as follows:

1. Measure current progress and effectiveness;
2. Analyze the external economic, political, and social environment;
3. Examine various elements of the organization;
4. Analyze implications of the first three steps (situation audit);
5. Develop strategic objectives and a mission statement;
6. Implement programs, budgets, and plans; and
7. Monitor progress toward the objectives.

So further states that a strategic plan should focus on a few clearly stated critical issues and objectives. It should define conditions that can be affected and those that cannot and it should emphasize intuition and decision making, not just forecasting and scenario development.

HOW DOES STRATEGIC PLANNING WORK?

Various authors have focused on certain elements or steps as the keys to successful strategic planning: formality; organization and linkages; situation audit; mission statement, goals, and objectives; strategy development; and implementation.

Formality

A formal strategic planning process emphasizes methodological steps, rigorous analyses, and documentation in developing a strategic plan. Accordingto Olsen and Eadie (*8*), "Perhaps the major fault found with the formal strategic planning process as it is often described is its abstraction, its loss of touch with the realities of human organizational dynamics." Formal strategic planning has often become merely a planning staff ritual with the result languishing on a manager's bookshelf. According to Ferris (*9*), the process should focus on key issues, establish a dialogue, and develop strategies rather than adhere to a specific methodology.

It is logical to assume that the scope of the effort should be directly related to the size and complexity of the organization. The large organization is likely to conduct an extensive and formal strategic planning process, consisting of planning staff, consultants, and all management levels, whereas the small organization probably will conduct a less formal process, consisting of brief research and strategy development by a small management team.

Organization and Linkages

The appropriate size and scope of the planning effort and the level of management and policy maker involvement are perhaps the major organizational questions. Whatever the scope of the planning effort, upper management must make a commitment to strategic planning and must actively participate in it in order to provide vision and direction (*2*). It should be understood that strategic planning is not a panacea for management problems, as many management tools have been promoted in the past.

Task forces or planning teams are an important part of the planning process. The teams should consist of management and staff and other stakeholders as needed. The chairpersons of such teams should be persons responsible for the areas under consideration and should have expertise in them (*10*).

Sorkin et al. (*11*) state that local governments must look beyond their own resources to ensure the best possible future. Strategic planning is an excellent vehicle for public/private partnerships and for concerted action on community problems and issues. The scope of the effort must be explicit and communicated throughout the organization. The focus should be rather narrow, so that only a few critical issues are addressed. The geographic area of analysis may need to be greater than a particular service area because various threats to the organization, as well as the resources of the organization, may be located outside the service area.

A fairly detailed work plan and budget need to be developed in order to tailor the effort to the scope and resources of the organization (*12*). The work plan must outline who will do what and what personnel are available. The plan should recognize the existing responsibilities of management and staff. Strategic planning should not be placed as an extra burden on fully used personnel. The resources should be available to conduct the process on an ongoing basis. Personnel objectives, appraisals, and compensation must be directly related to the conduct of the process.

Situation Audit or Environmental Analysis

According to Steiner (*2*), the situation audit is an analysis of past, present, and future and provides the base for pursuing the strategic planning process. The objective of the situation audit is to identify and analyze the major trends, forces, and phenomena that may impact the development of strategies. Each organization should identify what is of consequence in the environment. Decisions must then be made as to the depth and detail of the analysis. Olsen and Eadie (*8*) believe that understanding the external environment is the most challenging step in strategic planning.

The situation audit may first consist of the environmental scan, which identifies a handful of critical issues through a broad view of the organization's environment, both external and internal. The environmental scan analyzes the past and the present and attempts to look at the future. Many organizations omit the environmental scan entirely when the critical issues are apparent (*11*).

The analysis of the external and internal environment is a more detailed and focused look than the environmental scan. The analysis requires an examination of an organization's strengths, weaknesses, opportunities, and threats. Strengths and weaknesses are internal factors, whereas opportunities and threats are generally external.

The internal analysis factors are controllable. The analysis or audit must be objective in listing the strengths and weaknesses of the organization. The critical analysis issues are financial viability, quantity and quality of programs, managerial and organizational effectiveness, condition of physical facilities, productivity of human resources, technological capability, and marketing effectiveness (*4*).

External forces are not controllable by the organization. The significant external environmental forces are economic, demographic, social, political, technological, and legal. The external environment also consists of competitors, clients, special interest groups, and funding sources. The analysis of the external environment should have a "futures orientation" (*11*). Many firms that have implemented strategic planning use both quantitative and qualitative techniques of forecasting. The complexity and unpredictability of an organization's environment determine the formality and sophistication of the forecasting (*8*).

Task forces are often used to conduct the situation audit within an organization. The members may consist of organization staff, consultants, volunteers, and members of interest groups. Outside "experts" may be more knowledgeable about sources of information and more attuned to the environmental trends and the implications of those trends.

For many organizations a global approach to situation audits may not provide sufficient detail to revise missions or to develop effective strategies. A program-specific or portfolio approach uses the technique of positioning each program on a matrix. A variety of matrices or arrays have been developed and used in analyzing portfolios. David (*1*) provides an extensive survey of these techniques.

Wheelwright (*13*) believes that most strategic management/planning efforts fall on a continuum between a portfolio approach and a value-based incremental approach. A value-based incremental approach assumes that the values and beliefs of management and staff in an organization are more important to setting long-term direction than the actions of competitors and the structure of markets. Wheelwright (*13*) states that one problem with today's strategic management/planning systems is that they are

> . . . considered an objective, analytical, data-based area where evermore systematic analyses . . . will reveal the most appropriate strategy. What is missing is full recognition of the subjective nature of these techniques and the role of organizational values and commitment as a basis for strategy.

Mission Statement, Goals, and Objectives

The comparison of internal strengths and weaknesses with external opportunities and threats provides the basis for the appropriate mission. Once the mission is developed, specific goals and objectives must be formulated that enlarge and clarify the mission.

McConkey (*4*) states that any organization's development of a mission requires the proper answering of three major questions: "What is our present purpose? How will the future impact on our present purpose if we make no changes? What should our purpose become?" Effective mission statements always proceed from the needs of clients and from conditions in the environment to management's response to the clients' needs. According to Steiner (*2*), missions should be stated in product and market terms. Without a marketing perspective in the mission, goals, and objectives, there is a lack of direction in the provision of service and a weak basis for strategies, even strategies that deal with financial difficulties (*14*).

Missions should also account for the organization's values and legal mandates. According to David (*1*), "A mission statement is a declaration of an organization's reason for being . . . and reveals the long-term vision of an organization."

There is no one technique for developing missions, goals, and objectives. Their development is often assigned to task forces, but management and policy makers must be involved. Mission statements are most often expressed in broad, general terms, whereas goals are more specific and objectives are stated in terms of measurable results.

Strategy Development

Strategies are the actions that define how the objectives are to be achieved. The marketing orientation continues throughout strategy development and may involve the use of the marketing approach called segmenting or positioning. Segmenting means differentiation, that is, how an organization makes itself different in order to gain an advantage. An organization may segment its market in terms of users, geography, demography, delivery systems, programs, and services. By segmenting its market an organization can formulate strategies that establish advantageous niches (*4*). Thus, strategies are best developed by key individuals who are familiar with the external environment.

Brainstorming is often used as a means for generating new strategies and scenarios. Scenario development provides a sequence of events that should lead to accomplishment of the objectives. Strategies should then be evaluated in terms of cost, personnel requirements, agencies and organizations involved, time frame, impact on the environment, and legal implications (*11*). Nutt and Backoff (*15*) provide an extensive survey of strategy development techniques.

It is important to review the chosen strategies to ensure that they are acceptable and do not conflict. A stakeholder analysis may be necessary to identify parties "who can affect or are affected by the strategy to be introduced" (*15*). Parties with a direct interest in the strategy may respond to the strategy in ways that may affect the implementation. Resources may have to be allocated and tactics developed to address the concerns of stakeholders.

Implementation and Monitoring

Implementation is another of the crucial steps to successful strategic planning. Although strategy formulation is an intellectual exercise by relatively few individuals, implementation is operational in nature and involves skills in coordinating, managing, and motivating many individuals (*1*).

Successful implementation of strategic plans in the private sector has been accomplished with linkages to the budget cycle (*11*). Strategic planning is a resource allocation tool and the implementation of the resource allocations can be accomplished through the budget planning process. Steiner and Miner (*16*) also emphasize the importance of this linkage to the annual budget as "the most universally used and central basis for translating strategic decisions into current actions." Galbraith and Nathanson (*17*) point out that in addition to resource allocation processes, the evaluation and reward systems, human resources, and career development are also involved in effective implementation.

According to Lamb (*18*), human resource factors are perhaps the most critical to implementing strategies. Too many organizations have failed to carry out strategies because the wrong people were in charge, priorities were confused, and the chief executive did not lend weight to the strategic plan or did not institute the proper rewards for management and staff.

Because of the cooperative efforts of various individuals and interest groups in public-sector strategic planning, an implementation plan is required to define the responsibilities for implementation (*11*). It is not necessary to develop a formal planning document, but it is necessary to document the actions that must take place. The plan would specify the actions, the sequence of actions, and the timing of actions that would be assigned to individuals. Such strategic actions would be factored into management's objectives. Thus, program planning and budgeting techniques, performance management systems, scheduling techniques, and communications networks are used for strategy implementation.

The implementation plan would also specify any organizational changes that would be needed to implement the strategies (*8*). According to a TRB video on strategic planning, organizational change must be managed; it involves developing a clear picture of the desired state and moving an organization through the transition (*19*). Actions to motivate change include identifying dissatisfaction with the current state, building in broad participation in the process, rewarding the desired behavior, and providing time and opportunity to disengage from the present state.

The final task for strategy implementation is the monitoring of progress and the comparison of accomplishments with strategic objectives. An additional responsibility of the monitor is to periodically rescan the environment so that the planning process can react to any unforeseen circumstances (*11*). The person or organization responsible for monitoring should keep track of the resources and time expended as well as changes in the key personnel and their responsibilities. The monitor must also determine if the resources have been adequate for implementation and must convey the findings to management.

Fielding notes that the monitoring and measuring of performance constitute the difference between strategic management and merely supervising operations (*20*). A few indicators that track performance over time can be useful for evaluating results of strategy implementation. Many transit properties assess performance in terms of ridership, but a more balanced assessment using three performance concepts—cost efficiency, cost effectiveness, and service effectiveness—is needed (*20*). Service input, output, and consumption data are used to measure these concepts.

If measurement of agency performance indicates the need for corrective action, management can implement new programs or modify programs to improve performance. Renewing the strategic planning process is clearly appropriate when environments change, because entirely new strategies may be required.

TRANSIT PROPERTY CASES

The transit properties chosen for the case studies are indeed a diverse lot in terms of the selection criteria. The factors prompting strategic planning and the cases' experiences with strategic planning differ as well. The cases are described briefly in the next sections.

AC Transit

The Alameda/Contra Costa Transit District (ACTD) operates bus services in western Alameda and Contra Costa counties, California, and provides transbay services to San Francisco and Palo Alto. ACTD bus service consists of 106 local feeder, 6 express, and 17 transbay lines, using 872 buses. The property employs approximately 2,000 people.

A performance audit in 1984 cited a need for strategic planning given the anticipated rapid growth in transportation demand in the Bay Area and continued local federal funding constraints. The general manager made an organizational commitment to strategic planning and the first Strategic Development Report was issued in November 1986. Since then, financial crises and four general managers in 3 years have resulted in uneven support for strategic planning and strategy implementation.

New Jersey Transit

New Jersey Transit (NJT) is a statewide public transportation agency that, through three subsidiaries, operates bus and rail systems: 2,624 buses, 10 commuter rail lines, and a light-rail line. NJT as a whole employs approximately 7,500 persons.

In 1985 the management of NJT was concerned over future direction and expansion of services to meet rapid growth in the state. NJT began its strategic planning process by hiring a consulting firm in January 1985 to conduct a 3-day retreat for NJT managers. After the first retreat the strategic planning process consisted of the rail and bus subsidiaries' development of business plans, completed in May 1986. Implementation of the plans, dependent only on informal commitments and individual initiative, has been limited.

Port Authority Transit

The Port Authority of Allegheny County Transit (PAT) serves the city of Pittsburgh and surrounding Allegheny County, Pennsylvania. PAT employs approximately 3,000 people and operates a transit system of 932 buses and incline and light-rail transit.

A committee of the Pittsburgh Chamber of Commerce first recommended strategic planning to PAT in 1984 because of fundamental changes in the local economy and in transportation needs. The PAT board of directors announced a set of seven goals in June 1984 to guide the first strategic business plan, which was completed in March 1986. The second strategic plan and business plan were completed separately in late 1987. Implementation and monitoring of the second plans continue.

Seattle METRO Transit

The Municipality of Metropolitan Seattle (METRO) is an agency of metropolitan government that serves all of King County, Washington, including the city of Seattle. METRO has responsibilities for capital programs, water pollution control, and transit. METRO Transit employs approximately 3,200 people, operates a system of 1,226 diesel and trolley buses, and manages programs for the elderly and handicapped, as well as providing vanpooling and carpooling services.

METRO Transit underwent rapid growth in ridership in the 1970s, but in the early 1980s it faced declines in ridership and diminished financial resources. In 1985, the management of METRO Transit recognized a need for change in thinking, strategies, and organization. METRO Transit embraced a "market driven approach," including a market strategy development process, and by the end of 1987 issued three market strategy reports. The development of strategies continues and is being incorporated into the long-range planning process.

Utah Transit

Utah Transit Authority (UTA) serves the cities of Provo and Orem and the counties of Salt Lake, Davis, and Weber. UTA employs approximately 850 people and operates a transit system of 391 buses, coordinates a carpooling program, and works with various social service agencies to provide transportation to the elderly and handicapped.

UTA was one of the first transit properties to try comprehensive strategic planning. The UMTA regional administrator in the early 1980s was instrumental in guiding UTA toward strategic planning because of the expected reduction of federal funds for local transit operations. The strategic plan for UTA was completed in December 1984 and has been implemented. The mission, goals, and objectives were updated in late 1987.

ANALYSIS OF CASES

All of the cases organized planning staffs and upper management to conduct strategic planning, followed methodological steps, and documented their planning efforts. At PAT, METRO Transit, and UTA, upper management, including the general manager, was committed to and actively participated in strategic planning. At ACTD and NJT, upper management commitment and participation were more casual. All of the cases except NJT prepared a strategic plan or formal planning document. None of the cases emphasized rigorous analyses other than some travel forecasting, market research, and budgeting.

The role of the board of directors in strategic planning varied among the cases. The boards of ACTD, PAT, and UTA oversaw and periodically reviewed the processes. The other boards were merely informed of the effort and of the expected results. All of the cases involved other government officials or members of the public, or both, in an advisory committee to provide input.

The cases did not use task forces other than the management teams. They all relied on planning staffs to attend to operational details. Because strategic planning was new to all of the cases, there was a tendency for each to rely primarily on a management team with the understanding that the approach would become more participatory, if the initial attempt was successful. The cases' involvement of the private sector in strategic planning was limited to the use of consultants to facilitate strategic planning and to the establishment of some private-sector advisory groups after plans were completed.

From all of the cases except ACTD the response was that the resources were sufficient, but the time spent on the process was greater than originally planned. In all of the cases it was apparent that intraagency communication could have been improved. One interviewee observed that information is power and is thus rarely shared. Yet, all agreed that communication of the need for strategic planning, the process of strategic planning, and the impacts of strategic planning is necessary for organizational acceptance.

All of the cases incorporated some strategic planning tasks into the objectives of planning staff personnel. The managers at PAT, METRO Transit, and UTA had objectives for strategic planning or strategy implementation, or both, whereas managers at ACTD and NJT did not. All of the cases had intentions of adding strategic planning objectives to more management and staff personnel in the future.

It appeared that all of the cases did a thorough job of analyzing the external economic, political, developmental, and demographic trends, those factors that are generally not controllable. Management personnel at all of the case properties except METRO Transit identified their strengths, opportunities, and threats. The internal analysis factors, particularly the weaknesses, were not extensively analyzed or at least were not extensively addressed in any of the cases' planning documents. One interviewee speculated that perhaps in all of the cases there was a fear of pointing out the internal weaknesses of the organization in a public document. The cases did not use forecasting techniques; all of the cases except PAT developed alternative scenarios and then selected the most probable one for strategy development. NJT used a portfolio approach to analyze the environment and evaluate services and was apparently satisfied with the results.

Through strategic planning all the cases have established a new organizational emphasis on marketing, often downplaying the traditional mass transit products in their mission statements. All of the cases based the development of mission, goals, and objectives on a previous or concurrent analysis of the environment; PAT's board of directors established goals before the start of strategic planning. Each case expressed its mission, goals, and objectives similarly and in broad, rather general terms. Only UTA had objectives stated in terms of quantified targets.

All of the cases developed strategies to confront situations of declining or stabilizing ridership along with declining financial support. The strategies that were developed generally emphasized increasing ridership in a cost-effective manner with efficient use of resources. Strategies and programs were developed to provide various new mass transit technologies, enhance computerization of operations, increase financial support, increase market research, contract with private providers of transit, increase paratransit services, establish more control over land use decisions in service areas, and imbue the organization with a sense of mission and service to the public.

None of the cases used any formal method of strategy development other than brainstorming based on judgment and intuition. The cases did not use defined criteria for any formal evaluation of the strategies. Generally, management developed strategies that were in their judgment practical and appropriate.

Two cases, ACTD and UTA, reorganized after having planned strategically, whereas NJT did not reorganize as a result of strategic planning. Organizational change occurred before strategic planning at PAT and METRO Transit. The cases that reorganized did so to improve marketing and budgeting procedures in support of strategy implementation.

All of the cases attempted strategy implementation by development of programs in the program planning process. All of the cases except PAT had not developed a strong link between the program planning and budgeting processes and acknowledged this situation as a major limitation of their strategic planning efforts. The budgeting of programs often depended more on political realities and crises of the moment rather than on long-term strategy. Among all of the cases strategic planning was thought to instill strategic thinking, at least informally, into the program budgeting process.

At PAT, METRO Transit, and UTA some management and staff had implementation objectives and, subsequently, were evaluated on their performance. Programs were usually assigned to the staff unit with obvious responsibility in a certain area. NJT and ACTD did not impose implementation objectives on their personnel.

Strategy implementation by PAT was the most direct and certain because of strong management commitment and participation; strong links between strategy development, program planning, and budgeting; and formal implementation objectives, appraisal, and compensation. Implementation at METRO Transit and UTA was somewhat less direct and certain because of weaker links between program planning and budgeting. The implementation of strategies by NJT and ACTD was relatively restrained and tentative because of management's relatively casual commitment and participation; weak links between strategy development, program planning, and budgeting; and no formal implementation objectives.

All of the cases except NJT had established or were establishing progress reporting systems to indicate levels of program implementation. These cases were also attempting to develop measures or indicators for use in monitoring agency performance in meeting objectives. Some interviewees acknowledged that existing measures were too nebulous to measure agency performance or were not related to strategic programs. UTA, which had the only objectives with quantified targets, also had not yet developed performance measures. Only PAT and METRO Transit had designated groups and procedures for periodic monitoring of the environment.

Without appropriate measures in place to monitor agency performance, it is difficult to discern from the case studies the benefits of strategic planning. Strategic planning has long-term impacts and the cases have had relatively short-term experiences with it. However, the management interviewees did attribute certain benefits/strengths and weaknesses to their processes.

The resident strategic planning consultant for ACTD believed that strategic planning brought up certain key issues to management that must be resolved, if long-term financial stability is to be achieved. Management agreed that strategic planning should determine the direction of ACTD, but direction is currently determined by allocation of resources based on crises and political pressure. The consultant concluded that if strategic planning had received a stronger, earlier commitment by upper management, perhaps much of the current financial and managerial instability may have been avoided.

At NJT the strategic planning manager thought that the principal benefit of strategic planning is that a framework for developing the mission and for assessing the environment, history, services, stakeholders, and financial situation has been incorporated into the organization as a way of thinking and managing. On the other hand, the organization of the process and the level of commitment by top management to it may have been sufficient for environmental assessments and for strategy development but insufficient for comprehensive implementation of strategies. Given the major new initiatives on future services, a strong link between strategy development and implementation will be essential.

The perception of the planning director at PAT was that strategic/business planning has been a beneficial process that has allowed management to take greater control of PAT's direction and progress. The decision making for the programming and budgeting processes is more strategic and less operational. The plans are an excellent communicator of the organization's sense of purpose—its goals and objectives—among its own personnel, other agencies, and the public.

According to members of the planning department, the major weaknesses have been the lag in implementation of some programs, particularly those of managers without previous planning experience; the insufficient time budgeted for the process; and the hesitancy of some managers to suggest programs for which they would become responsible.

According to the superintendent for planning at METRO Transit, the benefits of the market-driven approach and strategy development are that the organization is better able to serve changing markets and to evaluate and improve existing services. The organization is now more systems-oriented and has embraced experimentation. Long-range planning, marketing, and policy and program planning are incorporating strategy development.

Some staff felt that there was insufficient communication during the reorganization and subsequent strategy development process, leading to some organizational and emotional upheaval. According to both management and staff, METRO Transit as a whole has adapted well over time to the reorganization and new market-driven approach.

The general manager at UTA believed that the strategic plan provides a sense of direction or purpose, "a map of the future," and a focus or benchmark for policy and program evaluation. Strategic planning has led to a more aggressive pursuit of public/private partnerships for the provision of new services.

According to one director, strategic planning at UTA has been an excellent communication tool. An orientation to people—employees and riders—has been built into the process. One major weakness is that strategic planning has placed some constraints on innovative ideas that were not covered in the plan. Also, because UTA was "fatigued" by the end of the process, management did not place enough emphasis on implementation and monitoring.

CONCLUSIONS AND RECOMMENDATIONS

It is clear that there are many different ways in which strategic planning can be accomplished. The operational details and the level of formality in terms of organization, analysis, and documentation certainly vary among the cases. A strategic planning process should focus on key issues, establish a dialogue, and develop strategies rather than adhere to a specific methodological approach. However, there should be a framework to the process, an orderly procedure of commonly accepted elements or steps.

Mere adherence to a process certainly does not guarantee success in developing and implementing strategy. All of the cases had some problems with strategy implementation and monitoring. Based on the literature and case studies, the authors have concluded that the following factors are important to completing a process, developing and implementing strategies, and achieving benefits from strategic planning:

- Upper management, particularly the general manager, must make an early and serious commitment of time and resources to the strategic planning effort. Management must organize and actively participate in the process to lend it the credibility and the direction that only management can give.
- The development and refinement of the mission, goals, and objectives should be based on a careful situation audit of the environment.
- Management must understand the strengths and weaknesses of the organization and the opportunities and threats in the external environment.
- The establishment of mission, goals, and objectives should emphasize a marketing perspective.
- The objectives should be stated in quantitatively measurable terms so that agency performance can be compared to the objectives.
- The marketing perspective should continue through the strategy development process. Thus, transit properties should develop strategies that establish advantageous market niches that are compatible with organizational values.
- Strong links should exist between strategy development, program planning, and the budget cycle (implementation plan), so that strategies receive the resources needed for implementation. Successful strategy implementation requires designated "strategy champions" who have responsibilities, objectives, and incentives to implement.
- During the organization of the planning process, a planning staff should be made responsible for monitoring the progress of programs and agency performance in meeting strategic objectives. Indicators should be developed that can be used to measure efficiency and effectiveness of transit services. The planning staff should plan to periodically monitor environmental change.

Based on the conclusions, the authors recommend the following general framework to a strategic planning process:

1. Organize a management team and strategic planning staff. Management should make a commitment of resources and time to develop a process and to participate in it; a planning staff, either formally or informally organized, is needed to assist management in developing a process, to gather information on the environment, to develop agency performance measures, and to monitor performance and the environment.
2. Conduct an environmental assessment/situation audit; determine the strengths, weaknesses, opportunities, and threats. The planning staff gathers information on environmental trends; input from a technical advisory committee on significant trends and sources of information would be of benefit.
3. Establish mission, goals, and objectives. The management team, using information from the environmental assessments, states the mission and establishes goals and measurable objectives.
4. Develop broad strategies. The management team with staff input develops strategies to position the organization to deal with the changing environment.
5. Establish programs and budgets to implement broad strategies. The management team and staff conduct program planning; "strategy champions" are assigned responsibilities to conduct programs.
6. Monitor implementation of strategies using appropriate measures. The planning staff uses measures to evaluate strategies and provides results to the management team. If results do not meet objectives, the management team modifies programs or returns to Step 5.
7. Monitor environment and conduct a situation audit. The planning staff periodically scans the environment to denote the latest trends; the management team decides when to return to Step 3.

ACKNOWLEDGMENT

This research was sponsored by UMTA's University Research and Training Program.

REFERENCES

1. F. R. David. *Fundamentals of Strategic Management.* Merrill Publishing Company, Columbus, Ohio, 1986.
2. G. A. Steiner. *Strategic Planning: What Every Manager Must Know.* Free Press, New York, 1979.
3. S. K. Marrus. *Building the Strategic Plan*, John Wiley & Sons, Inc., New York, 1984.
4. D. D. McConkey. Strategic Planning in Nonprofit Organizations. *Business Quarterly* (Canada), Vol. 46, No. 2, Summer 1981, pp. 24–33.
5. C. Bloom. Strategic Planning in the Public Sector. *Journal of Planning Literature*, Vol. 1, No. 2, Spring 1986, pp. 253–259.
6. M. D. Meyer. Strategic Planning in Response to Environmental Change. *Transportation Quarterly*, Vol. 37, No. 1, April 1983, pp. 297–320.
7. F. S. So. Strategic Planning: Reinventing the Wheel?, *Planning*, Vol. 50, No. 2, Feb. 1984, pp. 16–21.
8. J. B. Olsen and D. C. Eadie. *The Game Plan: Governance with Foresight.* Council of State Planning Agencies, Washington, D.C., 1982.
9. N. B. Ferris. Developing a Strategic Advantage for Your Community. *Public Management*, July 1983, pp. 16–18.
10. S. N. Espy. *Handbook of Strategic Planning for Nonprofit Organizations*, Praeger Publishers, New York, 1986.
11. D. L. Sorkin, N. B. Ferris, and J. Hudak. *Strategies for Cities and Counties: A Strategic Planning Guide.* Public Technology, Inc., Washington, D.C., 1984.

12. P. Lorange. *Implementation of Strategic Planning*. Prentice-Hall, Englewood Cliffs, N.J., 1982.
13. S. C. Wheelwright. Strategy, Management, and Strategic Planning Approaches. *Interfaces*, Jan.–Feb. 1984, pp. 19–33.
14. S. C. Jain. The Evolution of Strategic Marketing. *Journal of Business Research*, Dec. 1983, pp. 409–424.
15. P. C. Nutt and R. W. Backoff. A Strategic Management Process for Public and Third-Sector Organizations. *Journal of the American Planning Association*, Winter 1987, pp. 44–57.
16. G. A. Steiner and J. B. Miner. *Management Policy and Strategy: Text, Readings, and Cases*. Macmillan Publishing Company, Inc., New York, 1977.
17. J. R. Galbraith and D. A. Nathanson. *Strategy Implementation: The Role of Structure and Process*. West Publishing Company, St. Paul, Minn., 1979.
18. *Competitive Strategic Management*, (R. B. Lamb, ed.). Prentice Hall, Englewood Cliffs, N.J., 1984.
19. *Strategic Planning for State and Local Transportation Agencies*. Videotape. TRB, National Research Council, Washington, D.C., 1986.
20. G. J. Fielding. *Managing Public Transit Strategically*. Jossey-Bass, Inc., Publishers, San Francisco, Calif., 1987.

The authors are solely responsible for the conclusions and any errors or omissions.

Publication of this paper sponsored by Committee on Strategic Management.

Regional Economic Impact Model for Highway Systems (REIMHS)

ARTURO L. POLITANO AND CAROL J. ROADIFER

This paper provides a brief overview of the Regional Economic Impact Model for Highway Systems (REIMHS), a description of the methodology's components, and a sample application for the 16-county Dallas/Fort Worth area. Relying on the Bureau of Economic Analysis' multipliers for regional industrial output, earnings of employees in those industries, and employment, the methodology takes standard highway data input and derives industrial output, earnings, and employment impacts of addressing or not addressing highway construction or rehabilitation needs on a variety of highway systems. For example, this prototype methodology and model showed that not addressing construction needs on a typical Interstate highway results in a loss in motorist benefits for the Dallas/Fort Worth area equivalent to $1.8 million in regional output, $580,000 in regional earnings, and 27 jobs. On the other hand, undertaking $10 million in Interstate improvements will stimulate $17.6 million in regional output, $4.6 million in earnings, and 203 jobs. These findings were compared with earlier studies and found to be reasonable. The highway data input consists of allocating highway investments to the various highway industries and estimating and allocating savings resulting from highway construction and rehabilitation improvements. The savings result from increased efficiency, mobility, and safety for vehicular traffic exposed to congestion. The authors conclude that the methodology is practical and workable and that the results are reasonable.

The decision to build highways is always based on the supposition that highways are beneficial. Yet, how much they improve the economy has been an elusive question to answer. If the answer were readily available, state and local governments could more intelligently differentiate between the various alternatives for highway construction and, with more certainty, make a decision that maximizes the benefit of their investment to their economy.

The importance of answering this question was first noted in 1959 at the Highway Research Board Workshop on Economic Analysis in Highway Programming, Location, and Design. A number of observations were made, such as, "It is extremely important that some means be made available to properly evaluate changes in the highway system. . . ." and "any system analysis should consider the impact on the total economy. . . ."

Today, it makes just as much sense to focus highway resources on those roads that yield the greatest return for the investment.

We conducted a review of the practice and identified a range of methodologies for conducting project economic analysis but only a few for conducting regional system economic analysis. After a review of the methodologies, we determined that we needed a broader and more robust analytical framework. We decided to explore the use of input-output models.

Input-output, or interindustry models, were published by W. Leontief (*1*) as early as 1936, when a model of the American economy was developed. Since then, the use of interindustry analysis has become commonplace in the field of economics.

In the field of highway transportation, interindustry analysis has had a shorter, sporadic history. In 1971, R. W. Hooker of the University of Wyoming developed and used an interindustry model to estimate the impacts of the state highway department's investment, the nonlocal traveler's spending, and the local private investment on the economy of Unita and Sweetwater counties in the southwest corner of Wyoming, where the new 200-mi Interstate highway was to be built (*2*). In 1982, the Regional Science Institute developed, for the National Cooperative Highway Research Program, two manuals to assist state departments of transportation (DOTs) in performing regional economic analysis for policy analysis (*3*). In 1984, the North Central Texas Council of Governments used the interindustry model to estimate the local economic impacts of transportation fuel consumption (*4*). In 1987, the Washington DOT used the interindustry model to estimate the impact of changes in demand for transportation services on the rest of the economy (*5*). Finally, in 1987, the Ontario Ministry of Transportation constructed an input-output model to assist its member jurisdictions in predicting economic impacts of a variety of highway projects (*6*). Other transportation uses have been made of interindustry models, but they are not extensive.

Perhaps its sporadic history is because of the complexity of the analysis required. Yet, interindustry models can provide valuable information in support of a highway project or a program implementation decision. If the analysis were to be simplified, the models could be brought to bear more extensively on highway issues. For example, interindustry models could be adapted to answer these questions: which highway investment has the greatest potential for improving the regional economy? and by how much? Hence, we suggest a need to develop sketch planning tools for the application of the interindustry model.

In this development of a prototype regional economic analysis model, we make no judgments as to the relative economic impacts of alternative investment strategies. That is, we do not consider the regional economic impacts of investing $10 million in the private sector or other public infrastructure projects. We took such examination to be outside the scope of this exploratory study.

Planning and Programming Branch, FHWA, Washington, D.C. 20590. Current affiliations: A. L. Politano, Operations Research Office, FAA, 800 Independence Avenue, S.W., Washington, D.C. 20591. C. J. Roadifer, Corps of Engineers, P.O. Box 61, CESWT-EM, Tulsa, Okla. 74121-0061.

METHODOLOGY

Overview

Expenditures by highway agencies have secondary impacts on the economy, beyond providing new or better services. Such impacts are employment, income, and production. Moreover, these impacts are explicitly traceable from the transportation sector to other sectors of the regional economy.

For example, building a highway requires inputs of labor, raw materials, government services, unfinished products, and so on. Some inputs may be purchased within a region and others from outside a region. The services provided by the highway are likewise used by industries within a region and outside a region. To the extent that interdependencies between the highway construction sector and other sectors of the economy exist, a change in the production of highway service will affect the production of other industries in a region's economy (*2*). Construction of highways may specifically affect regional industries by (*7*)

- Decreasing the cost of transporting a product within or through a region;
- Increasing the income of a region through payment of construction workers and, in turn, other industries through the purchase of goods and services by construction workers; and
- Increasing income of those industries that supply construction materials.

These changes also bring about corresponding changes in employment and production of regional industries.

Process

The process of developing a methodology for applying the interindustry model to highway construction took the form of

- Distributing the monetary investment among the relevant highway industries of the region;
- Translating the efficiency, safety, and mobility improvements to equivalent monetary benefits;
- Using the investments and benefits as inputs to the interindustry multiplier matrices; and
- Observing the resulting impacts on the region's total economy.

The process and the interrelationships between these components are diagrammed in Figure 1.

Procedure

The process consists of 10 steps, as indicated in Figure 1. Each of the steps is described generally here. Steps 1 through 5 are described in more detail in the Technical Appendices, which are available on request from the FHWA Office of Planning. Appendices are entitled Appendix A: Investment in Highway Material Industries; Appendix B: Efficiency Savings—User Costs; Appendix C: Mobility Savings—Travel Time; and Appendix D: Safety Savings—Accident Costs.

- *Step 1: Distribute project cost as investment of money in regional highway material industries and to households.* A $10 million investment in construction funding was allocated among nine highway-related industries, including new construction, maintenance construction, petroleum refining, lumber, stone, metal, electric equipment, miscellaneous manufacturing, and households. The basis of allocation was the quantity of industry-related materials used by each of the project types. Twenty-eight projects were used, covering 11 construction categories.
- *Step 2: Calculate equivalent monetary benefits of operating efficiency savings.* For construction improvements, savings in maintenance repair, fuel, tire, oil, and depreciation were calculated for that traffic exposed to congestion, defined as a volume to capacity ratio of 0.77 or more. Savings were taken as the difference between operating costs, before the improvement, minus the operating costs, after the improvement. These are savings that would be available to households and industries for other discretionary expenditures. Some savings, such as fuel and oil, are of a shorter-term nature and are out of pocket. Others are not and may be felt in the longer term. Nevertheless, the savings or the lack of savings will influence household budgets and expenditures in the regional economy.
- *Step 3: Calculate equivalent monetary mobility savings.* For the traffic exposed to congestion, savings in travel time were calculated. Travel time savings were based on the vehicle miles of travel, the differences in running speeds after and before the improvement, and the value of travel time. For automobiles, the value of travel time was calculated as $8.20/hr, using AASHTO Redbook guidance; for trucks, it was $13.98/hr. It is easier to see that mobility savings of the truck fleets would lead to cash monetary benefits for industries. It is more difficult to understand the noncash benefits of commuter travel time. We reason that a commuter's time loss could also be translated to lost wages.
- *Step 4: Calculate monetary benefits of safety savings.* Using the total vehicle-miles of travel, the number of accidents per 100 million vehicle-mi, the cost of fatal, injury, and property-damage-only accidents, and accident reduction factors for various highway project types, it is possible to calculate savings in accident costs. Total vehicle-miles of travel were used, rather than vehicle-miles of travel exposed to congestion, because accidents are likely to be reduced at both congested and noncongested periods. These benefits are also noncash benefits, which may extend existing household and industry expenditure patterns.
- *Step 5: Distribute monetary savings to relevant industries and to households.* All savings of Steps 3 and 4 were calculated for automobiles and trucks. Automobile savings were attributed to households; truck savings were distributed to the regional industries. Distribution to the trucking industries was done on a basis of truck vehicle-miles of travel for various uses as reported by the Truck Inventory and Use Survey of 1982 (*8*). Where uses could be identified with regional industries, personal transportation, retail trade, and so on, vehicle-miles of travel data were used directly. Where uses were too general to be identified with specific regional industries, such as manufacturing, a further breakdown of truck vehicle-miles of travel was made on the basis of number of employees in that subindustry, such as electrical equipment manufacturing. The Department of Commerce's *County Business Patterns* was used as a basis for this breakdown (*9*). The percentage of truck vehicle-miles of travel for each industry was thereby calculated and used to distribute savings of Steps 2 and 3.

Savings in Step 4 were attributed to the household sector

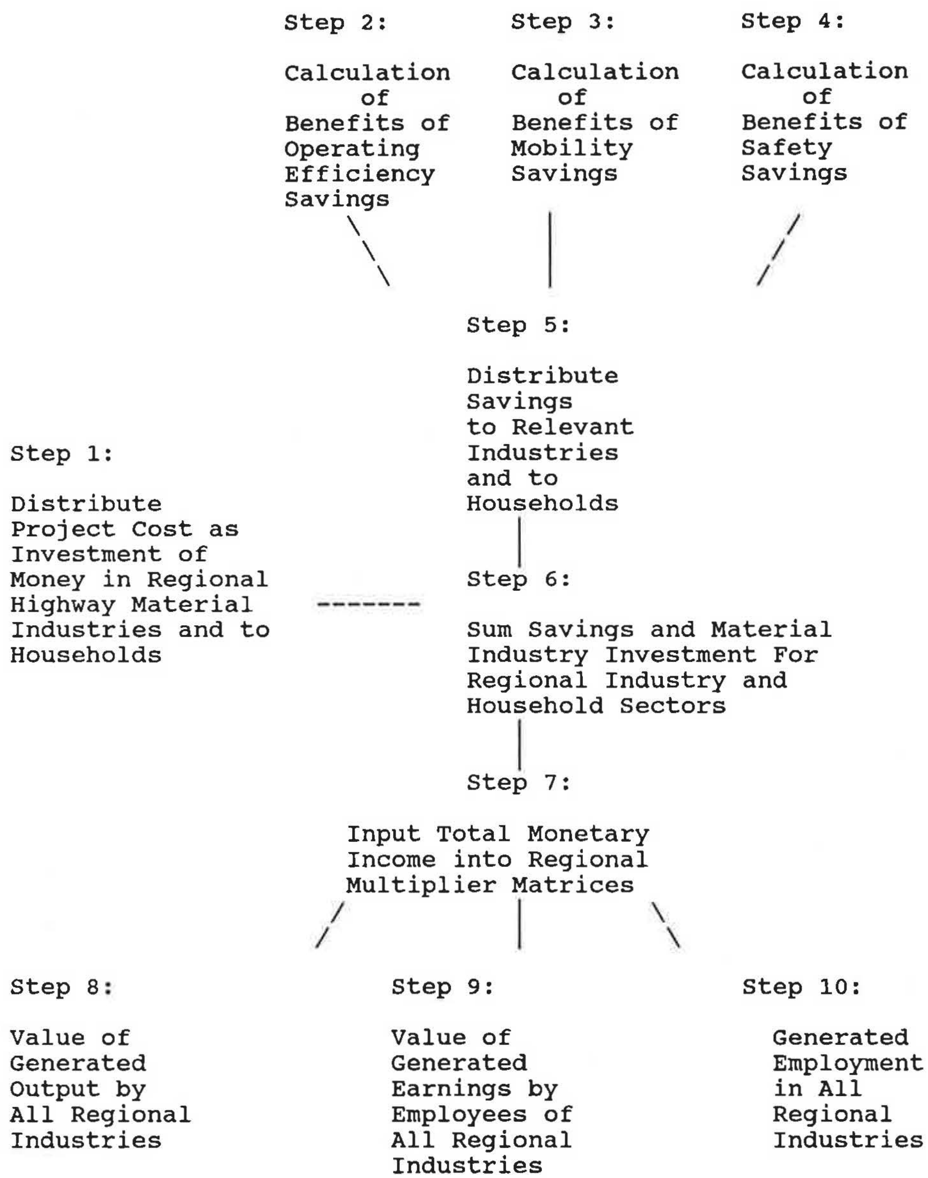


FIGURE 1 Process for developing the regional economic impact model for highway systems.

and to the insurance sector at the rate of 1:10, assuming that, in the event of an accident, households could incur 10 percent of the cost in the form of deductibles and increases in insurance premiums and that the insurance sector would bear 90 percent of the losses.

- *Step 6: Sum savings and material industry investment for regional industry and household sectors.* Step 1 distributes project costs among 9 industries, Steps 2 and 3 among 18, and Step 4 among 2. There is considerable overlap. The total number of different industries is 23. For each of the 23 industries, the sum of construction investment and efficiency savings was calculated.

- *Step 7: Input total monetary income into regional multiplier matrices.* Output, earnings, and employment multiplier matrices are available from the Bureau of Economic Analysis (BEA), Department of Commerce, for any region consisting of one or more counties. For this study, we used BEA's aggregate multiplier matrices of 39 industries (*10*). Each of these matrices is a closed set of interdependent coefficients representing the interrelationships of a study area's economy. The coefficients are called multipliers because they are dollar multiples of the initial dollar spent in each industry (*10*). Each coefficient is equivalent to the change in output that occurs in a regional industry, given a change in the input industry. The input of highway investment monies and monetary savings of efficiency, mobility, and safety improvements in the relevant industries results, through the use of the interdependent coefficients, in the estimation of required output for each and every industry in the region.

For this prototype model, we use multipliers that represent total requirements coefficients. These include direct, indirect, and induced economic impacts of an investment in a regional economy.

- *Step 8: Value generated output by all regional industries.* Finding the product of (a) all the monetary investment and savings for each of the 23 input industries and (b) the respective multiplier of the output matrix for each and every one of the 39 output industries, it is possible to obtain an estimate of the monetary value of all items produced by the regional industries. This we can label generated output.

- *Step 9: Value generated earnings of all regional industries.* Finding the product of (a) the sum of monetary investment and savings for each of the 23 input industries and (b) the respective multiplier of the earnings matrix for each and every one of the 39 output industries, it is possible to obtain an estimate of the monetary value of employee salaries in the regional industries. The salaries result from the infusion of travel savings and construction investment in the regional economy. This we can label generated earnings.
- *Step 10: Value generated employment in all regional industries.* As with Steps 8 and 9, Step 10 follows similar reasoning to arrive at the number of jobs created, or employment generated, for the regional economy.

CASE STUDY APPLICATION

Background

No process, methodology, or model is practical, unless it can be shown to yield anticipated results. A sample application also shows the capability of the analytical tool.

For the sample application of the interindustry model, the 16-county North Central Texas Council of Government's region is the focus. This region is shown in Figure 2. At its center the region has the Dallas/Fort Worth urbanized area. Counties adjacent to but outside the Dallas/Fort Worth Consolidated Metropolitan Statistical Area include Wise, Palo Pinto, Erath, Hood, Somervell, Navarro, and Hunt. These are rural counties.

Employment, earnings, and output multiplier matrices for analysis year 1986 were made available for our application by the generosity of the North Central Texas Council of Governments, which purchased the multipliers to conduct an FAA-sponsored study of airport expansion alternatives.

Data

Transportation data for this study were available through existing data bases. For highway material industry investment, usage data were available from Form FHWA-47, Statement of Materials and Labor Used by Contractors on Highway Construction Involving Federal Funds. This form provides such data as project type, highway system, total construction cost, labor cost, length of project, quantity of materials used, and total material cost. A total of 76 projects were reviewed, and 28 were used.

Six system types were used: Interstate, primary, and urban in urban areas and Interstate, primary, and secondary in rural areas. Travel data from the 1986 Highway Performance Monitoring System (HPMS) submissions of the Texas State Department of Highway and Public Transportation were used to determine percentage of vehicle-miles exposed to congestion, percentage of truck-miles under congested conditions, vehicle-miles for each of eight vehicle classes, and average urban and rural volume to capacity ratios.

For efficiency savings, consumption data for maintenance and repair, fuel, tire, oil, and depreciation were available from an unpublished FHWA-sponsored study on operating costs developed by Zaniewski in 1982 and entitled "Vehicle Operating Costs, Fuel Consumption, and Pavement Type and Congestion Factors." Consumption data were available for the 1980 vehicle fleet; unit prices were available for 1980 and 1985. The unit prices were updated to 1986, using straight-line extrapolation. Accordingly, 1986 consumption data are based on the consumption rates of 1980 automobile and truck vehicle fleets.

For mobility savings, running speeds were obtained from the use of the HPMS Analytical Process, Version 2.1 (*11*). Running speeds are a function of average highway speeds and volume to capacity (*V/C*) ratios. Average highway speeds were obtained from FHWA's *Highway Statistics 1986* (*12*, p. 60); average *V/C* ratios were obtained from 1986 HPMS data reported by the state of Texas. The differences in running speeds, resulting from changes in *V/C* ratios, were used to estimate savings in travel time. The monetary values of time for automobiles and trucks were obtained by applying the AASHTO manual on user benefits (*13*, p. 17), updated to 1986, using the Consumer Price Index (CPI) and the Wholesale Price Index for Industrial Commodities (*14*).

For accident savings, cost data were obtained from a 1984 FHWA publication titled, *Alternative Approaches to Accident Cost Concepts—State of the Art* (*15*, p. 123). This source was chosen because it provides recent data that integrate well with other travel data. Also, these estimates are conservative compared to many other sources considered. This source was used for direct cost of a fatality, of an injury accident, and of a property-damage-only accident. Accident reduction factors for each project type were obtained from a 1982 report by FHWA (*16*, p. 1). The accident rate data were obtained from two annual reports of accident statistics published by FHWA (*17*, p. 5) and the National Safety Council (*18*, p. 47). The 1985 rates are used because the 1986 reports were not yet available. All cost data were updated to 1986 using the CPI.

For all calculations, with the exception of accident costs, congested vehicle-miles of travel (CVMT) were used as the base statistic. CVMT were derived for each highway system's sample of highways by dividing (a) total daily vehicle-miles of travel (DVMT) with *V/C* at or over 0.77 by (b) the total DVMT. This ratio was then applied to the average DVMT for the respective highway system to arrive at CVMT. Total and average DVMT for each highway system were calculated using the 1986 sample data submitted by the state of Texas. Total DVMT were used for accident cost calculations, because we believed the benefits of accident improvements would be felt by all travelers.

Because HPMS data are not reported for bridges, travel data for a bridge project on a given highway system were assumed to be the same as the average of all roads on that system. For example, a bridge project on a primary system was assigned the same total and average DVMT as a highway project on a primary system.

Results

A $10 million highway improvement can be expected to stimulate industry production valued at between $12.8 and $18.5 million in a region; workers in those industries are estimated to earn between $3.8 and $5.1 million; and the number of jobs stimulated is expected to be between 159 and 232. These

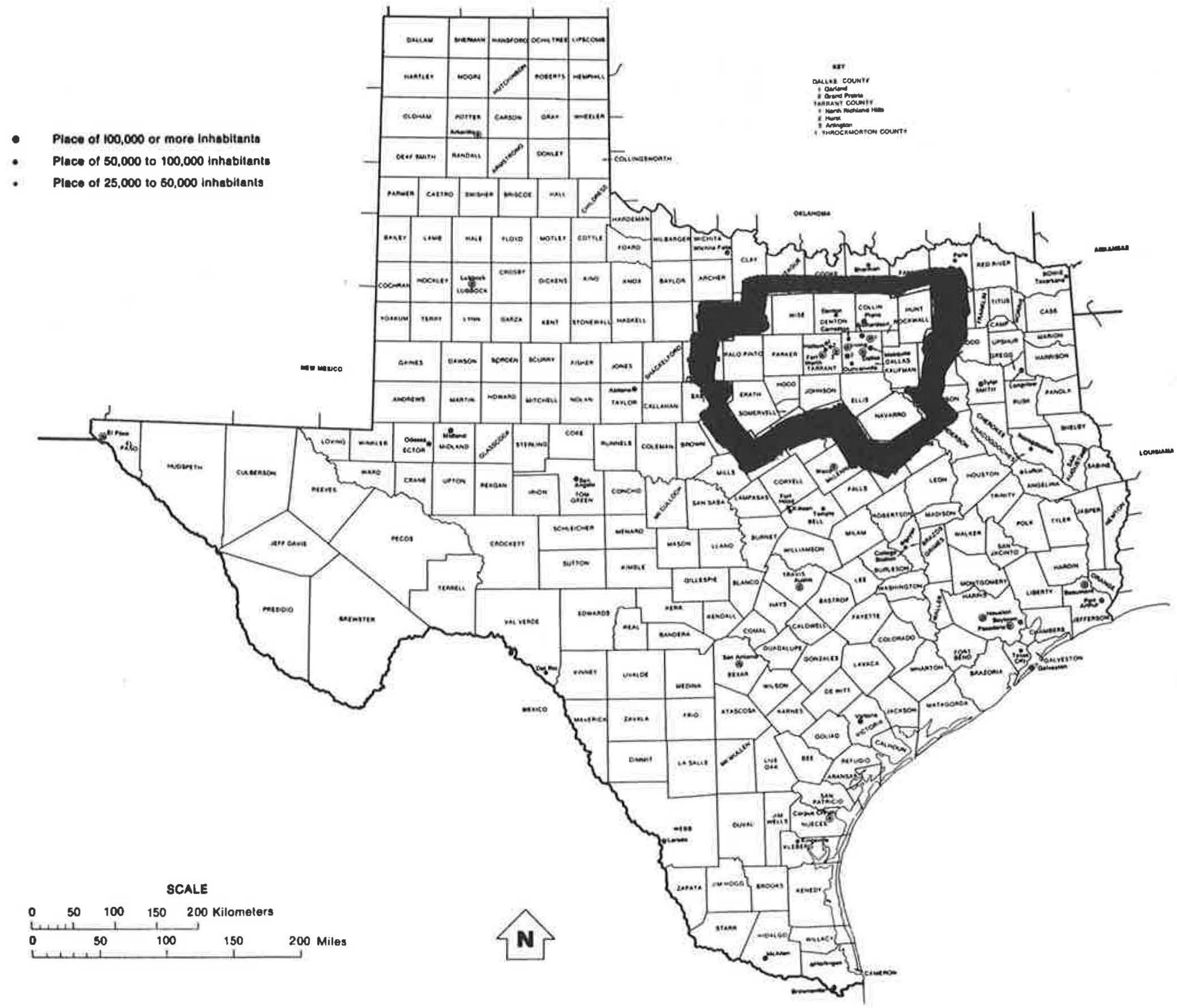


FIGURE 2 The 16-county Dallas/Fort Worth region (data from County Business Patterns, Texas; U.S. Bureau of Census, 1985).

results include the economic impacts of construction and of the attendant transportation improvements.

The construction impacts occur over a number of years as do the transportation impacts. The precise number of years may be a function of how long it takes the infusion of construction funds to completely circulate through the region and how long it takes for the transportation benefits to be completely negated by increased congestion. No assumptions were made regarding the temporal nature of the economic impacts.

For urban areas, five highway project types were considered. Of these, a rehabilitation project on the primary system can be expected to generate the most economic impact, and a bridge construction project on the urban system the least.

For rural areas, six highway project types were considered. Of these, a 3-R project on the Interstate system would generate the most impact on industry output; a new construction project the most impact on industry earnings and on new jobs. The least impact on industrial output is generated by a bridge 3-R project on the primary system; the minor widening project on the secondary system generates the least impact on industry earnings and new jobs.

These economic impacts result from the sum of $10 million invested in the region's highways and the corresponding monetary savings that the region would realize from improvement in operating efficiency, mobility, and safety of vehicular travel. Improvements in operating efficiency include such user benefits as savings in fuel, oil, tire, repair and maintenance, and depreciation; mobility benefits include travel time savings; and safety benefits include reduction in property-damage, fatal, and injury accidents.

Benefits from mobility savings were the greatest, topping the equivalent of $2.6 million for construction projects on the Interstate system. Benefits from savings in safety improvements were next in order of significance, topping $0.77 million for bridge projects on the primary system. Of least significance were benefits from operating efficiency. These topped $0.25 million for rehabilitation projects on the primary system.

These savings all used CVMT as a base statistic, and CVMT in urban areas was uniformly greater than for similar system types in rural areas. For example, CVMT on highway systems in urban areas is 10 to 80 times greater than CVMT for highway systems in rural areas. Correspondingly, improvements for urban areas uniformly resulted in higher savings in operating efficiency, mobility, and safety, when compared with improvements in rural areas.

This study does show that highway projects and, indeed, highway systems can be evaluated for their comprehensive impacts on the regional economy in an expeditious and inexpensive manner, using a sketch planning application of a region's interindustry model. This method allows comparison of practical economic impacts in terms of dollars and jobs, instead of the relative indicators provided by traditional benefit-cost analysis.

Table 1 summarizes the regional economic impact of a $10 million investment and the corresponding motorist benefits in efficiency, mobility, and safety savings. These impacts are provided for construction projects and maintenance and repair projects. Improvements in operating efficiency include such user benefits as savings in fuel, oil, tire, repair and maintenance, and depreciation; mobility includes travel time savings; and safety includes reduction in property-damage, fatal, and injury accidents.

If road construction and repair projects were not constructed, the existing road would be denied efficiency, mobility, and safety benefits. These benefits are the same as those used in Table 1 and were estimated to be the difference between efficiency, mobility, and safety costs before and after a prospective improvement. The calculations and the result would be identical to the calculations and results used for Table 1, with one exception. The exception is that if the investment in the highway construction industries would not occur, no project would be constructed. Inserting only the foregone user

TABLE 1 REGIONAL IMPACT OF A $10 MILLION HIGHWAY IMPROVEMENT ($ MILLIONS, EXCEPT JOBS)

Area Type	Project Type	Motorist Benefits: Efficiency	Mobility	Safety	Impact: Output	Earnings	Jobs
Urban	Interstate: New Construction	.15	2.6	.68	17.6	4.6	203
	Primary: Rehabilitation	.26	1.2	.70	18.5	5.1	224
	Primary: Bridge "3-R"	.26	1.2	.78	14.9	4.6	203
	Urban: Realignment Construction	-.003	.07	.18	16.6	4.9	223
	Urban: Bridge Construction	-.003	.07	.17	12.8	3.6	159
Rural							
	Interstate: New Construction	-.02	.27	.05	17.2	5.1	232
	Interstate: "3-R"	-.02	.27	.04	18.3	4.2	180
	Primary: Bridge "3R"	.002	.028	.05	15.0	4.4	191
	Secondary: Construction	-.0002	.016	.02	17.8	4.3	190
	Secondary: Minor Widening	.003	.02	.01	17.0	3.8	163
	Secondary: Overlay	.003	.02	.02	18.0	4.8	210

benefits in the output, earnings, and employment matrices, we can reasonably interpret the resulting impacts as those regional economic losses that could occur as a result of the loss in motorist benefits. Table 2 summarizes the impacts of efficiency, mobility, and safety losses on the regional economy assuming no investment is made in the highway system.

In urban areas, the results of no investment in highways is greatest where Interstate new construction, primary bridge widening, and primary rehabilitation projects are needed. The amount of industry output lost can be as high as $1.8 million, employee earnings as high as $0.59 million, and the number of jobs lost as high as 27. In rural areas, the results of no investment is greatest where Interstate construction projects are needed. In this case, the amount of output lost is valued at $0.17 million, employee earnings at $0.05 million, and the number of jobs at 2. As with the observations made regarding Table 1, the impacts are greater in urban areas. This is because cost data are driven by vehicle-miles of travel exposed to congestion, and it is much higher for urban areas than for rural areas.

In Table 2, operating efficiency includes such user measures as expenditures in fuel, oil, tire, repair and maintenance, and depreciation; mobility includes travel time costs; and safety includes reduction in property-damage, fatal, and injury accidents.

Analysis of Results

By comparing the impact of construction investment and user cost savings with the impacts of user costs alone, we can see that the magnitude of the construction investment can overshadow the magnitude in efficiency, mobility, and safety benefits or costs of their impacts on the regional economy. For

TABLE 2 REGIONAL IMPACT OF NO HIGHWAY IMPROVEMENTS ($ MILLIONS, EXCEPT JOBS)

Area Type	Project Type	Motorist Losses: Efficiency	Mobility	Safety	Impact: Output	Earnings	Jobs
Urban	Interstate: New Construction	.15	2.7	.68	1.8	.58	27
	Primary: Rehabilitation	.26	1.2	.70	1.6	.54	24
	Primary: Bridge "3-R"	.26	1.2	.78	1.8	.59	27
	Urban: Realignment Construction	-.003	.07	.18	.38	.13	6
	Urban: Bridge Construction	-.003	.07	.17	.37	.12	6
Rural							
	Interstate: New Construction	-.02	.27	.05	.17	.05	2
	Interstate: "3-R"	-.02	.27	.04	.15	.05	2
	Primary: Bridge "3R"	.002	.028	.05	.11	.04	2
	Secondary: Construction	-.0002	.016	.02	.04	.01	1
	Secondary: Minor Widening	.003	.02	.01	.03	.01	1
	Secondary: Overlay	.003	.02	.02	.04	.01	0

a rural Interstate construction project, \$17.2 million is the output of regional industries receiving a \$10 million highway investment and improvements in efficiency, mobility, and safety (Table 1). For this same project, \$0.17 million is the output of regional industries receiving efficiency, mobility, and safety losses alone (Table 2). The corresponding impact of the \$10 million investment alone is \$17.0 million. These comparisons are valid only until the \$10 million investment filters through the economy, or until the congestion level decays to the area's average. Over the life of the project, perhaps 20 years, user benefits may, indeed, equal and exceed the impact of the construction investment. This assumes of course that traffic does not increase measurably on the facility and thereby decrease the user benefits.

Lastly, mobility savings proved to be the most significant, ranging from \$2 thousand to \$2.6 million. Savings in safety improvements were next in order of significance, ranging from \$14 thousand to \$0.78 million. Operating efficiency savings were least significant. These ranged from losses of \$22 thousand to savings of \$0.26 million. The losses were a result of the nature of consumption curves for fuel, oil, tire, repair and maintenance, and depreciation. Consumption curves are concave for both fuel and oil with a minimum corresponding to a certain point. Beyond this low point, consumption increases as speed increases. For tire and for repair and maintenance, the higher the speed, the higher the cost of these consumption factors. Lastly, depreciation cost decreased with speed. Accordingly, the construction of a highway improvement, and the attendant increase in speed, does not necessarily result in savings in operating costs. Fortunately, savings in mobility and safety exceeded increases in operating costs, resulting in a net increase in user benefits from the highway improvement.

EVALUATION

Interpretation of Results

Given the investment of \$10 million to construct an Interstate project in an urban area, Table 1 indicates that regional industries will generate \$17.6 million in output, \$4.6 million in earnings, and 203 jobs. These and other results on regional economic impacts are derived using the existing economic infrastructure. These results do not imply that new industry will locate in the region or that the new industry will generate so much economic impact. The industrial interrelationships are assumed fixed, and the mathematical description of the regional economy is closed. Results, then, indicate how well the existing economy uses a given investment. As such, REIMHS can be used to evaluate the regional economic impacts of alternative investments and the potential economic growth of the existing industrial base, but not the potential new growth in the regional economy.

Validity of Results

In the early 1980s, the FHWA monitored the number of jobs directly created by highway construction. These studies were updated as recently as 1985 (*19*, p. 2). Nationally, it was found that a \$1 million investment would directly generate 10 on-site full-time construction jobs. REIMHS indicates that 16 to 23 jobs are created per \$1 million in the 16-county region around Dallas/Fort Worth. REIMHS' results are reasonably close, given that the figures represent (a) the number of jobs that are on site, off site, construction-related, and service-industry-related and (b) related increases in consumer demand (direct, indirect, and induced effects). REIMHS' jobs cover all sectors of the economy, including construction jobs. Lastly, REIMHS' jobs also include the results of the expenditure of monetary savings in operating efficiency, mobility, and safety costs.

In the middle 1970s, the Bureau of Labor Statistics used an interindustry input-output model to determine the employment impact of highway construction (*19*, p. 2). It estimated a total of 57.8 jobs per \$1 million of highway investment. Using the transportation CPI to find the current dollar equivalent for 1986, we estimate that 22.5 jobs would be generated for every \$1 million invested in the highway construction industry. This number is reasonably close to REIMHS' results.

Reliability of Results

The REIMHS is capable of yielding consistent results with each application at various locations and at various intervals of time. This remains true if the output, earnings, and employment matrices are replaced to reflect the change in location of study area and if the period of elapsed time between applications is limited. If too long a period of time lapses between application, perhaps 7 to 12 years, then the nature of the study area's economy may not be reflected by the model. This is because it is likely that the nature of a region's economy will change over a 7-to-12-year period. Nevertheless, the model would remain reliable for sensitivity analysis, because it is the relative changes in regional impact that would be of interest in such an analysis.

Caveats

The results obtained in this prototype development of REIMHS are based on data and information for the 16-county Dallas/Fort Worth area. The following simplifying assumptions were made to circumvent the paucity of data and to facilitate analysis:

- Highway sample travel data from the state can be used to represent project and network data.
- Vehicles-in-use data can be used to partition vehicle-miles-of-travel into three automobile classes.
- Travel cost savings are experienced predominantly by traffic exposed to congestion.
- Excess consumption of stop-and-go conditions is negligible compared to consumption at uniform speeds and excess consumption resulting from speed slowdowns.
- The pavement condition for improvements other than 3-R types is good before the improvement.
- Accident cost savings are experienced by congested and noncongested traffic equally.

In applying this prototype model to other regions, it is important to rely on actual state and local project and areawide data as much as possible to increase the model's relevance to local conditions and possibly avoid making the simplifying assumptions.

Issue of Imputed Monetary Benefits

This analysis assumes that out-of-pocket and noncash savings in operating efficiency, mobility, and safety costs can be treated as money to be spent into the regional economy. We recognize the existence of a debate as to whether these savings are realistic to include in an input-output analysis. Operating efficiency benefits include savings in tire, fuel, oil, depreciation, and maintenance and repair. Mobility benefits include the monetary value of travel time. Safety benefits include savings in accident costs. Savings in tire, fuel, and oil costs directly result in more discretionary monies to spend. However, savings in depreciation and in maintenance and repair are probably less noticeable. Travel time cost savings may not be noticed at all in a household or industry's budget. Savings in accident costs are not noticeable until an accident occurs and the household or industry budget is constrained. Nevertheless, use of user benefits is a long-standing practice in the highway community to evaluate the merits of highway projects, and this application is only a modest expansion of its use. Moreover, in the interest of comprehensiveness, we judged it wise to consider the total range of possible savings from the construction of a highway improvement.

Model

Efficiency Versus Cost

The interindustry model is one of the best analytical approaches for determining the impact of transportation on the regional economy (*2*). It is efficient because it explicitly and directly uses comprehensive data relevant to the region's specific economy. It does not use surrogate measures of economic activity. It takes into account economic changes at a regional level, a level that may implicitly incorporate internal counterbalancing changes of member jurisdictions. The multipliers do cost, however. Were a state such as Florida interested in applying a sketch planning model for its member metropolitan planning organizations (MPOs) (21 in all), the cost would be $750 for each set of multipliers, or $15,750. Applying such a model for the state itself would cost $1,500, the price if only one set of multipliers is purchased. Because the interindustry multipliers can be applied to impact analysis in other fields as well as transportation, the multipliers may well pay for themselves.

Complexity Versus Computer Efficiency

The detailed 531-industry classification matrix prepared by the BEA requires the use of a mainframe and a programming language as demonstrated by the experience of the Regional Science Research Institute. Such detailed analysis provides impacts at very detailed levels of the economy. However, for sketch planning purposes, it is more prudent to use the matrix of 39 industry aggregates. Reliance on the 39 industry aggregate matrix makes the task of data analysis and manipulation more manageable with microcomputers and existing software. Such software includes Lotus 1-2-3. As a sketch planning microcomputer tool, an interindustry model will make sensitivity analysis of differing highway system improvements on the regional economy very time efficient.

Implicit Causality

Because the multipliers are developed from actual expenditures in each of the national industries, and because the expenditures of these industries are mathematically interrelated, then as a mathematically closed system, any change in one sector of the economy directly causes changes in the other sectors. The causal relationship between highway improvement and impacts on the economy is implicit. This is because the nature of the highway improvement is structured in monetary terms for input into the existing relationship—the mathematical system is not altered.

Timeliness of Multipliers

A typical interindustry table comes from two data sources of the BEA: (a) its national input-output table, showing the inputs and outputs of the 531 national industries and (b) county wage-and-salary data (*10*). The national input-output table is available 7 years after the last census. County wage-and-salary data are available about 16 months after the last county-based survey (BEA staff, unpublished data). An interindustry table of multipliers purchased in May 1988 will have 1986 data and will be based on 1977 input-output relationships. In using the multipliers, the analyst assumes that the basic structure of the economy has not changed since the last available survey. This is a plausible assumption, given that the local economy's wage and salary data, which are updated much more frequently, are used to show a region's industrial and trading pattern.

The seriousness of these issues does not appear to be overwhelming and indeed is workable in applying the prototypical sketch planning model to a real and existing project improvement.

CONCLUSION

This paper demonstrates that interindustry models, and specifically REIMHS, can be used efficiently and effectively to evaluate alternative highway project investment decisions at the regional level. Given a choice of investments, for example, constructing a variety of highway projects, REIMHS can be used to estimate which investment will result in the greatest monetary value of production of regional industries, the number of jobs generated, and the earnings of employees in those regional industries. REIMHS can also serve as a reasonable sketch planning tool for determining the economic development potential of a region, if we take economic development potential to mean growth in existing regional industries, rather than bringing new industries to the region.

Moreover, the process is equally applicable at the project or network level. We have seen an application at the project level. Application at the network level can be undertaken by using the Urban Transportation Planning System (UTPS) model to provide total vehicle-miles of travel, congested vehicle-miles traveled and vehicle-hours of delay for the entire road network. The UTPS model would be run for the conditions of before and after the improvement, and the resulting differences in transportation data would be used as input to REIMHS. Over 150 MPOs already have the UTPS and can use its output to fashion a network application of REIMHS.

Applying REIMHS at the network level with actual project data is a possible future activity, as is converting the current Lotus IA-based REIMHS to Fortran or "C." Network testing, unfortunately, cannot be efficiently done at the national level but must be done at the state or local level because access to local UTPS networks and data is lacking. Conversion of REIMHS from a discrete set of about 10 Lotus files to Fortran or "C" is a better possibility. Conversion of REIMHS to a compilable programming language may make it more efficient, more flexible, and easier to apply.

ACKNOWLEDGMENTS

We acknowledge the North Central Texas Council of Governments for its generosity in providing us with the 1986 input-output matrices of output, earnings, and employment. Without the council's generosity, it would not have been possible to illustrate a currently valid application of REIMHS.

REFERENCES

1. W. W. Leontief. Quantitative Input-Output Relations in the Economic System of the United States. *The Review of Economics and Statistics*, Aug. 1936, pp. 105–125.
2. R. W. Hooker and K. R. Potter. *The Impact of a New Interstate Highway on a Corridor: An Input-Output Analysis*. University of Wyoming, Laramie, Jan. 1971.
3. *Basic Regional Input-Output for Transportation Impact Analysis*. Regional Science Research Institute. Amherst, Mass. July 1982.
4. *Local Economic Impacts of Transportation Fuel Consumption*. U.S. Department of Transportation, Jan. 1984.
5. *Washington State Transport-Oriented Input-Output Study*. Washington State Department of Transportation, Olympia, Aug. 1987.
6. B. L. Allen, D. W. Butterfield, A. Kazakov, M. L. Kliman, A. A. Kubursi, and J. D. Welland. Measuring Economic Stimulation from Capital Investment in Transportation. Presented at 67th Annual Meeting of the Transportation Research Board, Washington, D.C., 1988.
7. C. C. Harris, Jr. *Regional Economic Effects of Alternative Highway Systems*. Ballinger Publishing Company, Cambridge, Mass., 1974.
8. *1982 Census of Transportation: Truck Inventory and Use Survey, United States*. TC82-T-52. U.S. Department of Commerce, 1986.
9. *County Business Patterns, 1985*. CBP-85-45. U.S. Department of Commerce, April 1987.
10. *Regional Multipliers: A User's Handbook for the Regional Input-Output Modeling System (RIMSII)*. U.S. Department of Commerce, May 1986.
11. *HPMS Analytical Process, Volume II, Version 2.1*. FHWA, U.S. Department of Transportation, Dec. 1987.
12. *Highway Statistics 1986*. FHWA, U.S. Department of Transportation, Oct. 1987.
13. *A Manual on User Benefit Analysis of Highway and Bus Transit Improvements—1977*. AASHTO, Washington, D.C.
14. *Economic Report of the President*. Council of Economic Advisors, U.S. Government Printing Office, Feb. 1988.
15. T. R. Miller, K. A. Reinert, and B. E. Whiting. *Alternative Approaches to Accident Cost Concepts—State of the Art*. The Granville Corporation; FHWA; U.S. Department of Transportation, Jan. 1984.
16. Effectiveness Evaluation Branch, Program Evaluation Division, *Accident Reduction Levels Which May Be Attainable from Various Safety Improvements*. FHWA, U.S. Department of Transportation, Aug. 1982.
17. *Highway Safety Performance—1985 Total Injury Accident Rates on Public Roads in the U.S.* FHWA, U.S. Department of Transportation, May 1987.
18. *Accident Facts—1986 Addition*. National Safety Council, Chicago, Ill., 1986.
19. R. Gorman. *Analysis of Employment Statistics Field Survey to Determine Employment Impacts of the Surface Transportation Assistance Act (STAA) of 1982*. Final Report. FHWA, U.S. Department of Transportation, April 1985.

This paper does not necessarily reflect the views or policy of the FHWA but, rather, the views of the authors. Any errors of fact, calculation, or otherwise are the sole responsibility of the authors.

Publication of this paper sponsored by Committee on Application of Economic Analysis to Transportation Problems.

Legal Aspects of Competitive Construction Market Behavior—An Assessment in Support of VDOT's Antitrust Monitoring and Detection Effort

GARY R. ALLEN AND DONALD CULKIN

In this paper is presented part of the first phase of an effort in support of the Virginia Department of Transportation's (VDOT's) recently created Antitrust Monitoring and Detection Unit within the Construction Division. Provided are background on the legal aspects of anticompetitive market behavior and the recent experience with bid rigging in the construction industry. This paper is a companion to a paper in this Record by Allen and Mills, *An Economic Framework for Understanding Collusive Market Behavior*. The purpose of the work is to provide a framework for empirical studies of highway construction markets. The second-phase work will also support VDOT in its evaluation of collusion detection models, the ultimate goal of which is to establish a comprehensive antitrust monitoring and detection system for use by the Construction Division of VDOT. This report has three sections. The first describes major aspects of antitrust law that affect the highway construction industry. The second section is a summary of recent experience with bid rigging. The final section presents a number of proposals for hindering collusive behavior and detecting antitrust violations.

National experience in the early 1980s showed that collusive activity among bidders on highway projects can present serious barriers to an effective construction program.

The large number of highway projects Virginia has planned for the next decade will pressure the construction industry to expand rapidly. It is, therefore, particularly important that the Virginia Department of Transportation (VDOT) develop and implement effective methods to ensure competitive bidding. As part of such an effort, VDOT established a small unit within the construction division dedicated solely to bid monitoring and collusion detection. In addition, the Virginia Transportation Research Council (VTRC) has undertaken a program of applied research in support of that effort.

PURPOSE AND SCOPE

The authors of this paper present part of the research from the first phase of that supportive effort by providing background on the legal aspects of anticompetitive market behavior, as well as recent experience with bid rigging in the construction industry. The paper is a companion to a paper in this Record by Allen and Mills, *An Economic Framework for Understanding Collusive Market Behavior*. The purpose of the work is to provide a framework for a second phase, which will be an empirical study of the highway construction industry in Virginia. In addition, the second-phase work will support VDOT in its evaluation of collusion detection models, the ultimate goal of which is to establish a comprehensive antitrust monitoring and detection system for use by the construction division of VDOT.

This paper has three sections. The first describes major aspects of antitrust law as they affect the highway construction industry. The second section consists of a summary of recent experience with bid rigging. The final section presents a number of proposals for hindering collusive behavior and detecting antitrust violations.

Virginia Transportation Research Council, P.O. Box 3817 University Station, Charlottesville, Va. 22903.

LEGAL ASPECTS OF ANTICOMPETITIVE BEHAVIOR

Background

Economic inquiry is useful for understanding the causes and effects of anticompetitive behavior, whereas the legal system is concerned with providing the proper incentives to deter such behavior and the remedies for those injured by it. This section is an overview of federal antitrust law and its application to the highway construction industry.

The most significant antitrust provision is the Sherman Act of 1890. (15 U.S.C. §§ 1-7 [1973 & Supp. 1988]). Section 1 of the act is of primary importance to the highway construction bidding process and, in general terms, prohibits concerted action in restraint of trade. An obvious example of a Section 1 violation is a conspiracy among contractors to rig bids.

In addition to Section 1, the substantive federal antitrust statutes include Section 2 of the Sherman Act (15 U.S.C. 2 [Supp. 1988]), the Clayton Act of 1914 (15 U.S.C. §§ 12-27 [1973 & Supp. 1988]), and the Federal Trade Commission Act of 1914 (15 U.S.C. §§ 41-44 [1973 & Supp. 1988]). Section 2 of the Sherman Act prohibits the restriction of competition through monopolization or attempted monopolization. The Clayton Act of 1914 was intended to fill loopholes in the broad wording of Section 2 and to deal with incipient threats to competition that Section 2 may not reach. (*United States v. Penn-Olin Chemical Co.*, 378 U.S. 158 [1964]). The Federal Trade Commission Act is a sweeping provision that grants jurisdiction to the Federal Trade Commission to deal with a broad range of unfair methods of competition. A discussion of the applicability of these statutes to the highway construction industry is provided in the sections that follow.

The wording of the antitrust laws is broad and does not provide much guidance for their application to specific business practices. The Sherman Act is particularly vague and authorizes civil remedies and criminal penalties with brief phrases that define both the prescribed conduct and the jurisdictional reach in the most general of terms. (See *United States v. United States Gypsum Co.*, 438 U.S. 422 [1978]). The legislative history shows that the legislators recognized that the courts would have a significant role in shaping the scope of the act. However, after nearly a century of judicial elaboration on the antitrust statutes, clear rules for applying the laws have not been developed, and "open-ended and fact-specific standards" continue to be applied to determine liability. (Id., at 438).

Restraints of Trade: Section 1 of the Sherman Act

In 1890, Congress passed the Sherman Act, which according to the Supreme Court was intended to be a codification of common law principles concerning restraints of trade. (*Standard Oil Co. v. United States*, 221 U.S. 1, 60 [1911]). Section 1 of the act states that "[e]very contract, combination in the form of trust or otherwise, or conspiracy, in restraint of trade or commerce among the several states, or with foreign nations, is declared to be illegal." (15 U.S.C. 1). The Supreme Court has made it clear that the clear intent of the Act is to protect competition in the marketplace, notwithstanding economic theories to the contrary. (*Northern Pacific Railway v. United States*, 356 U.S. 14 [1958]).

Three elements must be proven to establish a Section 1 violation: (a) a contract, combination, or conspiracy among two or more separate entities, (b) an unreasonable restraint of trade, and (c) an agreement that is in or affects interstate or foreign commerce.

Contract, Combination, or Conspiracy

The crux of a Section 1 violation is concerted action that restrains trade. The terms "contract," "combination," and "conspiracy" have been given slightly different meanings under Section 1 than the meanings used in other areas of the law. (*Pearl Brewing Co. v. Anheuser-Busch, Inc.*, 339 F. Supp. 945, 950 [1972]). Although each of the terms has slightly different definitions, the essential element of each is "conscious commitment to a common scheme or to some type of joint action." (Id. at 951). The statute does not cover independent behavior by separate entities no matter how anticompetitive the behavior. (*Modern Home Institute, Inc. v. Hartford Accident and Indemnity Co.*, 513 F.2d 102, 108 [2d Cir. 1975]).

In cases involving intraenterprise agreements, the issue is whether different parts of the same firm are capable of conspiring. In *Copperweld Corp. v. Independence Tube Corp.* (467 U.S. 752 [1984]), the Supreme Court held that a corporation and its wholly owned subsidiary were incapable of conspiring because they had common economic purposes.

Since *Copperweld*, the law is not clear as to the ability of a parent company to conspire with a subsidiary it does not completely own. In addition, courts' decisions are split as to whether affiliates of a common parent company are capable of conspiring. (See *Antitrust Law Developments* [2d ed.], First Supplement 1983–1986 at 6). The relevant inquiry in any such case is, of course, whether the "collaborators" had independent economic interests that would be considered in competition in the absence of an agreement. If competition would not be found even in the absence of agreement, Section 1 is not applicable.

Proving Restraints Are Unreasonable

The courts use two types of analysis to determine whether a restraint is unreasonable: the rule of reason and the per se rule. The rule of reason is the prevailing standard of analysis under Section 1. (*Continental T.V., Inc. v. GTE Sylvania*, 433 U.S. 36, 49 [1977]). This method is used when the challenged restraint is such that its effect on competition cannot be evaluated without considering "the facts peculiar to the business, the history of the restraint, and the reasons why it was imposed." (*National Society of Professional Engineers v. United States*, 435 U.S. 679, 692 [1978]).

Per se analysis is appropriate when the challenged activity is inherently anticompetitive and when the inquiry into the harmfulness of the activity would be difficult and uncertain.

Rule of Reason

The courts generally use a three-step analysis in rule of reason cases (Areeda, *Antitrust Law*, ¶ 1502 [1986]). First, the plaintiff must show that competition in a specified market has been restrained by the collaborators' activities. Once this threshold has been reached, the burden shifts to the collaborators to show that they imposed the restraint with legitimate objectives in mind—in other words, that the restraint has significant redeeming virtues. If the collaborators meet this burden, the plaintiff can still prevail by showing that the legitimate objectives could have been achieved with fewer anticompetitive effects. By this point, most cases will have been resolved one way or the other. If not, the procompetitive effects are weighed against the anticompetitive effects to determine whether the restraint is, on balance, reasonable. (See also, *Chicago Board of Trade v. United States*, 246 U.S. 231, 238 [1918]).

Per Se Rule

The per se rule condemns certain classes of activities that "because of their pernicious effect on competition and lack of any redeeming virtue, are conclusively presumed to be unreasonable and therefore illegal without inquiry as to the precise harm they have caused or the business excuse for their use" (*Northern Pacific Railway*, 356 U.S. at 4 [1958]). The categories of practices that have been held to be per se violations of Section 1 include horizontal price fixing (*United States v. Socony-Vacuum Oil Co.*, 310 U.S. 150 [1940]); division of markets (*United States v. Addyston Pipe and Steel Co.*, 85 F. 271 [6th Cir. 1898], *affirmed* 175 U.S. 211 [1899]); and bid rigging (*United States v. Portsmouth Paving Corp.*, 694 F.2d 312 [4th Cir. 1982]).

Because the per se rule prohibits entire classes of behavior without analysis of the nature and extent of the resulting harm, it presents the possibility of deterring procompetitive behavior unless its application is limited precisely to those practices that have been shown to be "plainly" or "manifestly" anticompetitive. (*Broadcast Music, Inc. v. Columbia Broadcasting System, Inc.*, 441 U.S. 1, 8 [1979]).

Even though the per se rule may prohibit some commercial practices that have no harmful effect, it is appropriate because such practices are neither common nor important enough to justify the time and expense of trying to identify them. Moreover, the per se rule is a strong deterrent because the prohibited activities are defined with certainty. Nevertheless, it should be noted that the per se rule and the rule of reason are variations on a single theme: the search for competitive effects. Recent cases exhibit an emphasis on the parallel nature of these two modes of analysis. For example, in *NCAA v. Board of Regents*, 104 S. Ct. 2948 (1984), the Supreme Court refused to hold that a horizontal restraint on output is a per se violation of Section 1. The Court applied a rule of reason analysis, noting that "there is, after all, no bright line separating per se analysis from the rule of reason." (Id. at 2962 n.626). Because the restraints were deemed necessary to the marketing of the product (televised college football games), the defendants were allowed to present evidence in justification of the restraints. Whether *NCAA* signals a further convergence of the per se rule with the rule of reason is not clear. (See *Antitrust Law Developments*, First Supplement, pp. 15–16).

Interstate Commerce

The third element of a Sherman Act violation is that the challenged restraint be in or affect interstate or foreign commerce. (See *Goldfarb v. Virginia*, 421 U.S. 773 [1975] ["in commerce"] and *McLain v. Real Estate Board*, 444 U.S. 232 [1980] ["affecting commerce"]). This element derives from the Commerce Clause of the United States Constitution and is necessary to obtain federal subject-matter jurisdiction over a particular case.

Most antitrust cases in the highway construction industry involve paving companies that are local businesses. For this reason, most highway bid rigging cases proceed under the "affecting commerce" theory. However, because the indictments (or, in civil cases, the complaints) generally allege facts that purportedly would support both jurisdictional theories, it is often not clear from the cases which theory is being used or whether both tests are satisfied. (See, e.g., *United States v. Metropolitan Enterprises, Inc.*, 728 F.2d 444 [10th Cir. 1984]). At any rate, the key "analytical focus continues to be on the nexus, assessed in practical terms, between interstate commerce and the challenged activity." (*Crane v. Intermountain Health Care*, 637 F.2d 715, 724 [10th Cir. 1981]).

Monopolization: Section 2 of the Sherman Act

Section 2 of the Sherman Act provides in part that "[e]very person who shall monopolize, or attempt to monopolize, or combine or conspire with any other person or persons, to monopolize any part of the trade or commerce among the several states, or with foreign nations, shall be deemed guilty of a felony. . . ." (15 U.S.C. 2).

Section 1 of the Sherman Act is concerned with concerted action in restraint of trade by more than one person or firm, whereas Section 2 is intended to prevent anticompetitive behavior by the single dominant firm with the market power to control prices or to limit competition. Section 2 prohibits monopolization and attempted monopolization. Two elements are necessary to establish a monopolization offense: "(1) the possession of monopoly power in the relevant market, and (2) willful acquisition or maintenance of that power as distinguished from growth or development as a consequence of a superior product, business acumen, or historic accident." (*United States v. Grinnel Corp.*, 384 U.S. 563 [1966]).

A notable aspect of Section 2 is the use of the word "monopolize" rather than "monopoly." The distinction is important because Section 2 does not prohibit the possession of monopoly power; rather, the statute is designed to prevent firms from engaging in activities intended to smother competition. Section 2 also prohibits a dominant firm from wielding its monopoly power to unfair advantage, even when its monopoly power was gained through legitimate means. (*Berkey Photo, Inc. v. Eastman Kodak Company*, 603 F.2d 263 [2d Cir. 1979]).

The distinction between "monopolize" and "monopoly" underscores the fundamental tension—one might almost say the paradox—that is near the heart of Section 2. On the one hand, the goal of Section 2 is to prevent a stifling of competition by a dominant firm. On the other hand, the intent of the statute is also to encourage firms to use their expertise to improve their competitive position through innovation and hard work. Distinguishing between aggressively competitive behavior and the type of behavior prohibited by Section 2 is often difficult.

Monopolization cases draw heavily on the sophisticated economic theories of industrial organization; however, a thorough discussion of these theories and their application to the law of monopolization is beyond the scope of this paper. The purpose here is to provide a brief introduction to the legal system's approach to monopoly power.

Mergers: Section 7 of the Clayton Act

Section 7 of the Clayton Act states "[t]hat no person engaged in commerce" shall acquire the assets or stock of another person or firm where "the effect of such acquisition may be substantially to lessen competition, or to tend to create a monopoly." (15 U.S.C. 18). "The grand design of the original Section, as to stock acquisitions, as well as the Celler-Kefauver Amendment, as to the acquisition of assets, was to arrest incipient threats to competition which the Sherman Act did not reach." (*United States v. Penn-Olin Chemical Co.*, 378 U.S. 158, 170-71 [1964]). The wording of the statute and subsequent judicial interpretations make it clear that the Clayton Act is concerned with activities that present a reasonable likelihood of a substantial lessening of competition or that may have a tendency toward monopoly. Because the statute is designed to reach incipient threats, the standard of liability is lower than under the Sherman Act.

As with Section 2 of the Sherman Act, evaluation of anticompetitive effects under Section 7 of the Clayton Act requires an economic analysis of the challenged practice in the context of the relevant market. Such an analysis is even more difficult under Section 7 than under the Sherman Act because although the Sherman Act deals with behavior with demonstrated anticompetitive impact or that is blatantly anticompetitive (e.g., predatory pricing), Section 7 requires a prediction of the effect of the challenged practice. "Such a prediction is sound only if based upon a firm understanding of the structure of the relevant market; yet the relevant economic data are both complex and elusive." (*United States v. Philadelphia National Bank*, 374 U.S. 321, 362 [1963]).

APPLICATION OF THE ANTITRUST LAWS TO SPECIFIC BUSINESS PRACTICES

This section presents a discussion of the application of the antitrust laws to specific business practices of relevance to the construction industry. The list of practices is not intended to be comprehensive but rather to illustrate certain principles and help the reader understand how the laws relate to conduct that may have anticompetitive effects. An understanding of the basic principles will help the reader to identify patterns and practices that may indicate antitrust violations.

As a general matter, it is important to categorize correctly a given restraint as horizontal or vertical. Correct categorization is important because horizontal restraints are more likely to be held per se unlawful than vertical restraints. (*White Motor Co. v. United States*, 372 U.S. 253, 263 [1963]). Vertical restraints often offer procompetitive benefits that must be weighed under a rule of reason analysis (*Continental T.V., Inc. v. GTE Sylvania, Inc.*, 433 U.S. 36 [1977]), whereas arrangements among competitors in horizontal relationships are frequently "naked restraints of trade with no purpose except stifling competition." (*White Motor Co.*, 372 U.S. at 263). The anticompetitive practices of direct relevance to the construction project bidding process generally involve horizontal restraints. This section discusses the application of antitrust laws under such conditions.

Price Fixing

Protection against conspiratorial price fixing "is an object of special solicitude under the antitrust laws" (*United States v. General Motors Corp.*, 382 U.S. 127, 148 [1966]), and the Supreme Court has repeatedly found to be per se unlawful those arrangements that either directly or indirectly restrain price competition. (See, e.g., *United States v. Trenton Potteries Co.*, 273 U.S. 392 [1927][Direct price fixing] and *United States v. Socony-Vacuum Oil Co.*, 310 U.S. 150 [1940][Indirect price fixing]).

It is important to note that although conspiratorial price fixing has generally been condemned by the courts, not all restraints on price competition are per se unlawful or even unreasonable restraints under the Sherman Act. The Supreme Court has noted that in some cases, horizontal restraints on price competition are necessary if the product whose distribution is restrained is to be offered at all. (*NCAA v. Board of Regents of the University of Oklahoma*, 104 S. Ct. 2498). In *NCAA*, the Court decided that restraints on the type of television rights offered by member universities and on the prices to be charged for those rights did not constitute a per se violation of the Sherman Act. The particular restraints imposed by the NCAA were analyzed under the rule of reason and found to be unlawful, but the Court recognized that some restraints may be needed if college sports are to be televised at all.

Cases such as *NCAA*, in which price fixing arrangements were analyzed under the rule of reason rather than the per se rule, are exceptional. The use of rule of reason analysis in price fixing is limited to certain industries in which some sort of price restraint is needed if the particular product or service is to be offered in a competitive environment. The per se rule is the principal mode of analysis in which the challenged restraint has either the purpose or effect of limiting price competition. (ABA Antitrust Section, *Antitrust Law Developments* [2d ed. 1984], p. 30).

Market Allocation

Market division among competitors was held to be a violation of the Sherman Act in *Addyston Steel & Pipe*, 85 F. 271 (6th Cir. 1898), *modified and aff'd*, 175 U.S. 211 (1899). In the years following *Addyston*, the Supreme Court stated repeatedly that market division was per se unlawful, but those cases always involved market division accompanied by price fixing, by significant market power on the part of the defendants, or by both. It was not until 1972 that the Supreme Court made clear that market division is a per se violation of Section 1, whether or not accompanied by price fixing and whether or not the conspirators have the market power needed to have a significant impact on the relevant market. (*United States v. Topco Associates, Inc.*, 405 U.S. 593 [1972]).

Topco was the most significant in that the opinion recognized that the courts are not competent to determine whether a restriction of competition in one sector of the market is justified because it is outweighed by an enhancement of competition in another sector. The fact that an arrangement improved competition by facilitating entry into a particular market or by providing other economies of scale is irrelevant if the arrangement had the effect of precluding firms from competing for the same market.

Defendants in market allocation cases will often try to avoid per se categorization by describing the market allocation scheme as something other than territorial allocation. For example, in *COMPACT v. Metropolitan Government of Nashville & Davidson City*, 594 F. Supp. 1567 (M.D. Tenn. 1984), a group of architectural firms had agreed to refrain from competing against each other on certain types of contracts offered by the city government. The designated city contracts were to be allocated to a joint venture comprised of the participating firms. The conspirators described the scheme as "subject matter" allocation, but the court stated that the firms could not avoid the antitrust laws through an amorphous definition and, regardless of the semantic characterization, a horizontal allocation of any element of the market for which businessmen or professionals compete represents a per se violation of the Sherman Act.

Joint Ventures

Treatment of joint ventures under the antitrust laws is complicated by the lack of a clear definition of "joint ventures" and by a lack of consensus regarding the anticompetitive effects of joint ventures. (See Brodley, *Joint Ventures and Antitrust Policy, 95 Harv. L. Rev.* 1521 [1982]).

Joint ventures take a variety of forms. Some are created for a single project such as when two contractors combine to submit a joint bid on a particular highway project. Others are long-term arrangements for the development, production, and marketing of products or services, but they present difficult problems of analysis because they often offer both procompetitive and anticompetitive effects. Joint ventures often enhance competition by enabling the participants to combine resources to develop new technologies or enter new markets. Joint ventures also have the potential for hindering competition. By any definition, a joint venture is formed by two or more separate business entities who would otherwise be acting independently and often in competition with each other. By combining to form a joint venture, the parent firms partially unite their economic interest, ensuring that competition between them is reduced or eliminated.

Joint venture arrangements of relevance to the construction industry are subject to challenge under both Section 1 of the Sherman Act and Section 7 of the Clayton Act. However, joint ventures are traditionally analyzed under the rule of reason. The analysis focuses on the structure of the joint venture, the conduct and intent of the participants, and the resulting impact on competition. The variables of relevance include the size of the joint venture and the market share held by the participants, the contributions of each joint venturer and the benefits received, the likelihood that any of the individual companies would have the capability or inclination to undertake a similar project in the absence of the joint venture, the nature of any ancillary restraints imposed by the joint venture agreement, and the reasonableness of those restraints.

While rule of reason is the prevailing mode of analysis in joint venture cases, the courts often apply the per se rule if the venture is found to have elements that fall within the categories of restraint that have been held per se unlawful. A joint venture is more likely to be a per se violation if the individual participants are restricted from making independent marketing and production decisions. (See, e.g., *COMPACT v. Metropolitan Government of Nashville and Davidson City*, 592 F. Supp. 1567 [M.D. Tenn. 1984]).

Bid Rigging

The term "bid rigging" refers to any "agreement between competitors pursuant to which contract offers are to be submitted to or withheld from a third party" (*United States v. Portsmouth Paving*, 694 F.2d 312, 325 [4th Cir. 1982]). Such an agreement is per se violative of Section 1 of the Sherman Act. Bid rigging schemes may involve price fixing, market allocation, or a combination of these and other acts, but the common element of all bid rigging schemes is that the element of competition is removed from the bidding process. By conspiring with competitors, a bidder can be assured that he or she will not be underbid. Because price is the only criterion for choosing among qualified contractors on government-funded projects, the bid rigger is assured of getting the contract even when he or she charges supracompetitive prices.

Following is a description of some practices that have been condemned by courts as bid rigging. The list is not exhaustive because the design of bid rigging schemes is limited only by the imagination of the participants. The important thing to remember is that if an arrangement among competitors gives a bidder the knowledge that he or she can inflate his or her bid above competitive levels and still be low bidder, that arrangement will constitute bid rigging and will be a per se violation of antitrust laws. (See, e.g., *United States v. Brinkley and Sons Construction Co.*, 1986-1 Trade Cases CCH, 66,963 [4th Cir. 1986]). Also, any practice, such as complementary bidding, that makes uncompetitive bidding easier or more effective is probably a per se violation.

Working Out the Job

"Working out" a job is probably the most basic form of bid rigging. To work out a job, a contractor determines who his or her likely competitors are on a particular job and then finds a way of either convincing them not to underbid him or her or to give him or her something in return for not bidding against them. (*United States v. Ashland-Warren, Inc.*, 507 F. Supp. 433, 438 [M.D. Tenn. 1982]). State bidding procedures facilitate this practice by publishing a list of the contractors who "pulled" or obtained proposals for a given job. This list tells the contractor who his potential competitors are. If the contractor is unable to work out the job, he will normally notify the previously contacted competitors that the bid rigging scheme is off and that the job will be "bid hard" or "bid the hard way." In some cases, a contractor will work out a deal with the firms he or she feels are his or her toughest competitors and will then attempt to underbid the other potential bidders. (See, e.g., *United States v. Metropolitan Enterprises, Inc.*, 728 F.2d 444 [10th Cir. 1984]). Such a scheme would have an advantage in that the conspiracy would involve a smaller, more manageable group, which would promote reliability among the participants and make detection of the collusion more difficult.

Bid riggers use various methods to persuade other competitors not to "bid the hard way." These methods may include payoffs (*United States v. Young Brothers, Inc.*, 728 F.2d 682 [5th Cir. 1984]), agreements to grant subcontracts (*Metropolitan Enterprises*, 728 F. 2d 444), or promises not to compete on future jobs (*Ashland-Warren*, 507 F. Supp. at 439). Contractors may also work out a job by calling in favors owed to them by competitors. Such entitlements, referred to as "having a marker out," are indefinite in nature and are often 2 or 3 years in coming. Bid rigging schemes may also involve trading jobs on the same bid letting. The trading may be job-for-job, tonnage-for-tonnage, or dollar-for-dollar.

Bid Rotation

Although many bid rigging schemes involve working out specific jobs, bid rotation conspiracies are continuing arrangements in which the conspirators take turns being low bidder. The method of selecting the low bidder will vary from one bid rotation scheme to another, and many such schemes attempt to equalize the dollar amount of work among the participants, whereas others may be set up to proportion the work according to the size of the various firms involved in the conspiracy.

Market Allocation

Highway construction markets are often allocated by territory (See, e.g., *United States v. Koppers Co., Inc.*, 1981-1 Trade Cases [CCH] ¶ 64,134 [2d Cir. 1980]). The defendants in *Koppers* were two surface-treatment contractors who engaged in a conspiracy to allocate territories in Connecticut. One of the contractors had its facilities in the eastern part of the state, and the other was based in the western part of the state. The defendants agreed that each would always be low bidder in its region. To accomplish this end, the conspirators developed a system that involved communicating their base costs to the other. Because the two firms were based at opposite ends of the state, the use of common base prices allowed each to be low bidder in its region because it would have lower transportation costs. The scheme also involved the submission of artificially high complementary bids by the "losing" bidder on each job in order to convince state procurement officials that the job had been bid competitively.

United States v. Portsmouth Paving Corp., 694 F.2d 312 (4th Cir. 1982), involved a bid rigging scheme that combined market allocation with other bid rigging techniques. The defendants in *Portsmouth Paving* engaged in a conspiracy to allocate the paving markets in the Tidewater region in Virginia. The conspiracy involved paving work in Virginia Beach, Norfolk, Portsmouth, and Chesapeake whereby the Virginia Beach work would be done by the Virginia Beach contractors, and the work in the other three cities would be done by the other conspirators. Within these allocated markets, the conspirators would use various methods to distribute the contracts among the firms.

The government argued in *Portsmouth Paving* that the goal of the market allocation scheme was to prevent the occasional outbreak of competitive bidding in one market from affecting the prices in the other markets. Without such protection, low prices in one region would lead to lower prices in adjacent regions and the resulting "domino effect" would eventually affect even the most distant member of the conspiracy.

The defendants argued that such a domino effect would not occur because it was not economically feasible for contractors in Portsmouth, for example, to compete against the Virginia Beach firms for work in Virginia Beach because of the increased cost of trying to transport hot asphalt from Portsmouth to Virginia Beach. Therefore, even if prices in Portsmouth were to decrease, the defendants argued, prices in Virginia Beach would not be affected because the Portsmouth contractors were not in competition with the Virginia Beach contractors. The court, however, rejected the defendant's argument and found that the evidence supported a finding of market allocation.

Subcontracts

Although using competitors as subcontractors is not illegal per se, it is often necessary to consider whether such subcontracts are the result of collusion. In *Metropolitan Enterprises*, a contractor convinced a competitor not to bid against him on a package of construction contracts that were simultaneously let for bids by the state of Oklahoma. Oklahoma procurement regulations allowed the use of "tie bidding," which means that contractors had the choice of either bidding individual sections of highway work or to try bidding low on a combination of multiple sections. Broce Construction Company convinced Metropolitan Enterprises not to bid competitively for any of the work by agreeing to subcontract to Metropolitan one of the sections included in its tie bid. The court held that such a subcontract is not illegal per se but that a jury could decide whether the subcontract was a product of conspiracy, in which case the arrangement would violate Section 1 of the Sherman Act.

Complementary Bidding

Complementary bidding is the practice of submitting artificially high bids with the knowledge that someone else will be the low bidder. The purpose of complementary bidding is to convince the procurement officials that a job has been competitively bid as required by state procurement regulations. By creating the illusion of competition, the complementary bidders can ensure that the contract will be awarded to the low bidder chosen by the conspiracy. Conspirators will "even feign disappointment at bid openings when their bids, which they knew to be high, were unsuccessful." (Brief for Appellant United States of America, *United States v. Portsmouth Paving Corp.*, 694 F.2d 312 [4th Cir. 1982]).

Contractors will provide incentives to competitors to submit complementary bids by offering payoffs, promises of subcontracts, or other return favors. Sometimes a firm will receive complementary bids in its favor automatically because, for example, it has its asphalt plant closest to the job site. (*Ashland-Warren, Inc.*, 507 F. Supp. at 439 [M.D. Tenn. 1982]). Such a practice would be part of a tacit, or express, agreement that the conspiring firms would maximize profits by giving each job to the firm with the lowest cost for that job. Whatever the benefits the complementary bidder may receive in return for his or her bid, the practice is per se violative of the antitrust laws.

Request for a "Safe" Bid

In *Brinkley and Sons Construction Co.*, a contractor was convicted under Section 1 of the Sherman Act simply because he contacted a competitor and requested a "safe" number to bid in order to avoid underbidding that competitor. The contractor was convicted even though he decided not to submit a complementary bid. The court held that the request for a safe bid communicated to the competitor that he could inflate his bid without worrying that he would not be competitive. The communication of this knowledge was sufficient to constitute bid rigging and was per se violative of Section 1. (1986-1 Trade Cases CCH, at 61, 924).

Monopolistic Acts

Once a firm gains monopoly power in a given market, it can maintain that power though various acts such as predatory pricing, refusals to deal, or price discrimination. The use of such practices is prohibited by Section 2 of the Sherman Act, and attempts to gain such power through vertical or horizontal integration are subject to scrutiny under both Section 2 of the Sherman Act and Section 7 of the Clayton Act.

The case of *Arther S. Langenderfer, Inc. v. S. E. Johnson*

Co., 1984-1 Trade Cases (CCH ¶ 65,905 [6th Cir. 1984]) illustrates the application of the statutes to the highway construction industry. *Langenderfer* was a civil action between rival paving contractors in Ohio. Langenderfer accused Johnson of unlawfully acquiring monopoly power in the northwest Ohio paving market and of wielding that power to exclude competitors from the market.

S. E. Johnson Co. was established in 1929, and by 1956, when founder Sherman Johnson died, had grown to be the largest asphalt paving contractor in northwest Ohio. Johnson's successor, defendant John Kirby, embarked on an ambitious expansion program during which S. E. Johnson's operation grew from 2 quarries and 3 hot-mix plants to 7 quarries, 14 hot-mix plants, and 3 sand pits. The horizontal acquisitions eliminated much of the competition in the paving market, and the vertical acquisitions gave Johnson "a captive supply of stone and sand for its asphalt paving jobs. Furthermore, defendants became primary stone suppliers for the remaining asphalt paving competitors who did not own conveniently located quarries." (Id. at 67,864). As the size of the operation grew, so did the firm's profitability.

The crux of Langenderfer's complaint was that Johnson was excluding competition by bidding artificially low until competitors were driven out (better known as "predatory pricing"). Langenderfer claimed that the size of Johnson's company was such that he could afford to sacrifice short-term profits until competition was eliminated, at which time he could raise prices and reap monopoly profits. Langenderfer also claimed that the acquisitions through which S. E. Johnson allegedly gained monopoly power were in violation of the Clayton Act.

Langenderfer presented extensive expert testimony concerning the predatory nature of S. E. Johnson's conduct. After discussing the various economic tests the courts have applied in such cases (see, e.g., A. S. Turner, *Predatory Pricing and Related Practices under Section 2 of the Sherman Act*, 88 *Harv. L. Rev.* 697 [1975]), the court held that the evidence of predatory pricing was insufficient to constitute a monopolization or attempted monopolization under Section 2 of the Sherman Act.

The *Langenderfer* case illustrates the complexity of litigation in monopolization cases. The case also shows why predatory pricing may not be common practice. In order for such a scheme to work, two important conditions must hold: (a) the monopolist must be willing to lose money long enough to drive competitors out of the market, and (b) once monopoly power is achieved, the monopolist must be able to charge high enough prices to recoup his or her losses without attracting new competition. The relevance of monopolization doctrine to the Virginia highway construction industry is difficult to gauge without further study into the actual structure of the market, the costs of entering new markets, and so on.

RECENT BID RIGGING CASES: DETECTING AND PROVING ANTITRUST VIOLATIONS

From 1980 through 1986, the U.S. Department of Justice filed 291 indictments for Section 1 violations by highway construction contractors. (Trade Reg. Rep. [CCH], ¶ 45,070-45,086). Most of the indictments resulted in either guilty or nolo contendre pleas. The indictments were the result of the largest investigation of an industry's anticompetitive behavior in U.S. history and was reportedly instigated by a comment made by a confessed conspirator during a federal investigation of alleged bid rigging at O'Hare Airport in Chicago. (*Washington Post*, Aug. 5, 1982, at A1). During an interview with U.S. Department of Transportation investigators, the conspirator noted, "If you think this is bad, you should go to Tennessee." The investigators went to Tennessee and found numerous antitrust violations by highway contractors. This discovery led, in turn, to investigations in several other states.

Whether or not this is an accurate account of the beginning of the investigation, it illustrates the nonscientific manner in which many violations are detected. Once investigators identify a market where collusion is suspected, they will attempt to obtain direct testimony regarding the existence of an illegal agreement among competitors. Participants in conspiracies often provide such testimony pursuant to plea agreements with prosecutors. The key is to induce the first witness to testify. Once the members of the conspiracy are identified through direct testimony, obtaining guilty pleas or convictions is relatively straightforward. The methods of inducing testimony will of course vary according to the facts in each case, but an example of one method used by investigators is to interrogate suspected conspirators before a grand jury until one conspirator is caught in a lie or inconsistency. Once a witness is caught lying before the grand jury, the investigators wield considerable leverage on him.

Although many of the cases rely almost entirely on the direct testimony of witnesses, courts also consider circumstantial evidence that an illegal agreement was reached. In fact, in *United States v. Finis P. Ernest, Inc.*, 509 F.2d 1256 (7th Cir. 1975), a conviction under Section 1 was upheld solely on circumstantial evidence. The next section is a review of the types of circumstantial evidence considered relevant by the courts in bid rigging cases.

Parallel Behavior Among Competitors

When the firms comprising a particular market recognize their economic interdependence, cartel-like behavior may result, even in the absence of formal agreements to collude. This noncompetitive behavior may arise through a rational assessment of the consequences of pricing decisions taking into account the probable reaction of competitors. (Turner, *The Definition of Agreement Under the Sherman Act: Conscious Parallelism, and Refusals to Deal, 75 Harv. L. Rev. 655* [1962]). Such consciously parallel behavior is not illegal by itself, but parallel behavior, whether conscious or not, may be circumstantial evidence of an agreement, especially when viewed in conjunction with additional factors such as identical prices on sealed bids or line items of bids. (See, *Theatre Enterprises, Inc. v. Paramount Film Distributing Corp.*, 438 U.S. 537 [1954] and ABA Antitrust Section, *Antitrust Law Developments* 3 [2d ed. 1984]).

The probative value of parallel behavior varies according to the facts of a case, but the inference to be drawn from such behavior is relatively weak in oligopolistic markets in which competitors are strongly interdependent and have good information about each other's actions. On the other hand, parallel behavior gives rise to a strong inference of agreement when the market is diverse, when the products involved are nonstandard, when labor or overhead is a large component of the project cost, or when similar conditions that would normally lead to price variations among competitors are present. Identical, or very similar, prices on line items of sealed bids are one of the clearest indicators of collusion.

The Relevance of Market Definition

Market definition often plays a key role in antitrust litigation. In order to show that a challenged practice exerts an unreasonable restraint on trade or commerce, it is necessary to define the market where that trade or commerce occurs. In bid rigging cases, market definition can be used as circumstantial evidence of the existence or absence of a conspiracy. However, the value of this circumstantial evidence may be more important to the detection of collusion than to the actual litigation of cases. For this reason, the issue is not often addressed in the cases.

The issue of market definition is often raised by defendants in bid rigging cases to show that they were not in competition with their alleged coconspirators and therefore had no reason to collude with them. (See, e.g., *United States v. Portsmouth Paving Corp.*, 694 F.2d 312 [4th Cir. 1982] and *United States v. Ashland-Warren, Inc.*, 537 F. Supp. 433 [M.D. Tenn. 1982]). In *Portsmouth Paving*, the defendant attempted to present testimony by an expert witness regarding the definition of markets in the Tidewater area in Virginia. The expert testimony was intended to show that the defendant's bidding behavior was influenced by economic reality rather than by an agreement among competitors. The thrust of the expert testimony was that the market area of a paving contractor was, in large part, defined by the limited haul distance of hot asphalt. According to the defendant's expert, Portsmouth Paving almost always limited bids to the Portsmouth area because to compete outside Portsmouth, it would need to construct a new asphalt plant. This geographic limitation of bidding was not, they argued, the result of an agreement to allocate markets. The court in *Portsmouth Paving* refused to allow the testimony of the expert on the grounds that it was cumulative and would possibly be confusing to the jury. The court recognized that market areas were relevant and that the farther a contractor had to travel, the less competitive he or she would be. However, the court ruled that the argument was a common sense notion and that the jury could understand it without the aid of sophisticated economic analysis.

Market definition plays a less significant role in bid rigging cases than in other antitrust cases because it tends to show only the potential effectiveness of a bid rigging conspiracy. Because bid rigging is per se violative of federal and state antitrust laws, the government need not show that the defendants actually had the means to fix prices effectively, only that they engaged in the conspiracy. (Cf., *United States v. Socony-Vacuum Oil Co., Inc.*, 310 U.S. 150, 224 n. 59 [1940]). Another reason that market definition plays a relatively minor role in the actual litigation of bid rigging cases is that contractors may have an incentive to collude with firms with which they are not in direct competition. In *Portsmouth Paving*, the court apparently accepted the government's characterization of the "domino effect" that would occur if one market were to become competitive. The result that the bid riggers were trying to prevent, according to the government, was that low prices generated by competition in one region would cause low prices in the adjacent regions until the most remote member of the conspiracy was adversely affected. The court's opinion did not address the defendant's contention that such a domino effect would not occur because the alleged conspirators were not in competition.

An interesting aspect of the market definition arguments put forth by various defendants is the reliance placed on the limited haul distance of hot asphalt. The standard argument is that the expense of setting up new or relocated plants makes it economically infeasible to compete for work outside the firm's immediate area. In *Ashland-Warren*, a defendant's witness testified that certain types of asphalt plants could be relocated for $25,000 to $30,000 (in 1980). However, such an expense would probably not be prohibitive considering the fact that contractors would pay competitors upward of $80,000 to refrain from bidding. (See, e.g., *United States v. Allied Asphalt Paving Co.*, 451 F. Supp. 804 [1978]). If these figures have any accuracy at all, they indicate that the "limited" market areas for paving contractors may be attributable in part to the existence of well-developed job and market allocation networks as well as the physical limits on haul distance.

Trade Associations

The main purposes of trade associations are to educate and to exchange information among members of an industry. Trade associations enhance the performance of competitive markets by promoting new and better methods of conducting business. However, trade associations also provide competitors an opportunity to meet and discuss possible collusive activities. Such an exchange of information is generally considered vital to the continued success of a conspiracy (Hay, *Oligopoly, Shared Monopoly, and Antitrust Law, 67 Cornell L. Rev.* 439 [1982]). In fact, bid rigging cases will often mention the fact that the conspirator attended trade association functions at which the details of the conspiracies were worked out. (See, e.g., *United States v. Washita Construction Co.*, 789 F.2d 809 [10th Cir. 1986]). In *Washita*, the defendants had attended a cocktail party hosted by the local trade association the night before a bid letting at which negotiations were conducted concerning the allocation of jobs among the conspirators. The negotiations may have included subcontracts, promises not to compete in the future, or any other aspect that needed to be coordinated among the participants in the bid rigging scheme. Once a job was worked out, the designated low bidder would tell the complementary bidders what figure to bid above.

Trade association membership and attendance at trade association functions is considered relevant circumstantial evidence in bid rigging cases because of the opportunity for communication among conspirators, not because of any inherent tendencies of trade associations. (See, e.g., *United States v. Finis P. Ernest, Inc.*, 509 F.2d 1256 [7th Cir. 1975]).

CONCLUSIONS

The purpose of this paper was to summarize the legal aspects of competitive market behavior, provide a source document for use by highway agencies, and provide a framework for empirical study of highway construction markets.

Clearly, both legal and economic approaches to this subject are closely related, although they differ in focus. Economic inquiry focuses on the causes, effects, and characteristics of markets that exhibit anticompetitive behavior, whereas the legal system is concerned with deterring such behavior and with providing remedies for those injured by it.

The unifying theme of the two approaches is that the basic doctrines are general and that problems in the area of antitrust cannot be dealt with effectively without a thorough understanding of the specific markets and firms involved. It is clear that effective collusion detection and encouragement of competition require a thorough understanding of the construction industry. This goal can be achieved through empirical studies of markets to identify those in which competition may be enhanced and those that may be at greatest risk.

The opinions, findings, and conclusions expressed in this paper are those of the authors and not necessarily those of the sponsoring agencies.

Publication of this paper sponsored by Committee on Application of Economic Analysis to Transportation Problems.

Predicting Financial Impacts on Rural Roads of Potential Rail Line Abandonments

KENNETH L. CASAVANT AND J. C. LENZI

Private decisions by railroads to abandon rail lines are having significant impacts on public costs. Specifically, the increasing amount of rail line abandonments are exacerbating road deterioration, with resultant increase in costs of road maintenance and reconstruction. At this point the magnitude of financial impact on roads of such abandonments has been identified only in an "ex post" fashion. Information on road damage is needed by policy makers *before* such abandonment. In this paper, a procedure is developed that can be used to predict such road damage before its occurrence. A conceptual model is presented and then applied in a case study in Washington State. The model was slightly modified, based on the case study experience, and was found to achieve its purpose in an efficient fashion. It is suggested that similar procedures be developed to also predict safety, pollution, and economic development impacts of rail line abandonment.

The economic development of the state of Washington and the United States was caused by and based on the development of a multimodal transportation system. This system required massive investment but produced efficient movement of commodities. The access to resources for growth, country expansion, and consolidation depended heavily on these efficient transportation linkages. Railroads were, and continue to be, an efficient contributor to the development of the nation's dominant industries: agriculture, forest products, and industrial products. An important contribution to the efficiency of the overall transportation system was the competition between and among the modes of transportation.

The modes are still competitive, but this competition is affected by recent changes occurring in the railroad system. Today many changing conditions in the United States are resulting in the abandonment of rail branch lines. Before the 1980s, the railroad system was under tight economic regulation, even while experiencing low or negative rates of return on investment, undergoing mergers, and filing bankruptcies. Legislation in the late 1970s and early 1980s partially deregulated the railroad industry, which allowed flexibility in railroad decision making and substantially eased the process of rail line abandonment. The 4-R Act, legislation enacted in 1976, "established the principle that a railroad cannot be forced to provide service on which it loses money" (and costs in this case are specified to include a return on investment). Provisions of the Staggers Act of 1980 reaffirmed the liberalization of rail abandonments in two ways. First, a time limit of 225 days from the date of application, including appeals, was established. Previously, the long, costly proceeding before the Interstate Commerce Commission (ICC) over abandonment was a deterrent to abandonment (*1*). Second, under Staggers it was further specified that the railroad's return on investment should include the opportunity cost of railroad capital.

K. L. Casavant, Department of Agricultural Economics, Washington State University, Pullman, Wash. 99164-6210. J. C. Lenzi, Transportation Planning Office, Washington State Department of Transportation, Olympia, Wash. 98504.

These changes have facilitated the abandonment of rail branch lines. Rail abandonment, common in the Midwest since the 1950s, has come to the state of Washington in full force. Over the past 10 years, the extent of the rail network nationally and in Washington has shrunk considerably. Since 1980, 63 rail line segments constituting over 1,100 mi of track have been abandoned in Washington. This abandonment is directly affecting the highway mode of transportation because it forces more and more shippers to use trucks to carry grain and other commodities to more distant rail lines or river ports.

Discussions with Burlington Northern and Union Pacific officials suggest more requests for abandonment are forthcoming. Recent filings in Washington indicate an additional 209 mi are under consideration for abandonment in 3 years (Category I on the Systems Diagram Maps). Moreover, a recent study of the Palouse Empire Region's rail system by the Idaho and Washington Departments of Transportation found the entire 540-mi system to be a likely candidate for abandonment in the future (*2*). Further, a current study by Wilbur Smith Associates for the Rail Development Commission of Washington State found that 26 lines, totaling 1,098 mi or 31 percent of the state's system, are potential abandonment candidates (*3*). Thus, the impacts of such abandonments may be increasing in magnitude in the future.

The impacts of abandonment vary in magnitude as well as in who is affected. The most immediately discernible impact is the transportation costs faced by the shippers undergoing a rail line abandonment. Associated impacts concern the loss of quality of service (flexibility) caused by rail line abandonment. Seasonal movements over roads constrained with weight limits or even closures could result in lost market opportunities. Further, the loss of the competitive environment surrounding rail and truck modes has caused rates to move toward or above the cost of service. Loss of such competition may upset the negotiating balance between shipper and remaining carrier. In most instances of rail line abandonment, the total demand for transport is quite inelastic (especially in rural agricultural areas), and the net price to producers simply decreases. Other impacts could be loss of employment in industries or firms forced to close or relocate, energy consumption increases, safety, economic development, and so on.

An important impact of the abandonment of a rail line is the damage to roads caused by the traffic shift. Such traffic shifts cause increases in costs of maintenance and reconstruction, costs borne by the public but caused by private decisions. These costs traditionally have been neither available nor quantified before an abandonment and, hence, are not specifically considered by the ICC in granting a petition to abandon. However, in the abandonment proceeding for the line from Rosalia to Spring Valley, Washington, abandonment was temporarily restrained by describing potential impacts on local roads that could result from abandonment. However, because of a lack of specific financial detail on these impacts, the line was later approved for abandonment.

Several studies have provided estimates of impact of past rail line abandonment on roads—both county and state highways—in Washington. A preliminary examination of impacts on state highways found that rail line abandonment in general has only marginal effect but is creating "pockets of potential problems" (*4*). A subsequent examination of impacts on county roads found rail line abandonment had caused $5 million and $6 million of damage to roads in Lincoln and Spokane counties, respectively (*5*). The total estimated financial need to repair roads was about $1.5 billion, for the 10-county study area in eastern Washington (approximately $400 million related directly to rail line abandonment).

However, the central theme of these findings, and the overall problem, is that the potential magnitude of impact—physical and financial—on nearby rural roads resulting from abandoning a line segment has not been established. These studies have been ex post facto and a process is needed to predict and estimate the size of such impacts so policy makers, planners, and local and state government officials can adequately prepare for (and defend against) rail line abandonment, as well as develop financing to offset damages.

OBJECTIVES

The authors' purpose in this paper is to report on a study identifying fiscal road impacts resulting from rail line abandonment. Specific objectives are to

1. Develop a procedure to allow identification of physical location and financial magnitude of impacts on roads before an abandonment;
2. Test the conceptual procedure on a past rail line abandonment as a case study; and
3. Reformulate the procedure and outline problems and implementation.

CONCEPTUAL MODEL

The damage resulting from increased traffic is directly related to the weight and frequency of such movements. The load weight impact depends on the gross vehicle weight (GVW), per axle weight, and distance between axles (measured by the bridge formula). The general relationship between vehicle weight and damage is shown in Figure 1. Damage increases in a greater proportion than a given increase in weight; thus, overloaded grain, lumber, or freight trucks are especially hard on roads not designed for those loads. The overall impact of the increased weight and traffic volume on pavement life is shown in Figure 2. The shaded area reflects the increased

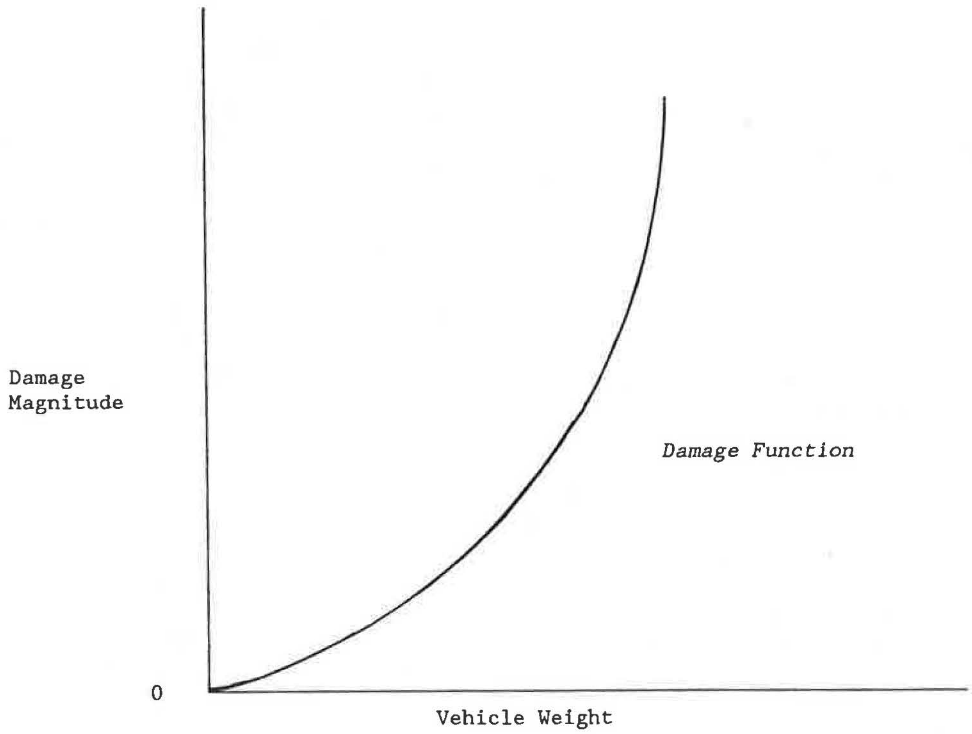


FIGURE 1 Roadway damage and vehicle weight.

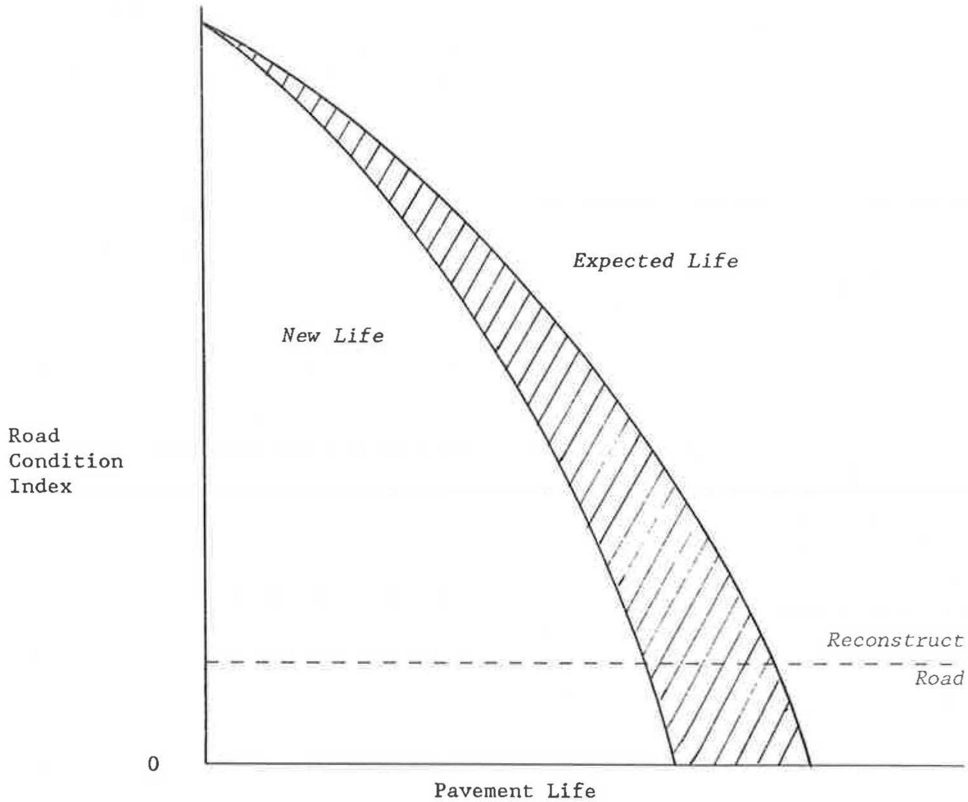


FIGURE 2 Weight and pavement life.

maintenance and reconstruction costs necessary to recapture the desired road life. It is this financial impact that the procedure outlined in this paper is designed to predict.

PROCEDURE MODEL

The general approach used to identify and predict impacts of potential abandonment is schematically presented in Figure 3. At each stage of the procedure it is necessary to identify (a) the information needed, (b) its characteristics, and (c) its source.

Stage I

The information developed at this stage is designed to identify lines that should be evaluated because of their potential or imminent abandonment. The actual number of lines included in the planner's evaluation will depend on the planning time horizon of each situation where the procedure is applied.

The near-term source to identify potential abandonments will be carrier system diagrams and those lines put in the Class I category. These obvious choices can be supplemented in an expanded time horizon by monitoring light-density lines and those that seem to have undergone deferred maintenance. Other sources of line identification are analyses such as those done in the Palouse Empire Regional Rail Study or the Wilbur Smith study for the Washington Rail Development Commission (*3*). Other states have similar ongoing "special interest studies."

Stage II

The shippers presently being served on the line under evaluation will then be identified. This inventory will include the major shippers, by both physical volume and revenue to the carrier, as well as minor shippers as time and expense permit.

Although the difficulty will increase if the number of shippers is large, the following approach appears to be reasonable. The most direct source of such information is the listing of shippers obtained from the carrier. Additional sources of more detail on potential movements on the railroad include the state departments of transportation (SDOTs), agriculture, economic development, and so on and county and city public works and planning departments. County commissioners and chambers of commerce and others who deal directly with business firms can provide general, and sometimes specific, information that is current. All of this information can be supplemented by visual inspection of the line and interviews with the shipping community.

Stage III

This stage is critical to the procedure's success. Specific information on volume of shipments and transportation characteristics of shipments is needed to determine the location and magnitude of the road impacts. Shipper volume expected on the line, if abandonment were not to occur, will be identified. Our work and interviews have determined that all shippers can, in their own estimation, determine confidently how they will move the product if abandonment occurs. That traffic

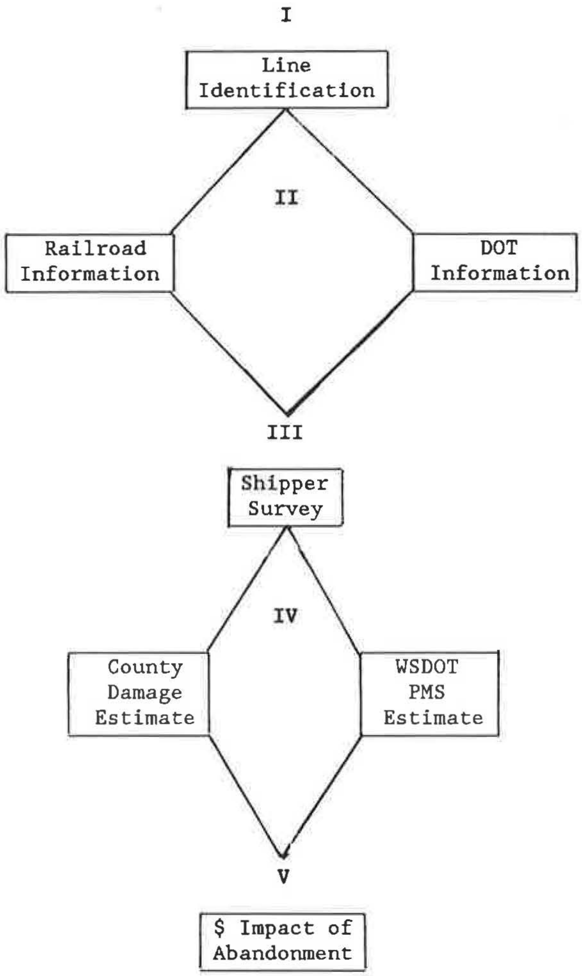


FIGURE 3 Procedures model.

pattern now, and expected after abandonment, will be determined by specific road segment and mode of movement. The seasonality of potential movement and new alternative market determination (and traffic patterns) will also be discussed. Further information collected at this stage of the procedure includes the types of vehicles to be used, respective weights, configurations, incidence of overload, and so on. Finally, the composition, condition, and jurisdiction of the affected roads will also be needed.

The principal source of this information will be interviews or surveys of shippers identified in Stage II. The condition of the specific road segments will be obtained from the SDOT Pavement Management System (PMS) or from county road engineers, as appropriate. Field inspections may be used to supplement other sources.

Stage IV

The information developed in Stage III will be presented to county engineers and SDOT engineers for evaluation of the physical impacts. Through the use of damage functions, the physical deterioration caused by the increased traffic is determined for each road segment. This information is then developed into an estimate of financial impact on each segment of road, using maintenance and reconstruction cost estimates of county and state engineers.

Stage V

Stage V is the culmination of the financial evaluation. Cost estimates, by segment, are aggregated into an estimate of total damage caused by the rail line abandonment under analysis. The aggregate figure can be segmented into a state versus county jurisdiction, a county by county basis, and so on.

CASE STUDY APPLICATION

The procedure outlined in this paper is being applied in four branch line abandonments in Washington that took place over the past 8 years (*6*). The largest abandonment, in terms of miles of track, was the Columbia River to Mansfield line in central Washington, which was the initial case study to be completed. This line had substantial documentation available because efforts to set up a short-line railroad had been initiated by the principal shipper, Central Washington Grain Growers (CWGG).

Situation

The Columbia (mile post 0.0) to Mansfield (mile post 60.7) rail line, referred to in this report as the Mansfield line, was a Burlington Northern (BN) branch line put on BN's system diagram map in late 1982. The line was authorized for abandonment January 31, 1985, by the ICC, with actual abandonment taking place in 1986. The line had been served by BN 1 day per week or on an as-requested basis. Box cars were used on this line, rather than covered hopper cars, because of the condition of the line. The line was laid with light rail, predominantly less than 90 lb/yd (42 mi of 68-lb track, 11 mi of 77-lb and 7 mi of 80-lb), and had numerous 12-degree curves and a generally descending grade from Mansfield. Few rail anchors were in place on most of the line. In 1983, BN estimated that it would cost $7.2 million to rehabilitate the line to accommodate fully loaded 100 ton hopper cars at 25 mph. This would have necessitated relaying the entire line with 115-lb rail, replacing one-half of the ties, and placing new ballast. Costs of operation, on and off branch, were $1,076,130 with revenues of $1,213,665 in 1982, yielding a net return to BN of $137,535. Granted, such an estimate is based on an accounting, rather than economic, basis but because ICC considers such data as relevant, the estimate is appropriate for this discussion.

Elimination of the rail line made the development of a viable trucking alternative necessary. This was accomplished when CWGG, the principal shipper on the line, developed a multiple-car loading facility at Coulee City (see Figure 4).

CWGG made attempts in 1982 to 1984 to form a Columbia-Mansfield Railroad, Inc., a wholly owned subsidiary. Because of the impacts of the abandonment in Douglas County, there was a local effort to aid CWGG in maintaining service. The local interest in the problem resulted in the Washington legislature establishing enabling legislation for the formation of a special rail district authority for counties. The question of

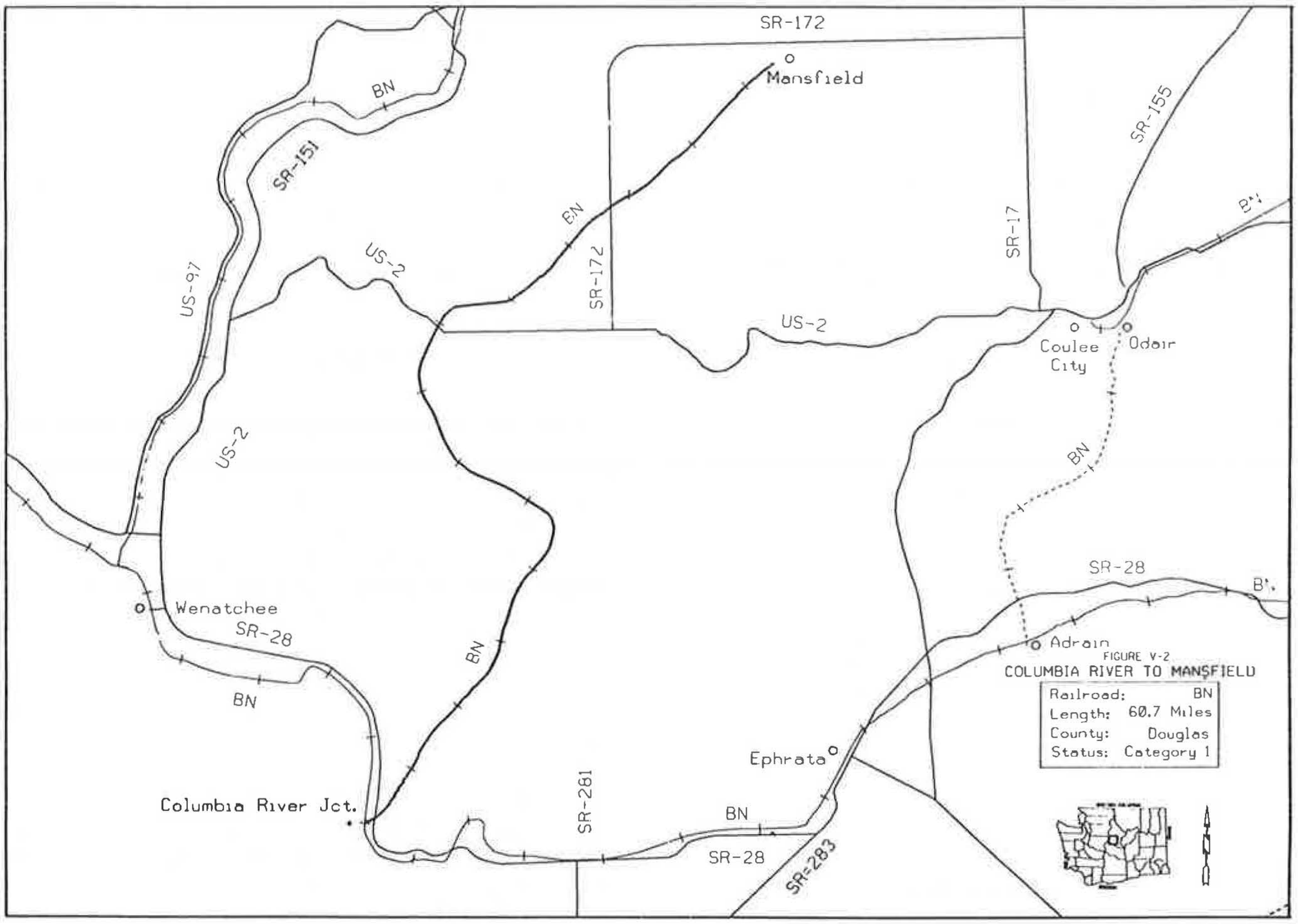


FIGURE 4 Mansfield line general area.

forming a district was put before the voters in Douglas County and rejected by a small margin of four votes in November 1983, after which the line was finally abandoned. (It is interesting that the Washington State Rail Plan identified a benefit/cost ratio of 1.71 to any funds designed to rehabilitate the line.)

Stage I

This line was obvious in its disposition toward abandonment. The line consisted of lightweight rail and numerous bridges and had only one agricultural shipper. The system diagram maps and the light density on the line (200 thousand gross ton miles per mile) were indicators of the need to examine the line. Additionally, BN worked with the shipper, warning about the problem early, and gave time for the shipper to seek alternatives to abandonment.

Stage II

Identification of shippers was straightforward. The major shipper on the line was CWGG, a large grain marketing cooperative that had houses (elevator facilities) at seven locations. No other historical or potential shippers were identified. Retail businesses relied on trucking for delivery of their inventory. No new industrial or commercial possibilities were evident.

Stage III

The traffic moving over state highways as a result of the abandonment is effectively the wheat production of Douglas County, as handled by CWGG. The wheat volume handled by CWGG averaged 5.2 million bushels from 1973 to 1987. Over the last 10 years this has decreased to 5.1 million bushels. For the purpose of road damage analysis, the 5.1 million bushels figure was used. This aggregate figure was apportioned out to the seven locations based on capacity of the elevators and historical shipping level.

The traffic pattern resulting from that origination pattern resulted in the distribution shown in Table 1. The interviews conducted with the shippers, engineers, and so on indicated that all movement is now by trucks; these trucks use 48-ft trailers with 18-ft pups and generally operate at the legal maximum weight. The impacted roads are all state highways (SR numbers) with only minor collection occurring on county roads.

Seasonality of wheat movement was evident. Only 10 percent of the annual volume is moved during harvest time, August through September. About 70 percent moves in two

TABLE 1 HIGHWAY TRAFFIC PATTERN AS A RESULT OF THE ABANDONMENT OF THE MANSFIELD RAIL LINE

Number Highway Route:	Increase in Truck Traffic:	Truck Weight: (lbs.)	Configuration:
2 (Waterville to Jct. SR-17)	varies by segment	GVW 80,000 "	48 ft. trailer with 18 ft. pup
2 (Jct. SR-17 to Coulee City)	8,570	"	"
172 (Withrow to Farmer	1,820	"	"
172 (Mansfield to Sims Corner)	2,970	"	"
17 (Sims Corner to SR-2)	2,970	"	"

periods: October through November and January through February. The remaining months move about 5 percent each. Road restrictions do force some of this seasonal pattern.

Stage IV

Projected impacts to maintenance and construction on these highways were made by the Materials Lab of the Washington State Department of Transportation (WSDOT). The pavement management system (PMS) was used to project the equivalent single axle loads and the respective impact on each road segment of the added traffic configuration. (See Casavant and Lenzi (*6*) for a development of the PMS damage identification procedure.) In general, optimum rehabilitation costs over a 20-year period were compared using prior and post traffic volumes of abandonment. The differences in costs were averaged per mile per year for each highway section, then totalled for the entire year. The damage estimates were as shown in Table 2.

Stage V

The annual cost of road maintenance and reconstruction caused by the Mansfield abandonment was estimated to be over $379,000. In order to test the validity and accuracy of this procedure, the actual costs of increased maintenance and construction on these routes were obtained from the respective district office of the WSDOT. The results, summarized in Table 3, indicate a reasonable and even strong correlation between the projected impacts and actual expenditures. In all cases, the actual expenses relative to projected expenses appear to simply reflect partial inflationary pressures over the time period. This suggests that the PMS is providing a reasonable estimate of the increased road maintenance expenditures necessitated by the added traffic.

PROCEDURE EVALUATION

The procedure tested in the case study and reported in this paper performed well, but some modifications to the procedure were identified that would provide better damage estimates. The modified procedure, as indicated in Figure 5 should include the corroboration of PMS findings by surveying the district engineering office and county engineering personnel, as appropriate. In this case study it became apparent that the "hands on" knowledge of the district personnel provided a fairly complete and specific picture of road impacts. This parallel estimate should be incorporated into Stage IV of the procedure.

Shipper identification in Stage III should be broadened to include past and potential shippers in the inventory (IIIA and IIIB in Figure 5). The case studies under way reveal that some historical ex-shippers could be planning to return to railroad usage; similarly, some firms, identified by such entities as the chambers of commerce, were considering moving into the

TABLE 2 MANSFIELD RAIL LINE ABANDONMENT DAMAGE ESTIMATES

INCREASED COSTS

Route:	Miles:	Average Cost/ Mile/Year:	Cost/Year:
2 (Waterville to Jct. SR-17)	37	$ 1,427	$ 53,076
2 (Jct. SR-17 to to Coulee City)	4	871	3,049
17	14	10,733	149,618
172 (Mansfield to Farmer)	22	5,299	117,850
172 (Mansfield to Sims Corner)	12	4,469	55,416
TOTAL ANNUAL INCREASED COST:			$379,009

TABLE 3 MANSFIELD RAIL LINE ABANDONMENT DAMAGE ESTIMATES COMPARED TO ACTUAL EXPENSES

Route:	Projected Cost (1982)	Actual District Expenditures (1988)
SR 172 (Withrow to Farmer)	$ 32,059	$ 40,000
SR 172 (Mansfield to Sims Corner)	55,416	60,000
SR 2 (Waterville to Coulee City)	56,119	70,000
SR 17	149,618	168,000

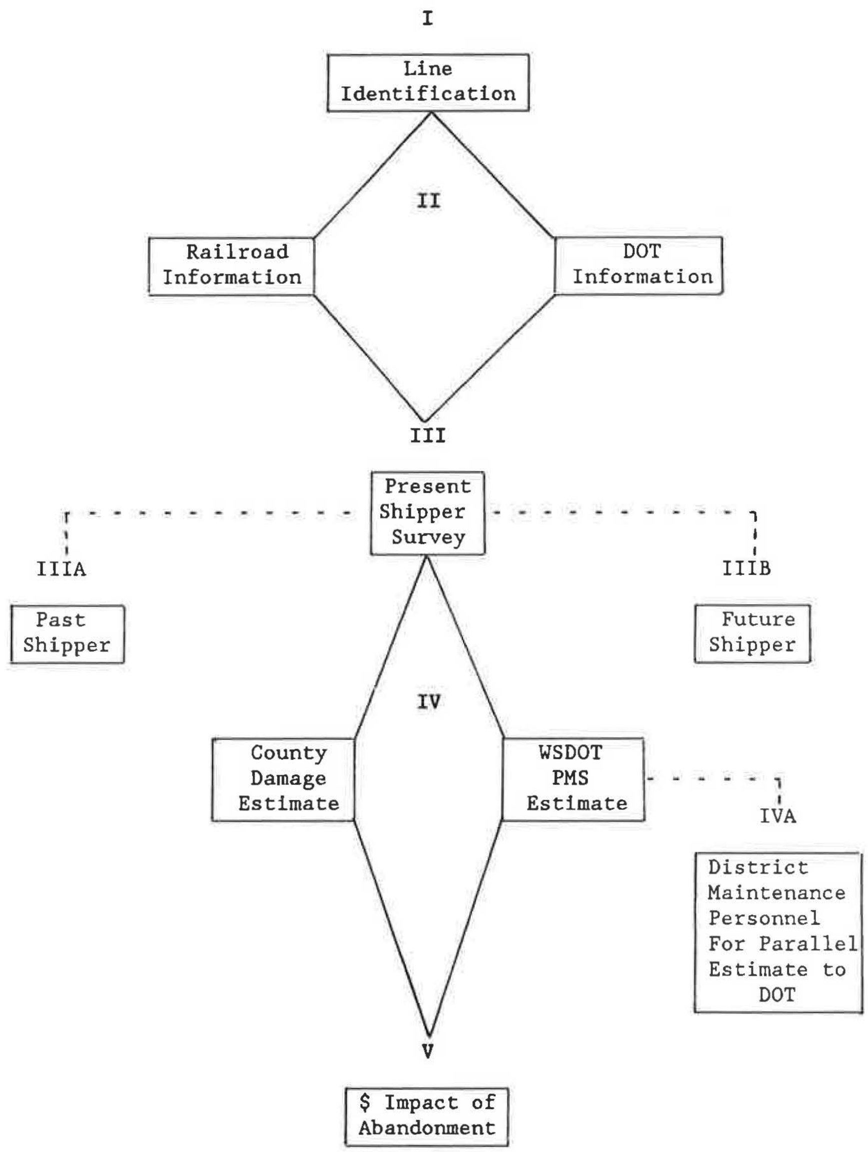


FIGURE 5 Modified procedures model.

area and were potential shippers. Both of these firms could increase the potential damage to roads if abandonment were to occur.

In summary, the procedure developed, tested, and modified in this research effort gives planners the ability to predict damage to roads before a rail line abandonment. But proactive use of this procedure is dependent on continual monitoring by state, county, and local personnel of probable rail line abandonments. Without such a "warning," even this procedure is not beneficial to planning.

Finally, the impacts of rail line abandonment reach past road impacts to other concerns of energy, environment, safety, and economic development. Similar procedures must be developed so that these "public" costs can be interjected into "private costs consideration" so the public can work with private decision makers to achieve societal goals. Using this procedure can be a contributing step to decreasing aggregate public and private costs.

ACKNOWLEDGMENTS

Partial support for this research was obtained from the U.S. Department of Transportation, FRA and FHWA, Washington, D.C., and Washington State Department of Transportation Research Office, Olympia, Washington.

REFERENCES

1. T. E. Keeler. *Railroads, Freight and Public Policy*. The Brookings Institution, Washington, D.C., 1983.
2. K. L. Casavant, J. C. Lenzi, R. Kerr, R. Taylor, and J. Jackson. An Evaluation of the Viability of a Regional Railroad System in the Palouse Region of Washington and Idaho. In *Transportation Research Record 1177*, TRB, National Research Council, Washington, D.C., 1988, pp. 16–26.
3. R. Taylor. *Likely Abandonments*. Draft of Working Paper to the Rail Development Commission, Wilbur Smith Associates, Columbia, S.C., Aug. 1, 1988.

4. B. Borris, K. Casavant, J. Newkirk, and F. Dooley. *A Preliminary Assessment of the Impact on Washington Highways of Rail Line Abandonment and Other Transportation Changes in the Washington Grain Industry.* Washington State Department of Transportation, Olympia, Oct. 1986.
5. K. L. Casavant, R. Sanders, and J. C. Lenzi. *A Review of Impacts on Washington County Roads of Grain Transportation Changes.* Final Report WA-RD 135.1. Washington State Department of Transportation, Olympia, April 1987.
6. K. L. Casavant and J. C. Lenzi. *A Procedure to Predict Selected Impacts on Roads of Rail Line Abandonment.* Draft Report. Washington State Department of Transportation, Olympia, Feb. 1989.

Publication of this paper sponsored by Committee on Application of Economic Analysis to Transportation Problems.

Economic Framework for Understanding Collusive Market Behavior: Assessment in Support of VDOT's Antitrust Monitoring and Detection Unit

GARY R. ALLEN AND CHERYL MILLS

An economic framework for understanding collusive market behavior is presented in this paper. It was prepared to provide key background information to the Virginia Department of Transportation in support of creating an Antitrust Monitoring and Detection Unit within the Construction Division. Although the scope of this paper is confined to economic background and general proposals for hindering collusive behavior in construction markets, an overview of antitrust case law is presented in a paper in this Record by Allen and Culkin, *Legal Aspects of Competitive Construction Market Behavior*. The purpose of this paper is to provide a primer on the nature of collusive markets; thus, this paper is directed toward highway construction program managers, rather than professional economists. In addition, the economic and legal reviews serve as necessary background for undertaking an empirical study of highway construction markets in Virginia. The first section of this paper defines market failure, discusses the origin of collusion, and reviews 10 key market characteristics that affect the likelihood of collusion. The second section surveys various methods that have been proposed for deterring collusive practices in highway construction.

In the fall of 1986, the Commonwealth of Virginia enacted legislation creating a Transportation Trust Fund, an intermodal transportation policy board, and greatly enhanced revenue for airports, seaports, transit, rail, and highways. As a result of the legislation, Virginia embarked on the largest construction program in its history—an average of $1 billion/yr for 10 years. The large number of highway projects Virginia has planned for the next decade will pressure the construction industry to expand rapidly. As part of an effort to develop and implement effective methods to ensure competitive bidding, the Virginia Department of Transportation (VDOT) has established a small unit within the Construction Division dedicated solely to bid monitoring and collusion detection. In addition, the Virginia Transportation Research Council (VTRC) has undertaken a program of applied research in support of that effort.

PURPOSE AND SCOPE

This paper is focused on a portion of the early work performed as part of VTRC's applied research program. In particular, an economic framework for understanding collusive market behavior is presented. Key background information in support of creating an Antitrust Monitoring and Protection Unit within the VDOT is provided, and the paper is intended to serve as a primer on the nature of collusive markets. Its audience is, therefore, construction program managers rather than professional economists. The concepts of market failure and contestable markets are presented, the origin of collusion is discussed, and 10 key market characteristics that bear on the likelihood of collusion are reviewed. In the second section of this paper, various methods that have been proposed for deterring collusive practices in highway construction are surveyed. Allen and Culkin, in a separate paper in this Record, *Legal Aspects of Competitive Market Behavior*, present an overview of antitrust case law as it applies to highway construction markets.

Virginia Transportation Research Council, P.O. Box 3817, University Station, Charlottesville, Va. 22903.

ECONOMIC FACTORS AFFECTING COLLUSIVE MARKET BEHAVIOR

The Marketplace and Contestable Markets

When defining a market, one delineates all parameters that compose the market: the buyers, the sellers, the products sold, the geographic limits of competition, the prices, and so on. Defining the market is often critical in antitrust cases because the definition tells the court who is and who is not in competition. In the strictest sense, a market is deemed perfectly competitive when it exhibits the following characteristics: (a) many firms, (b) a homogeneous product, (c) free entry to and exit from the market, (d) perfect knowledge by participants in the market, and (e) independence in the decisions the firms make.

When the conditions for a perfectly competitive market are disrupted, different market types arise, most notably monopolies and oligopolies (*1*). In the case of a pure monopoly, consumers lose the choices presented by a large number of brands of the commodity in question. Instead, the market has one producer of the good, with barriers to entry that keep other competitors from entering the market. Prices tend to be high and production levels low. In an oligopoly, a similar situation arises because there are only a few sellers. These sellers recognize that they produce substitutable goods and that they, as well as their rivals, can influence the price of the goods (*1*). An oligopolist recognizes this "mutual interdependence" among firms and that the maximization of profit depends not only on his or her firm's behavior but on other firms' behavior as well.

In both monopolies and oligopolies, the sellers recognize that their individual output decisions affect price and that they each have some degree of market power that depends not on absolute firm size but rather on the size of a firm relative to the market (*1*).

Markets need not adhere to an idealized, perfectly competitive schematic to ensure desirable outcomes. The theory of perfectly contestable markets proposes what many view as a more realistic benchmark for assessing the degree to which markets are effectively competitive (*2*). Although a detailed discussion of the theory is beyond the scope of this paper, elements can be summarized as follows:

- A perfectly contestable market is a market (consisting of any number of firms) that is subject to potential entry by firms that have no disadvantage relative to the firms already comprising the market; such potential entrants make the determination about the profitability of entry by assuming that existing firms will not alter their prices even when new firms enter. Furthermore, whether the market consists of many firms or only a few, it is said to be a sustainable contestable market equilibrium if there are no profitable opportunities for any potential entrant who charges prices no greater than existing firms.
- Industry structure in perfectly contestable markets is determined by the fundamental forces of demand, production technology, and *potential* entry.
- The theory of perfectly contestable markets is a generalization of perfect competition that is applicable regardless of the cost structures faced by firms and, in many instances, produces the same expected outcome as does perfect competition.
- *Potential* competition from *potential* entrants, not active competition of existing rivals, drives perfectly contestable markets to equilibrium where demand and supply are equal, industry costs of production are minimized, and prices equal marginal costs and are at a level that renders further entry unattractive.

Market Failure

Monopolies and oligopolies sometimes lead to what is termed "market failure." The market fails in that productive resources may not be used efficiently (that is, labor, equipment, and other resources are not combined in a fashion that yields minimum costs); however, market failure need not always be the result of market structure alone. Often, it is the product of actions on the part of market participants in conjunction with market structure.

Generally speaking, the type of market failure addressed in this paper falls in the category of cartelization, a form of market failure typically resulting from the actions of sellers. It is "an explicit arrangement among, or on behalf of, enterprises in the same line of business that is designed to limit competition among them" (*3*). This concept includes conspiracy, price fixing (bid rigging), and explicit collusion.

Collusion

Collusion is a term used to define the actions of firms that coordinate their pricing or production policies in an attempt to increase their profits (*4*). It is usually a "formal or explicit agreement among competitors" (*5*) as a means to earn greater-than-competitive returns, but it can take many forms. In some cases, a large group of competitors selling a product that differs among transactions (e.g., construction) may have regularly scheduled formal meetings with or without the aid of a trade association. In other instances, a small group of competitors in a market with a simple product may communicate under less formal circumstances. Sellers in markets with repetitive purchases (such as materials suppliers) may agree on a single list price for an item or draw up a price list for referral with or without customer allocation schemes. Sellers in markets characterized by nonrepetitive purchases may even choose to allocate jobs or territories through complementary bidding (*5*) or may rotate winning bids and shares of the market (*1*). One analyst describes the situation as follows (*6*):

> All these schemes and countless others have one thing in common: Regardless of their design, the Sherman Antitrust Act renders illegal any form of agreement (open or secret) designed to fix prices or restrict output. Yet despite its illegality, for many businessmen, firms, and even industries, collusion has been a way of life—an accepted method of doing business.

Why Collude?

The question "why collude?" has a very simple, and perhaps even obvious, answer: the purpose of virtually all collusive arrangements is to attain joint maximization of profits for those firms participating in the conspiracy. Clearly, if the firms can act as a unit, they will effectively operate as a monopoly, enabling them to price and produce as a monopolist.

The necessity of and feasibility for collusion are determined by the structure of the market. Therefore, market structure should be examined as a check on the validity of any concerns regarding collusion. Necessity and feasibility vary in a fashion consistent with the structure of the market. Two examples can be given to demonstrate this relationship. The first example is a market with hundreds of small firms selling a standardized product, such as wheat. A cartel is necessary if firms are to achieve joint maximization of profits (high profits) because the large number of sellers forces prices and costs to be very close, but collusion is infeasible because of market structure, that is, recognized interdependence is too remote, the incentive to cut prices is too great, private enforcement of such a hypothetically large conspiracy is too costly, and the likelihood of detection is too great. A second example is when the market has only two sellers of a simple, standardized product (perhaps asphalt). A cartel is quite feasible in this instance, but collusion is entirely unnecessary. With only two firms in the market, recognized interdependence is unavoidable; there are relatively no incentives to cut prices; the opportunity for price leadership is clear so that conscious parallelism can yield a monopoly outcome; and, because explicit collusion is illegal, tacit collusion will most probably occur instead (*7*).

Thus, collusion is most likely to be found when it is not only feasible but also necessary in order to maximize profits. If the market's structural conditions are unfavorable, necessity and impossibility will rule collusion out. With extraordinarily favorable conditions, feasibility and lack of necessity will probably lead to tacit collusion (i.e., price leadership) (*7*). It is in the realm in between—when "feasibility and necessity blend"—that one may find collusion thriving (*7*). This situation leads one to question which structural aspects of markets affect the feasibility and necessity to collude. It is only after recognizing these factors and their impact that one can analyze a market for its ability to support collusive activity.

Factors Relevant to the Feasibility of Collusion

Number of Firms

The number of firms in a given market plays a significant role in determining whether collusion is likely, because it directly affects the ease with which coordination between the involved firms can be achieved. Simply, the more sellers there are in a given market, the more difficult it is to maintain a price at a level significantly greater than cost (*1*).

There are several reasons for this. First, as the number of sellers of a product increases and the share of the output contributed by firms in a conspiracy decreases, the more likely firms are to ignore the impact of their behavior and pricing policies on the overall market price structure. Thus, sellers in large markets lose awareness of how their individual pricing decisions hurt (or help) their rivals. As a consequence, collusive agreements in a market with a large number of sellers (greater than 10) tend to dissolve more readily than those markets with fewer participating sellers (*1*). Second, as the number of firms increases, the chance of having an independent firm with its own pricing policy increases. If such a firm were to supply a significant portion of the market's demand for the good, it would create a major problem for the other colluding firms (*1*). The fewer firms involved, the less likely there is to be such a maverick in the group. Third, as the number of sellers increases, the more divergent the ideas about the most advantageous price at which to sell the product. Divergent ideas are obstacles to setting prices, yet they are inevitable given the variability of firm size, cost structure, and other aspects of the market (*5*). However, with fewer firms, this possibility is less likely and agreements are reached more rapidly.

Industry Concentration

The effect of industry concentration (percentage of the market controlled by the four to eight top revenue-earning firms) is still being debated. The conclusion reached in most studies is that profits do rise with increasing concentration (*1*), and this leaves open the possibility that these firms maintain their profits through collusive activity. However, it is also agreed that highly concentrated industries can collude tacitly (i.e., without formal agreements) by recognizing their interdependence. The resulting behavior, which is called conscious parallelism, is not illegal per se. In such a market, it is argued, there is no need for overt collusion. One might want to reflect, however, on the fact that a high degree of interdependence, if recognized by the participants in the market, might quite naturally lead to collusion (*5*). Hay and Kelly found in a study of a sample of 65 cases brought to court that "the preponderance of conspiracies lasting 10 or more years were in markets with high degrees of concentration" (*5*). This seems to corroborate the theory many economists find most plausible: firms with moderate-to-high four-firm concentration ratios are most prepared to foster collusive activity (*5*).

Nature of the Product

The nature of a product in a given market can play an integral role in defining the structure of the market and, in turn, can influence the feasibility of collusive activity. Products are generally described as either homogeneous or heterogeneous within their market. If the products are described as homogeneous, it means that in the consumer's mind there is little or no relevant difference among the products. Put simply, the goods are perfect substitutes for one another (*1*). Economists thus use the term homogeneous to (*5*)

- Denote that the cross-price elasticity of demand among products is high (i.e., if the price of Good A rises slightly, consumers will increase the quantities purchased of Good B by a significant amount);
- Describe a situation in which the product is not complicated but comes in different grades and types; and
- Denote homogeneous overtime with stable qualities

Each type of homogeneity contributes to the degree to which individuals regard the products as substitutes. In a homogeneous market, though, there is only one dimension along which rivalry can occur: price. Thus it is easier to reach an agreement in a market with homogeneous products, as one must agree only on price (*1*).

Rate of Technological Change and Industry Growth

The rate of technological change in a given product market can also affect the structure of the market and the probability of collusive activity. Its effect is similar to that of the homogeneity or heterogeneity of the product in that the degree of technological change affects the ease with which an agreement can be brought about between potential coconspirators. When a product market is undergoing a large degree of technological change, long-term agreements become more difficult to arrange (*3*). Ultimately, the costs of maintaining an agreement are increased because terms must be renegotiated with each technological change. If innovations allow the firm to increase its market share, the firm will be an even larger threat (*8*). Furthermore, the more rapidly a producer's cost functions are altered through innovation, the more unevenly the profits generated by collusion are distributed throughout the industry and the greater the influence on the performance of any price-fixing agreements. Conspiracies depend on the stability of certain market characteristics, and because innovation affects the most significant factor, that is, constancy of members' market shares, one would expect it to have a large impact on the ability to coordinate activities and prices (*9*).

The rate of growth of an industry can similarly affect market structure, particularly if the industry is experiencing significant growth. Because firms rely on maintaining a constant share of the market, in an industry with rapid growth, it is difficult to determine shares of the market among colluding firms. It is also difficult to police a collusive arrangement for price cutting in a rapidly expanding market because increases in market share may be a result of increased demand rather than price cuts. A conspiracy favors status quo and, thus, is more likely if market shares are relatively constant over time and demand fluctuations are moderate (*9*). In the case of the rapidly growing VDOT construction program, the conditions are clearly not procollusive.

Type of Sale

Another factor that can, and usually does, affect the way a product market functions is the size distribution of orders over time. The frequency or infrequency of sales, as well as the "lumpiness" or evenness of the size of sales, affects an industry's ability to coordinate. In this context, collusion is least likely "with large infrequent orders at irregular intervals" (*1*). A firm that is in a conspiracy constantly weighs the gains and the losses from possible undercut bidding. The gains to a firm from undercutting coconspirators are great on large orders, particularly if the probability of getting such an order is low (irregular). Ultimately, the effect of "lumpy," infrequent orders will be an increase in the cost of policing any conspiracy formed in such an environment, rendering collusion unlikely.

A market is, therefore, more conducive to collusion if it has small, frequent, regular orders. Under these circumstances, the payoff from undercut bidding is not so lucrative; thus, conspirators have few incentives to cheat.

Sealed Bidding

The threat of rival retaliation allows collusive conspiracies to thrive. Secrecy is contrary to the aims of a group involved in collusion. In fact, a collusive arrangement can survive only if there is a mechanism to detect cheaters (price cutters) and subsequently punish them. Thus, the sealed bidding process is the answer to every coconspirator's dream. Conspirators need price information to discover cheating, and the sealed bidding process literally does the work for them. The key to the process for conspirators is that all bids are opened publicly on a set date, with the lowest winning. Because the results are announced publicly, conspirators are provided with an excellent mechanism for detecting those members of the cartel who reduced their price below the agreed-upon level. The process greatly reduces the cost of obtaining this type of enforcement information (*8*). Because conspirators know that cheating will be detected immediately, the incentive to cheat is greatly reduced (*5*). Economist Paul Cook said it best, "it would . . . be hard to find a device (that is, sealed bidding) less calculated to foster open and aggressive competition among sellers" (*1*). The likelihood of collusion depends on the ease with which an agreement can be reached and the means used to monitor cheating. In sealed bid markets, the second issue is eliminated by the announcing of the winning bids, so it is necessary only to reach an agreement (*4*).

Elasticity of Demand

A market with an inelastic demand for its goods is conducive to collusion. In such markets, if the price of the good goes up or down, the quantities demanded will not be significantly affected. If the demand for an industry's products is relatively inelastic, then any conspiracy to raise prices above the competitive level will simply result in higher revenues because the quantities demanded will not be significantly reduced as prices rise. In such a conspiracy, all suppliers of substitutes would have to be included in the conspiracy so that a potential buyer would not escape the higher-priced product by choosing a suitable substitute (*8*).

The association of price fixing with industries that have inelastic demand curves is based on the argument that the penalties for failing to fix and raise prices, in terms of lost profits, are high and the rewards of high fixed prices are great (*9*). Thus, the likelihood of collusion increases markedly with an inelastic demand curve. Once again, this is not to suggest that collusion occurs only in such instances, only that the chance of its occurrence is enhanced by such an environment. Ultimately, an inelastic demand is a major influence on conspiratorial stability. The more inelastic industry demand is, the more profitable the conspiracy and the greater the incentive for its continued life (*9*). Clearly, departments of transportation run the risk of increasing the probability of collusion in instances where construction advertisements are let in the presence of bids significantly in excess of the engineer's estimate.

Industry Social Structure and Trade Associations

The social structure of an industry affects its conduct; yet, this structure is difficult, if not impossible, to measure in economic terms. The social structure of an industry also affects the market by affecting the ability of competitors or conspirators to coordinate pricing behavior (*1*). Often, industries are close knit and competitors are friendly with each other, respect each other, and share a spirit of camaraderie. On the other hand, industries with producers from diverse backgrounds with different styles of doing business and different goals will not be likely to participate in collusive arrangements (*1*). If there is an independent seller in a close-knit group, collusion may be unlikely. In addition, the strength of the industry's leadership may affect the creation of collusive agreements, and a strong leader may be enough of a force to create a conspiratorial ring in an entire product market.

Although one may still wonder how such bonds are formed between apparent rivals, informal social contacts at trade associations have frequently been found to foster tacit or explicit collusion (*5*). This has led trade associations to come under increasing fire. Trade associations, by the very nature of their concerns and functions, raise serious questions for those seeking to prevent collusion. They present ideal opportunities for conversations about prices under the auspices of performing functions that are within the bounds of the law. Yet, research shows that 30 percent of all cases brought by the government involve trade associations (*3*). In fact, in a study involving 50 antitrust cases, Kuhlman found that trade associations were named as codefendants in 23 (*8*). In summary, it is generally accepted that the "larger the portion of the industry encompassed by trade associations, the more conspiracy you'll expect to find" (*9*).

Production Costs

Production costs clearly affect the functioning of markets. The "more costs differ from firm to firm (in a product market), the more trouble the firms will have maintaining a common pricing policy" (*1*). Thus, vastly differing production costs may preclude collusion, as the joint maximization of profits for the individual sellers will be less likely in such a market. "Widely divergent costs across firms breed divergent opinions concerning the optimum price" (*3*). Although the most efficient means to handle the problem of divergent costs is to shut down inefficient plants and pool the profits to rewardable firms, such behavior is usually obvious to antitrust prosecutors and is not, therefore, undertaken.

High fixed costs present special difficulties for potential colluders. Fixed costs are costs that do not vary as output changes. They include building rent, the capital cost of equipment, insurance, and so on. Industries with high fixed costs (e.g., cement, steel, aluminum) are more susceptible to breakdowns in pricing discipline when demand falls. For example, if demand falls, capital will go unused and firms will find it tempting to reduce price and expand output, sales, and general revenue to offset the effect of the high fixed costs (*5*). However, if more than a couple of firms choose this course of action, prices will fall rapidly. Thus, agreements in industries characterized by high fixed costs (capital-intensive production processes) become fragile and subject to disintegration with each downward turn of demand (*5*). In essence, excess capacity functions as a powerful incentive to cheat and can cause a widespread departure from fixed prices. The incentive to cheat is greater for firms with high fixed costs because "individual firms can gain high profits not only from additional business, but from the decrease in cost associated with higher output" (*9*). The incentive to cheat is less if fixed costs are low. Thus, cost structure can play an integral role in an industry's ability to maintain collusive arrangements.

Barriers to Entry

A barrier to entry is anything that prevents prospective sellers or producers from entering a given market. Barriers to entry play a significant role in determining the complexion of an industry because "the condition of entry into a market determines the possibility for long-term profits" (*10*). If entry is relatively easy, high profits cannot be sustained, because they will entice new entrants into the market. Therefore, if a market is to enjoy continued high profits generated by collusive arrangements, there must be some barrier to prevent the entry of rivals; otherwise, the degree of pricing discretion for established firms will become quite limited. Many things, however, can function as a barrier to new entrants: absolute cost advantages, economies of scale, product differentiation, or something less categorically specific (*10*). Absolute cost advantages may arise because of patents, trade secrets, and contracts that prohibit certain factors of production from use or distribution proximity. Economies of scale can be a barrier to entry if a firm must maintain a large output level to achieve reasonable production costs. Product differentiation is also an effective barrier, as consumer brand loyalty may make buyers reluctant to try a new product. There may also be legal obstacles, licensing requirements, labor contracts, or any number of other factors that may function as an entry barrier (*10*).

Barriers to entry are particularly important to firms considering collusion because, to the extent that collusion yields high profits, others will try to enter the market; the success of the collusion revolves around the firms being able to keep them out. Therefore, firms in a market with low barriers to entry are less likely to form and be able to maintain collusive agreements than firms in a market with high barriers (*8*).

Supporting Antitrust Monitoring Programs

The following 10 categories of market characteristics offer a starting point from which to examine construction markets to establish the extent to which, if at all, any markets exhibit characteristics that would facilitate collusion:

- Number of firms;
- Industry concentration;
- Product characteristics;
- Technology change;
- Type of sale;
- Type of bidding;
- Demand elasticity;
- Industry social structure;
- Production cost; and
- Entry barriers.

This information can then become an integral part of a construction antitrust monitoring and detection program. Highway construction markets appear to exhibit several characteristics that have been shown to facilitate collusion. The industry produces fairly standardized products (e.g., asphalt), appears to have relatively high barriers to entry because of capital costs, and has firms likely to experience similar production costs throughout a given market. Technological innovation appears to be slow in the construction industry, and the sealed bidding process enhances the opportunity for collusion. It is this type of information that needs to be empirically verified so that one may determine if such a list of factors could be helpful in identifying any markets in which collusion may be likely.

Thus, there are several logical steps that can serve to help develop an effective antitrust monitoring program:

1. Define the major highway construction markets in terms of number of sellers, concentration ratios, rate of growth, geographical boundaries, number and size of contracts, and so on;
2. Analyze each market for conduciveness to collusion on the basis of the factors listed in the previous paragraph; and
3. Analyze tests for collusion available to the states in the AASHTO Bid Analysis System (BAMS) on the basis of these factors.

REFLECTIONS ON DETERRING COLLUSION

Various methods have been proposed for deterring collusive bidding. Some are intended to reduce the impact of collusion by increasing competition in the particular market or by making a successful conspiracy more difficult to coordinate. Other suggestions are geared to improving detection techniques. Because bidding procedures are governed by state law, the implementation of certain ideas may be difficult. The purpose here is to summarize the various techniques and discuss some of the positive and negative aspects of each.

Improving Competition in the Marketplace

The most obvious way to increase the competitiveness of a sealed bid market is to encourage more firms to bid. State procurement agencies can provide incentives for firms to bid by reviewing prequalification requirements, on-site inspection policies, and other overhead-related items to ensure that the benefits derived from such requirements are not outweighed by the burdens placed on the contractors.

Overhead-related items such as prequalification requirements serve a beneficial purpose because they improve the monitoring capability of state procurement agencies. However, they may deter firms from bidding if the requirements are overly burdensome. The policy of debarring collusive firms has a similar double-edged effect. The threat of debarment is a strong deterrent to firms that might consider rigging bids. On the other hand, debarment of firms tends to hinder competition by reducing the number of potential bidders. It is not possible to propose general guidelines for setting prequalification and debarment policies that will work in all markets all the time. The policies should be the subject of continuous review by state officials who are intimately familiar with the relevant markets and who are in touch with the contractors and trade associations involved. Detailed recommendations for prequalification requirements are prescribed by Welsch and Furth (*11*) and in the *Report of the Task Force for Strengthening Bidding and Contract Procedures* (*12*).

Another approach to increasing competition in sealed-bid markets is to gear the work to the existing capacity of the market. For example, it may be advantageous to split the work into relatively small portions, thereby encouraging smaller firms to bid. On the other hand, by dividing the work into several smaller contracts, economy of scale advantages may be lost. Also, it has been argued that clustering projects into large contracts will induce at least one firm to violate cartel prices and win awards with a competitive bid.

North Carolina has proposed two techniques for clustering projects into large contracts without discouraging the smaller firms from bidding (*13*). One technique is to cluster several smaller projects into a large bid package. Firms are allowed to choose whether to bid on one project or on the whole package. The system may encourage more firms to bid by allowing them to tailor their bidding choices to their available capacity. A disadvantage may be that large firms will be unsure about which jobs may go to smaller firms and therefore will be unable to take full advantage of all production efficiencies.

The other approach proposed by North Carolina is referred to as "sequential bidding." With this system, the bidder submits a bid on the condition that the total award will not exceed a specified level. The bids on the various projects are opened sequentially. Once a firm's specified limit is reached, its bids are not considered on the remaining projects. Sequential bidding provides incentives for firms to bid on more projects without having to worry about taking on more work than they can handle.

In summary, the competitiveness of a sealed-bid market can be improved by increasing the number of bidders. Firms can be encouraged to bid through relaxing requirements on overhead items such as prequalification requirements and by matching the work load to the available capacity. The implementation of these competition-enhancing measures requires judgment on the part of procurement officials and intimate familiarity with the relevant markets.

Hindering Collusive Practices

In an oligopolistic market, that is, one in which a few firms are dominant, a successful conspiracy must accomplish two tasks: (a) establish a mutual understanding of the price or output level to be used by the conspirators and (b) promote mutual confidence that the terms of the understanding will be honored by the participants. Standard bidding procedures often facilitate the accomplishment of the first task by disseminating certain information in connection with the bidding process. The most important piece of information is the list of potential bidders. Bid riggers use this list to identify and contact the other potential bidders in order to ensure that no one will underbid the firm chosen by the conspiracy to win the contract award. By keeping this list secret until after the bid letting, the state could create uncertainty among the conspirators about whether a newcomer may decide to bid competitively. The effectiveness of keeping the list secret will probably be limited in those markets where the cost of entry is high and the existing firms have a long-standing working relationship with each other. Even so, the slight uncertainty could discourage some firms from colluding.

The state engineer's estimate is another useful piece of information for conspirators. If bidders know what the state thinks a job is worth, they will have a basis from which to start their job allocation negotiations. The rigged price will then exceed the engineer's estimate but not by so much that the bids will be rejected. If the contractors are unsure of the state's valuation of a project, they will be uncertain about how high to bid and they could be inclined to bid close to competitive prices.

Another method for hindering the establishment of mutual understanding among conspirators is to have frequent advertisements. Frequent bid lettings force potential conspirators to communicate often to set up jobs, thus raising the cost and complexity of the conspiracy.

The accomplishment of the conspirators' second main task, promoting confidence that the participants will adhere to the terms of the conspiracy, is not difficult in the typical bidding scenario. The conspirators can easily detect competitive bidding because the identity of the bidder and the amount of the bid are announced after the bid letting. Firms will be hesitant to violate the terms of the conspiracy because their actions will be immediately detected and the competing firms would be able to retaliate effectively by submitting competitive bids on subsequent projects. The renegade firm would win the first contract but would forgo the large profits that would be gained by rigging future projects. The confidence of the conspirators would be significantly undermined if the identity of the low bidder and the quantity of his or her bid were kept secret. Obviously, keeping the identity of the low bidder secret is not possible. Although keeping the quantity of the low bid secret may be desirable, as a practical matter, the low bid must be disclosed to avoid the appearance of impropriety in the contract award process.

Another avenue for creating uncertainty among potential conspirators is occasionally to award projects to randomly selected bidders, rather than to the low bidder. If the bids are clustered closely, the state could award the contract to someone other than the low bidder without paying an excessively high price. If one bid was much lower than the others, the state would award the contract to that bidder. If the bids on the project were kept secret, the conspirators would be unsure whether anyone violated their agreement. This uncertainty will provide an incentive for firms to violate the terms of collusive agreements. The main problem with the proposal is that it does not provide an incentive to bid below the collusive price because, in a random selection process, a low bid will not ensure a firm's winning the contract. The scheme may, however, deter firms from submitting complementary bids on projects they are not prepared to complete. If a firm is awarded a contract it is unable to fulfill, it would be forced to subcontract the job to other contractors. In this manner, the conspiracy would become more complex and therefore more expensive and prone to detection.

The use of a random selection process may not be effective unless it is used on a regular basis. The problem with the frequent use of the system is that, in order for it to work, the bids must be kept secret. This secrecy would likely present the appearance of impropriety and would probably be unacceptable to the contractors and the public.

The well-established practice of requiring bidders to submit affidavits of noncollusion should be continued because it can have an impact on a conspirator's willingness to adhere to the terms of the conspiracy. The affidavit requirements remind the contractors of the seriousness of antitrust violations. Also, by signing false affidavits, collusive bidders would risk committing a separate offense they might be unwilling to bear.

Detecting Collusion

The best way to "detect" collusion among bidders is to obtain direct testimony from witnesses to the illegal agreement. Because such testimony is generally not available, investigators must be able to draw inferences from the circumstantial evidence that is available. Numerous methods have been proposed for using the available information to detect collusion. Generally, these methods rely on common sense analysis of bidding patterns (*14*). Other methods use sophisticated statistical tests to detect collusion (*15*). Although the proposals vary in sophistication, they all depend on an intimate familiarity with the relevant firms and markets. There is no "automated" collusion-detection system, and there is not likely to be.

Procurement officials can improve their understanding of construction markets by gathering information about construction firms and their affiliations. Generally, some information of this nature is obtained through the prequalification process. However, timely updates of this information and the detailed assessment of the need for more complete information should be an ongoing process within any transportation agency.

A sophisticated cost-estimating system like that used by VDOT (BAMS) is also essential to a thorough analysis of bids. The estimating system must be sufficiently detailed to identify all factors affecting project cost including such variables as transportation costs. A detailed, objective cost estimate will allow bid analysis to identify line item costs in bids that do not reflect rational business decisions on the part of bidders. In this regard, it is also important that the state continue to require detailed line item bids. By breaking the project costs into easily analyzed cost items, the state will make it more difficult for contractors to submit irregular bids.

Once procurement officials are armed with comprehensive data on the relevant firms and a sophisticated cost estimate, the bids can be analyzed to identify irregular patterns that may indicate collusion. Four source documents (*11, 12, 16, 17*) provide a comprehensive compilation of possible indicators of anticompetitive behavior that states may wish to use in moving forward to implement an antitrust monitoring and detection effort.

ACKNOWLEDGMENT

The Virginia Transportation Research Council is a cooperative organization sponsored jointly by the Virginia Department of Transportation and the University of Virginia.

REFERENCES

1. F. M. Scherer. *Industrial Market Structure and Economic Performance.* Rand McNally & Co., Chicago, Ill., 1971.
2. W. J. Baumol, J. C. Panzar and R. D. Willig. On the Theory of Perfectly Contestable Markets. In *New Developments in the Analysis of Market Structure* (J. Stiglitz and G. F. Mathewson, eds.). MIT Press, Cambridge, Mass., 1986.
3. D. Greer. *Industrial Organization and Public Policy.* Macmillan Publishing Co., Inc., New York, 1984.
4. M. Coate. Techniques for Protecting Against Collusion in Sealed Bid Markets. *The Antitrust Bulletin*, Winter 1985.
5. G. Hay and D. Kelly. An Empirical Survey of Price Fixing Conspiracies. *The Journal of Law and Economics*, Spring 1969.
6. How the Justice Department Is Bagging Highway Bid Riggers. *Business Week*, July 4, 1983.
7. P. Asch. *Industrial Organization and Antitrust Policy.* John Wiley & Sons, Inc., New York, 1983.
8. J. Kuhlman. Nature and Significance of Price Fixing Rings. *Antitrust Law & Economics Review*, Spring 1969.
9. W. Erickson. Economics of Price Fixing Rings. *Antitrust Law & Economics Review*, Spring 1969.
10. P. Asch. Collusive Oligopoly: An Antitrust Quandry. *Antitrust Law & Economics Review*, Spring 1969.
11. J. P. Welsch and H. F. Furth. *Suggestions for the Detection and Prevention of Construction Contract Bid Rigging.* Interdepartmental Bid Rigging Investigations Coordinating Committee of the U.S. Departments of Justice and Transportation, 1983.
12. Report of the Task Force for Strengthening Bidding and Contract Procedures; *Proc., AASHTO*, Washington, D.C., 1981.

13. *Actions Being Taken To Deal with Bid Rigging in the Federal Highway Program.* U.S. General Accounting Office, 1983.
14. W. A. McFarlane. Anti-trust and State Contracting. *Proc., AASHTO*, Washington, D.C., 1982.
15. M. D. Maltz and S. M. Pollock. Analyzing Suspected Collusion Among Bidders. In *White Collar Crime: Theory and Research* (G. Geis and E. Statland, eds.), 1980.
16. *United States Attorneys' Manual.* U.S. Department of Justice, 1986.
17. *Indicators of Fraud in EPA Procurement.* U.S. Environmental Protection Agency, 1986.

The opinions, findings, and conclusions expressed in this report are those of the authors and not necessarily those of the sponsoring agencies.

Publication of this paper sponsored by Committee on Application of Economic Analysis to Transportation Problems.

On the Concept of Total Highway Management

KUMARES C. SINHA AND TIEN F. FWA

The need for a total highway management system is defined in this paper. A highway system serves a set of objectives, such as provision of an adequate level of service, preservation of the facility condition, safety, economic development, and others. It consists of a number of physical facilities, such as pavements, bridges, roadside elements, and traffic control devices. The system is managed through operational functions of a highway agency, such as planning, design, construction, maintenance, and so on. The highway system can thus be envisioned in terms of a three-dimensional matrix of objectives, facilities, and functions, all of which interact with each other. The current trend of developing separate management systems for pavements, bridges, and maintenance activities is a piecemeal approach, because it ignores the needs of the total system. Consequently, many current systems are either conflicting or involve duplication, or both. Instead, individual management subsystems, such as pavement management, bridge management, and maintenance management, should be developed in proper coordination with each other and with a clear understanding of the requirements of the total system. With the rapidly developing new information and communication technologies, there is an opportunity for organizing a total highway system that can assist in managing highway facilities in a highly efficient and productive manner.

The use of a systems approach to the management of highway facilities has gained much momentum since the 1960s when the need for systematic management of highway pavements was emphasized (*1–3*). Highway facilities include pavements, bridges, traffic control devices and structures, and roadside elements. These facilities must constantly be maintained or upgraded to cope with (a) automobile and truck traffic increase associated with growth in population and economic activity; (b) additional access roads required for new development; (c) higher quality and standard requirements in terms of travel comfort, safety, traveling speed, and environmental concerns; and (d) continuous deterioration and wearing out of the facilities. Besides planning, design, and construction, the major activities of a highway agency, therefore, also include maintenance, upgrading, rehabilitation, and reconstruction of highway facilities.

In an era of limited resources, it is not possible to implement all required activities to satisfy highway needs. An optimal selection of these activities has to be programmed and executed. Thus, a systems management tool is required to identify the best mix of activities that will achieve an acceptable level of system performance now and in the future.

K. C. Sinha, Department of Civil Engineering, Purdue University, West Lafayette, Ind. 47907. T. F. Fwa, Department of Civil Engineering, National University of Singapore, Kent Ridge, Singapore 0511.

Significant research and implementation efforts have been made by highway agencies in the last two decades in the area of pavement management. In contrast, management of other highway facilities has not received the attention it deserves. It is clear that research and implementation priority should be assigned to areas in which highest returns or savings could be realized, however, such work must be carried out toward the achievement of optimal management of the total highway system. An optimal solution derived for a subsystem may not be the best strategy for the entire highway system.

In the light of tremendous interest in improving the expertise and technology in managing highway pavements, as evidenced in the current emphasis on research related to pavement materials and long-term performance of pavements (*4*), it is the intent of the authors in this paper to stress the importance of the concept of total highway facility management and the need for establishing a framework within which various management subsystems can be developed to enhance the effectiveness and efficiency of the entire highway system.

ELEMENTS OF A HIGHWAY MANAGEMENT SYSTEM

A comprehensive highway management system can be considered in terms of a three-dimensional matrix structure. The three dimensions are the highway facility dimension, operational function dimension, and system objective dimension. Table 1 lists the possible elements in each of the three dimensions.

The three-dimensional matrix structure indicates that a highway agency has a number of facilities in the highway system. The objectives of the agency are primarily related to cost-effective delivery of highway services. In this effort, the organizational framework of the agency is divided into a group of functions. Each facility in the system requires all of the management functions, and through planning, design, construction and other functions associated with the facilities in the system, the overall system objectives are fulfilled. If one chooses to look at a particular function (for example, planning), it is necessary to establish proper coordination among all the facilities in the planning process in order to contribute to the achievement of the objectives. Similarly, with regard to any one of the objectives, an optimal highway management system will have it satisfied through all the functions for any of the facilities. These interacting characteristics of the highway management system are schematically depicted in Figure 1.

TABLE 1 ELEMENTS OF HIGHWAY SYSTEM DIMENSIONS

Dimension	Highway Facility	Operational Function	System Objective
Elements	1. Pavement	1. Planning	1. Service
	2. Bridge	2. Design	2. Condition
	3. Roadside	3. Construction	3. Safety
	4. Traffic control devices	4. Condition evaluation	4. Cost
		5. Maintenance	5. Socioeconomic factors
		6. Improvement	6. Energy
		7. Data management	

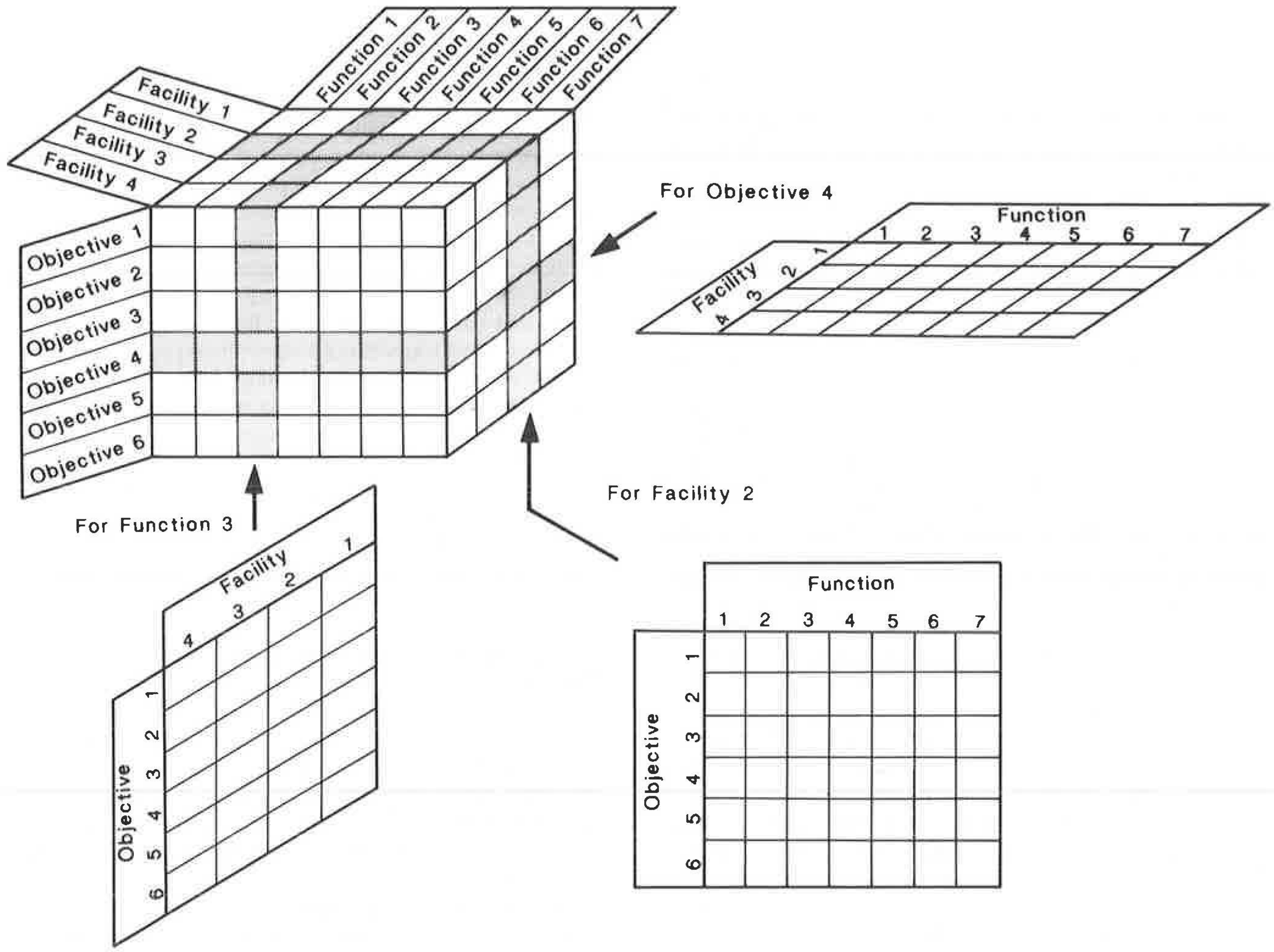


FIGURE 1 Three-dimensional matrix structure of highway management system.

Highway Facility Elements

A highway system has a number of physical facilities. Pavements, bridges, roadside elements, and traffic control devices are all different in their service characteristics. Pavements and bridges are to carry traffic and traffic control devices are for traffic safety and guidance, whereas roadside elements are for convenience and aesthetics. Pavements rarely fail catastrophically, but bridges may collapse with potential loss of life. On the other hand, although pavements and bridges deteriorate progressively with age, traffic control devices and some roadside elements may be put out of service instantly by traffic accidents or mechanical faults. Activities performed on pavement and bridges unavoidably affect flows of traffic and cause delay to users. Activities related to roadside elements and some traffic control devices may, however, be managed without a major traffic disruption.

The differences between different highway facilities are also reflected in their life-cycle spans. Table 2 shows the range of life cycles for each facility type. The varied life-cycle spans among the facilities along with the difference in the type of services provided make it necessary for highway agencies to adopt different management strategies for each facility.

Because of such differences in service characteristics, it is a common practice in field operation to consider management of different facilities independently. The classification of highway facilities, however, does not end here. Within the broad category of four major highway facilities identified in Figure 1, it is often necessary to subdivide them further into types of similar physical and service features. Table 3 gives examples of facility element types commonly found in a highway network.

The significant implication of the multielement structure of highway facilities is that each subsystem would compete for funds and other resources such as manpower, equipment, and materials within the same highway organization. The overall effectiveness of a highway system depends on the levels of service provided by the individual subsystems. Because resources are limited, an optimal allocation among the various subsystems must be formulated. Because each facility element has a different impact toward achieving various objectives of the total highway system, the relative importance of these facility elements needs to be assessed for a logical resource allocation.

Although there exist many management subsystems by facility element types, and they may differ in technical details and emphases, one must recognize that the sequence of functional activities in each and the objectives for all these subsystems remain the same. Discussions on these two aspects of management systems follow.

Operational Functions

It is clear from the matrix structure, shown in Figure 1 and Table 1, that in the management of each highway facility element, the following operational functions are involved: planning, design, construction, condition evaluation, maintenance, improvement, and data management. Some of these functions may be combined in some agencies, and some of them may be further subdivided. The basic functional aspects, however, remain the same. The concept of systems approach in carrying out these highway operational functions, in the area of highway pavement management in particular, has been frequently addressed in the literature since the 1960s (*2,3,6,7*).

Figure 2 shows the functional activities involved in a typical management system of a highway facility. The planning phase deals with the preparation of capital expenditure programs for highways as a whole based on overall road needs including facility expansion and system preservation. The planning phase covers demand analysis and estimation of facility needs to accommodate the current and future traffic. There are many priority programming methods available for selecting highway capital projects, although project selections are often made on the basis of historical trends or regional needs estimates.

The design phase is a subsystem that generates alternative facility configurations, analyzes these alternatives, and evaluates and selects the optimal configuration. Construction involves the management of budget, time, people, equipment, and materials to transform designs into physical realities. The major concerns of the construction phase are preparation of specifications and contract documents, scheduling of construction activities, control of costs and quality of construction, and monitoring of work progress.

The next three functional activities, condition evaluation, maintenance, and improvement, are the main focus of most facility management systems. Condition evaluation includes facility condition survey, analysis and prediction of facility performance, and decision analysis on actions required. A facility condition would include not only the physical condition of the facility, but also the traffic service. The decision analysis is usually a trade-off analysis to select facilities for either the maintenance or improvement program. An improvement program would include both condition improvement, such as resurfacing of pavements and bridge decks, and facility expansion, such as widening of roads and bridges. Often, the function of condition evaluation is included in the planning function.

AASHTO (*8*) defines highway maintenance as a program to preserve and repair a system of roadways with its elements to its designed or accepted configuration. Highway maintenance activities are distinguished from improvement programs by either the scale of operation in terms of the extent of work performed (*8*) or by the mode of operation according to whether the work is performed by highway agency maintenance crew or by contractors (*9*).

Data management is a vital link in any management system. It covers acquisition and compilation of data, organization and updating of data bases, and provision of efficient retrieval of relevant data. Figure 2 also illustrates the important role of data management in coordinating various functional activities within a subsystem, as well as those activities in other subsystems, through a continuous transfer and exchange of information.

TABLE 2 LIFE CYCLE SPANS OF HIGHWAY FACILITIES (*5*)

Highway Facility	Life Cycle Span (yr)
1. Pavements	
Flexible	15–20
Rigid	35–40
2. Bridges	25–50
3. Traffic Control	
Signs	1–3
Pavement markings	1–3
4. Roadside	
Drainage structures	25–50
Right of way	100–150

TABLE 3 LIST OF HIGHWAY FACILITY TYPES

Pavement	Bridge	Roadside Facility	Traffic Control Devices
1. Flexible	1. Concrete	1. Guardrails/barriers	1. Signs
2. Rigid	2. Steel	2. Utility poles	2. Pavement markings
3. Composite	3. Timber	3. Drainage	3. Traffic lights
4. Interlocking	4. Other	4. Rest areas	
5. Unpaved roads		5. Rights of way	

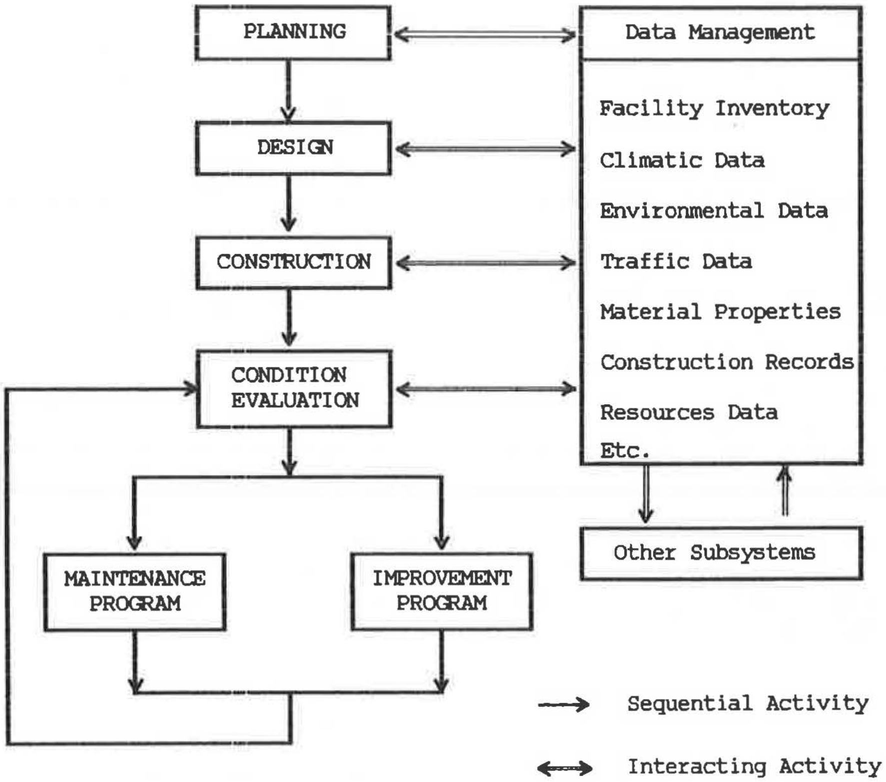


FIGURE 2 Activities in the management system of a highway facility.

System Objectives

The highway management process is a multiple-objective problem. As listed in Table 1, the major objectives may include the following: provision of an adequate level-of-service for traffic, preservation of facility condition at or above a desired level, achievement of a high level of traffic safety, minimization of agency and user costs, maximization of socioeconomic benefits, and minimization of the use of environmental and energy resources. The ultimate goal of a highway program is to satisfy these objectives as closely as possible within the constraints of available budgets.

To facilitate highway management programming purpose, the system objectives can be assessed quantitatively by means of highway performance indicators. In Table 4 are listed, for various highway facilities, a set of performance indicators that can be considered for each system objective. Performance indicators are useful in a number of ways. Because they provide indications of the degree of fulfillment of system objectives, priority ranking of facilities can be established based on the relative values of performance indicators. They can also be used for comparison of the effectiveness or adequacy of alternative design schemes, or maintenance and improvement strategies. Last but not least, they can be easily incorporated into a mathematical optimization programming model for highway management (*11,16,17*).

As in any complex multiple-objective system, contradictions exist in fulfilling the various system objectives of highway management. For instance, maximizing traffic volume/capacity ratio necessarily brings about an increase in noise and air pollution and accelerates the physical deterioration of pavements and bridges. The provision of wider lanes and shoulders improves highway safety and traffic flow, but it results in a corresponding increase in capital investment and an increase in the consumption of land and environmental resources. These examples illustrate the nature of the highway system management problem. It is not possible to achieve a complete fulfillment of all objectives simultaneously. Instead, one has to strive for a suitable mix of actions that will ensure the best achievement of system objectives without violating any constraint.

Requirements of Highway Management Systems

The primary function of a highway management system is to serve as a decision making tool for highway agencies. Toward this end, the system must satisfy the following criteria:

- *Comprehensiveness:* A highway management system must address all major issues affecting the performance of highways. Elements in the three dimensions of the matrix structure of highway systems must be considered. Because of the multiple-objective nature of the system, solutions developed for individual subsystems or for a single objective are unlikely to be globally optimal for the total highway system.
- *Flexibility:* The management system must be flexible to accommodate variations in different regions of a highway network. Such variations include functional classes of highways, unit costs of highway activities, priorities among system objectives, preferences over different highway functional activities, differences in climatic and environmental conditions, and so on.
- *Applicability:* In order to be useful to top managers at different levels, the management system must be tailored in

TABLE 4 PERFORMANCE INDICATORS FOR HIGHWAY SYSTEM OBJECTIVES

Objective / Facility	Service	Condition	Safety	Cost	Socio-Economic Factors	Energy
Pavement	1. Volume/Capacity ratio 2. Travel speed [10,11]	1. Structural capacity 2. Pavement distress severity 3. Serviceability [3,12]	1. Skid resistance 2. Geometric alignments 3. Lane width 4. Shoulder width Occurrences of accidents [10,11,12]	1. Agency costs 2. User vehicle operating costs [3,12]	1. Noise level 2. Air pollution level 3. Visual quality [10,11,13]	1. Fuel consumption [10,11]
Bridge	1. Clear deck width 2. Vertical clearance 3. Traffic speed [14,15]	1. Load capacity 2. Remaining service life 3. Deck, superstructure and substructure deterioration index [14,15]	1. Load capacity 2. Clear deck width 3. Occurrences of accidents [14,15]	1. Agency costs 2. User costs [14]	1. Travel time savings 2. Visual quality 3. Saving in accident costs [13,14]	1. Fuel consumption [10,11]
Roadside Facility	1. Travel speed 2. Clear roadway width [20,21,22]	1. Structural adequacy 2. Deflection/ Displacement 3. Ditch erosion [20,21]	1. Impact performance 2. Occupant risk 3. Roadside slope [20,21,22]	1. Agency costs 2. User costs [21,23]	1. Saving in accident costs 2. Visual quality [20,22]	1. Fuel consumption [10,11]
Traffic Control Devices	1. Volume/Capacity ratio 2. Delay time [18]	1. Visibility 2. Physical deterioration [18,19]	1. Sight distance 2. Luminance [18,19]	1. Agency costs 2. User costs [18]	1. Travel time delay 2. Fuel waste 3. Pollution 4. Driver satisfaction [13,18]	1. Fuel consumption [18]

accordance with the organizational structure of an agency to ensure continuity in management operations.

- *Sensitivity:* To be a good strategic decision making aid, the management system must be capable of analyzing the impacts of changing macroeconomic factors such as inflation, energy price and availability, changes in automobile and truck characteristics, and changes in type and intensity of traffic loadings. It should also be capable of analyzing the implications of different highway policy decisions such as relative emphases of various system objectives among and within highway classes, performance standards for various highway classes, and priorities for different activities.

LIMITATIONS OF EXISTING MANAGEMENT SYSTEMS

The concept of total highway system management provides a useful yardstick to assess the adequacy of existing management systems for highways. Major areas of deficiency of common management systems in use today are highlighted and discussed in the following sections. Because pavement management systems are the most developed of all highway facility management systems, they are used to illustrate the points presented.

Lack of Comprehensiveness

Listed in Table 5 are the results of a literature review showing representative work reported in the last two decades on programming procedures used in management of highway pavements. A great majority of the procedures produced solutions that optimized only one single system objective. Most of these single-objective procedures sought to optimize pavement conditions under the constraints of budget and other resource constraints; others selected projects to minimize agency costs or maximize user benefits.

TABLE 5 PROGRAMMING PROCEDURES IN HIGHWAY PAVEMENT MANAGEMENT

Study	Objectives	Techniques	Application
1. Gulbrandsen 1967 [26]	Single	Dynamic Programming	Resource Allocation
2. Lemer & Moavenzadeh 1970 [29]	Single	Repeated Trials	Project Level Programming
3. Hutchinson 1972 [27]	Single	Benefit-Cost Analysis	Investment Programming
4. TRANS 1973 [17]	Multiple	Investment Return Analysis	Resource Allocation
5. Chapman 1973 [25]	Single	Dynamic Programming	Construction Investment
6. Rankin 1973 [32]	Single	Unconstrained Technique	Funds Allocation
7. Carstens 1973 [24]	Single	Dynamic Programming	Project Selection
8. Lu & Lytton 1976 [30]	Single	Integer Programming	Rehabilitation & Maintenance
9. Knox et al. 1976 [28]	Multiple	Judgmental	Improvement Programming
10. HIAP 1976 [16]	Multiple	Ranking by Cost-Effectiveness	Investment Programming
11. Robinson 1976 [31]	Single	Direct Estimation	Project Evaluation
12. TRRL 1976 [34]	Single	Cost-Benefit Analysis	Project Evaluation
13. PIAP 1978 [33]	Multiple	Ranking by Cost-Effectiveness	Highway System Programming
14. Mahoney et al. 1978 [35]	Single	Integer Programming	Rehabilitation & Maintenance
15. Zegeer et al. 1981 [36]	Multiple	Dynamic Programming	Resurfacing Projects Selection
16. Muthusubramanyam 1982 [11]	Multiple	Goal Programming	Maintenance & Rehabilitation
17. Colucci-Rios 1984 [37]	Single	Integer Programming	Maintenance & Rehabilitation
18. Kher and Cook 1985 [38]	Single	Linear Programming	Rehabilitation Investment
19. Shahin et al. 1985 [39]	Single	Incremental Benefit-Cost Technique	Maintenance & Rehabilitation
20. Markow et al. 1987 [40]	Single	Dynamic Control Theory	Maintenance & Rehabilitation
21. Fwa et al. 1988 [41]	Single	Integer Programming	Highway Maintenance
22. Feighan et al. 1988 [42]	Single	Markov Chain Dynamic Programming	Pavement Maintenance & Rehabilitation

Of the few approaches that considered multiple objectives, however, none had included a broad range of objectives mentioned in Table 1. The TRANS model (*17*) evaluated user and external impacts, whereas the Highway Investment Analysis Package (HIAP) (*16*) maximized either user benefits or one of several accident reduction measures. Knox et al. (*28*) described the highway programming and techniques developed in Illinois. Although recognizing the multiple objective and dynamic nature of the problem, the methodology is essentially an exhaustive listing of alternative solutions, and specific projects were selected based on interactive judgments of district and central officials. Zegeer et al. (*36*) considered user and agency costs and energy and socioeconomic factors in a dynamic programming model for resurfacing project selection.

A major contribution in this field is the Performance Investment Analysis Process (PIAP) (*33*), which was developed for estimating existing and future highway system performance and for determining appropriate investment levels and program priorities. Each highway section is examined for a deficiency in a prioritized order—new location, operating speed, traffic volume/capacity ratio, lane or approach width, alignment, and surface type and condition—until one deficiency is found. Only one deficiency is determined for each section. A ranking process is then employed to select improvement projects under a given investment level. Mathematical optimization was not used in the analysis.

An example of the multiobjective approach was presented by Muthusubramanyam (*11*) who developed a goal programming technique to analyze the impacts of highway improvement and maintenance policies. The following seven highway activities were considered: reconstruction, major widening, minor widening, restoration, resurfacing, safety and traffic engineering improvements, and routine maintenance. Five system objectives were considered for simultaneous optimization. They were pavement condition, level-of-service for traffic, safety, energy, and air pollution. The approach, although applied only to pavement related activities, can be extended to cover more activities and system objectives, if desired.

A literature review indicates that there is a general lack of comprehensiveness in the management systems currently in use. There is a high risk of accepting suboptimal solutions in management systems that do not address adequately the major issues identified in Table 1. For instance, most pavement management systems do not consider level-of-service for traffic and user costs in their analyses. Because pavement condition is the measure of effectiveness in most pavement management systems, a highway section in need of both widening and resurfacing would be considered only for resurfacing. However, a better solution would be to widen and resurface the section, leading to better flow of traffic, reduced congestion, lower vehicle operating costs, and likely slower rate of pavement deterioration.

Lack of Systems Coordination

Most of the current management systems have been developed in virtual isolation from each other. Highway agencies adopt the practical approach of developing management subsystems within the constraint of their organizational structures. Thus, the purpose of management systems is to serve the needs of a specific division or unit rather than the overall objectives of the agency. Unfortunately, this has led to a lack of coordination and often to a duplication of efforts. Figure 3 illustrates a case of poor system coordination commonly found in practice.

A pavement management system (PMS) encompasses various functional activities on pavements, including their maintenance. A maintenance management system (MMS) involves managing maintenance of all highway facility elements including pavements. Both PMS and MMS therefore have, as a component of their system, a pavement maintenance management system (PMMS), a term commonly used in the literature. Problems arise in the following areas:

- The thrust of MMSs is resource management (labor, material, and equipment) with the primary measure of effectiveness being work productivity or accomplishments per day. On the other hand, PMSs are directed mainly toward facility management with the primary objective being the improvement of pavement condition. Although PMSs are envisioned to encompass all activities related to pavements, most common elements are 4R-type improvement projects involving reconstruction, rehabilitation, restoration, and resurfacing.
- Pavement improvement and maintenance activities are performed separately and by different units in a highway agency. Although improvement activities may involve planning and construction divisions, maintenance activities are planned and implementated by maintenance divisions in most highway agencies. There is little exchange of information between these two functions, often causing expensive duplication of efforts. For example, some highway sections may be resurfaced only a few months after receiving such expensive maintenance work as seal coating. A coordinated program could save substantial amounts of both agency and user costs.
- The forms of pavement condition data required for planning of pavement improvement and maintenance works are quite different (*43,44*). Aggregate pavement performance data are useful for trade-off analyses between the two types of activities and are appropriate for improvement planning. They are, however, not adequate for programming and scheduling of routine maintenance activities. Many PMSs specify condition surveys without giving due consideration to the data requirements for maintenance management.

The problems of poor coordination are not unique to the area of pavement management. It is easy to visualize by looking at the illustration in Figure 3 that similar conflicts can exist for other facility management systems if proper coordination is not ensured.

Relationships of Functional Activities

The primary purpose of a highway agency is to provide a quality service at a reasonable cost to the users and taxpayers. In this effort, the common goal of all individual organizational units and functional activities within an agency is to see that the objectives of the agency are fulfilled. Consequently, an important dimension of the total highway management concept is to emphasize the interrelationships among different functional activities. A common weakness of today's highway management approaches is a sort of "Balkanization," or fragmentation, of efforts. In addition, there is often a sense of

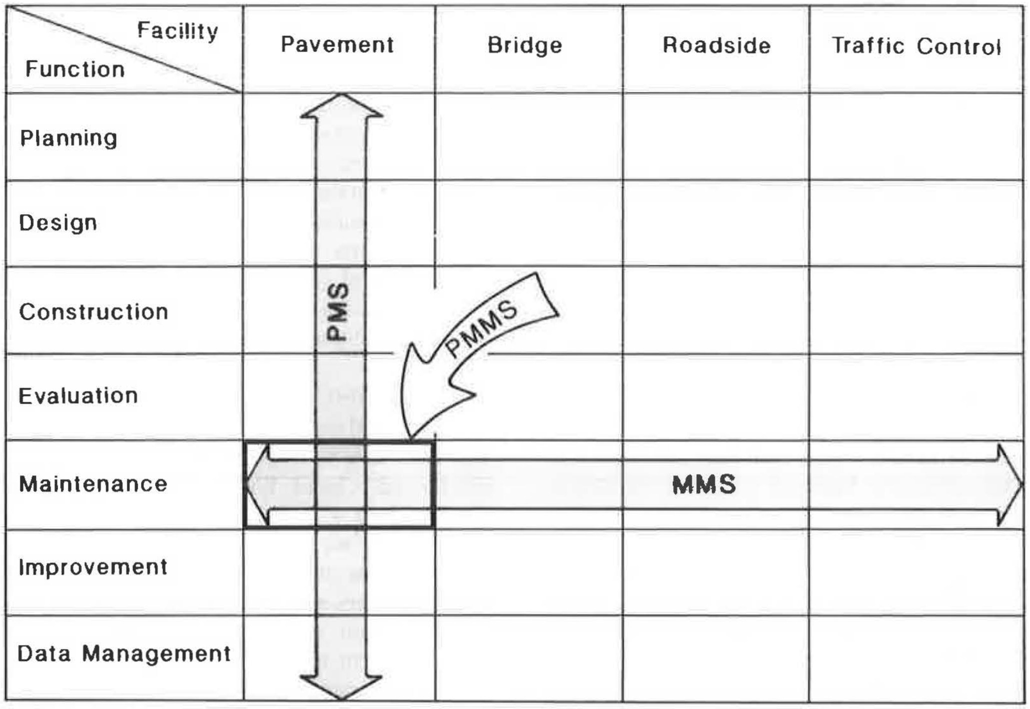


FIGURE 3 Relationships between a pavement management system (PMS), pavement maintenance management system (PMMS), and maintenance management system (MMS).

"territorial sovereignty" among the organizational units performing such functions as planning, design, construction, maintenance, and so on. The loyalty of individuals within a particular unit or division often does not reach beyond the limits of that unit. The development and implementation of specific management systems along the work functions of individual organizational units foster and institutionalize the tendencies toward "Balkanization" and territorial claims. This situation has become apparent at several state highway agencies where efforts have been made to implement pavement management systems. A strong resistance has been offered by maintenance and other divisions against the development of a common data base in the fear of being "taken over." In this connection, it must be pointed out that there is an utter lack of research information on such items as the effect of maintenance activities on facility performance and service lives. Consequently, many activities are performed without any clear idea about their usefulness or effectiveness.

A life-cycle cost-analysis approach in the management of highway pavements has been proposed by Markow (*45*). Life-cycle cost analyses, if properly formulated, can help one to understand the roles of various functional activities, such as maintenance and improvement, in influencing the performance of highway pavements. The same concept is also applicable to the management of other highway facilities. Much research and implementation work is, however, still needed in this direction.

Quality of Data Management

The importance of data management has been depicted in the flowchart in Figure 2. One of the major challenges to highway agencies is the establishment and upkeep of the flow of information between various subsystems of the highway system. Information flow channels should allow various subsystem decision makers access to all information collected and enable them to analyze strategies in the area of their responsibility. The information presented in Figure 3 implies that an efficient data management system must allow free flow of information in both vertical and horizontal directions of the matrix structure.

Lack of relevant information greatly impairs the proper functioning of a highway management system. This is a common problem with pavement maintenance. Maintenance planners often receive little information on construction or design, although such data have a direct impact on formulation of maintenance programs and policies. Many maintenance planners also are not informed well in advance of pavement rehabilitation decisions in order to make necessary adjustments to their maintenance programs.

There appear to be two schools of thought in terms of data management systems. Many highway agencies are developing comprehensive data systems on large mainframe computers. Such large systems have been found costly and difficult to maintain (*46*). With the emergence of microcomputers, the concept of integrated information systems is gaining acceptance by more and more highway agencies (*46,47*). Whatever the system adopted, the following basic requirements have to be fulfilled (*48*): (a) a common reference for all subsystems, (b) immediate accessibility to users of different management levels, and (c) easy data updating at regular intervals.

Organizational Structure

Most highway agencies have an organizational structure in which functions such as planning, design, construction, and others are centrally managed with districts and subdistricts performing field operations of construction and maintenance. In recent years, there have been some agencies that have decentralized much of the decision making process with districts taking direct responsibilities for selecting construction, improvement, and maintenance projects. In either case, the potentials offered by the information and communication technologies have not been explored and the effective application of management systems has remained far from being accomplished. To accommodate installation of highway management systems, the management structure and operational system of highway agencies may need to be revised.

Byrd and Sinha (*43*) proposed two alternative organizational structures that could enhance the integration of PMS and MMS in a highway management system. The first alternative is a separate organizational unit that is responsible for data management, program planning, and scheduling of all pavement maintenance and improvement activities. The other alternative is the establishment of a coordinating committee that serves as the advisory group for all pavement functional activities. This concept can be extended to fit the operational requirements of a highway management system into any existing highway organization.

Linkage to Pricing and Taxation

An important function of a highway management system can be to monitor the cost responsibilities of various user groups in terms of damages caused and system use. Appropriate information on facility performance and traffic loadings can assist in determining proper pricing and taxation policies. At present, highway cost-allocation studies are occasionally undertaken by state highway agencies, as a part of a legislative move to raise highway user fees. Instead, a periodic analysis of cost responsibilities and revenue contributions of various vehicle groups can be routinely performed as a part of highway management systems.

CONCLUSION

About two decades ago, MMSs were developed primarily to manage resources for highway routine maintenance. PMSs have since then been developed and implemented in some states and local agencies to make decisions regarding pavement resurfacing and other improvement activities. At present, much work is under way in the area of bridge management systems. All of these management systems have unique data requirements and specific purposes to serve. The implementation of these separate systems is a piecemeal approach that does not optimally serve an agency's management objectives.

Both MMSs and PMSs have so far served well their intended specific purposes. However, the need for consideration of a total highway system management requires that individual subsystems be realigned. For example, MMSs must also consider the condition of pavement, structure, drainage, and other highway facility elements in addition to the management of labor, material, and equipment. At the same time, the preoccupation of PMSs with pavement and shoulder conditions must change to include such items as the traffic level-of-service so that decisions regarding surface improvements can be made in conjunction with facility expansion such as widening and lane additions. This is particularly important in view of the growing concern about congestion in many metropolitan corridors and the inability of the highway system to cope with traffic demands.

In the coming years, state highway agencies will have to face more and more the challenge of legislative scrutiny and accountability with respect to highway budgets. In this connection, it will be necessary for top highway managers to have quick access to facility management information systems. In addition, questions are being raised about the role of highways in economic development. This issue is becoming an important factor in highway budgeting decisions in many state legislatures. Consequently, highway managers must start to broaden their perspectives and take account of how the highway system serves the state and local economy and to what extent new investment can stimulate growth. Highway management systems, therefore, must also have the ability to incorporate economic potentials in investment decisions and, thus, would also serve as a tool for long-range planning.

REFERENCES

1. A. B. Moe. Pavement Maintenance. In *Highway Research Record 40*, HRB, National Research Council, Washington, D.C., 1963, pp. 13–17.
2. W. S. Housel. Evaluation of Pavement Performance Related to Design, Construction, Maintenance, and Operations. In *Highway Research Record 46*, HRB, National Research Council, Washington, D.C., 1964, pp. 135–153.
3. R. Haas and W. R. Hudson. *Pavement Management Systems*. McGraw-Hill Book Company, New York, 1978.
4. *Strategic Highway Research Program Research Plans*. Final Report. TRB, National Research Council, Washington, D.C., May 1986.
5. J. H. Shortreen. Transportation Investment Decisions. *RTAC Forum*. Road and Transportation Association of Canada, Ottawa, Ontario, Vol. 1, No. 4, 1978.
6. W. R. Hudson, F. N. Finn, B. F. McCullough, K. Nair, and B. A. Vallerga. *Systems Approach to Pavement Design*. Final Report for NCHRP Project 1-10. Materials Research and Development, Inc., March 1968.
7. R. Haas. General Concepts of Systems Analysis as Applied to Pavements. In *Transportation Research Record 512*, TRB, National Research Council, Washington, D.C., 1974, pp. 3–15.
8. *AASHTO Maintenance Manual*. AASHTO, Washington, D.C., 1987.
9. E. A. Sharaf. *Analysis of Highway Routine Maintenance Costs*. Ph.D. thesis. School of Civil Engineering, Purdue University, Lafayette, Ind., 1984.
10. K. Hu. *Macro-Assessment of Impact of Highway Improvement and Maintenance Activities*. M.S. thesis. School of Civil Engineering, Purdue University, Lafayette, Ind., 1982.
11. M. Muthusubramanyam. *Highway Improvement and Preservation under Limited Financial Resources—An Application of Multi-Objective Optimization*. Ph.D. thesis. School of Civil Engineering, Purdue University, Lafayette, Ind., 1981.
12. *Pavement Management Guide*. Roads and Transportation Association of Canada, Ottawa, Ontario, 1977.
13. E. R. Alexander and E. A. Beimborn. Sensitivity Analysis of Multiple-Choice Decision Methods for Transportation. In *Transportation Research Record 1124*, TRB, National Research Council, Washington, D.C., 1987, pp. 36–42.
14. *Bridge Management Systems*. FHWA-DP-71-01. FHWA, U.S. Department of Transportation, March 1987.
15. C. F. Galambos. Bridge Design, Maintenance, and Management. *Public Roads*, Vol. 50, No. 4, 1987.
16. J. E. Gruver, F. P. Patron, J. H. Batchelder, and R. D. Juster. Highway Investment Analysis Package. In *Transportation Research Record 599*, TRB, National Research Council, Washington, D.C., 1976, pp. 13–18.

17. D. S. Gendell, T. J. Hillegass, and H. Kassoff. Effects of Varying Policies and Assumptions on National Highway Requirements. In *Highway Research Record 458*, HRB, National Research Council, Washington, D.C., 1973, pp. 21–30.
18. *Management of Traffic Control Systems*. Instructor's Notebook. FHWA, U.S. Department of Transportation, n.d.
19. J. F. Paniati, D. J. Mace, and R. S. Hostetter. A Sign Management System to Maintain Sign Visibility at Night. *Public Roads*, Vol. 50, No. 4, 1986.
20. *NCHRP Report 230: Recommended Procedures for the Safety Performance Evaluation of Highway Appurtenances*. TRB, National Research Council, Washington, D.C., 1981, 42 pp.
21. G. J. Malasheskie. Development of Condition Surveys and Inventories for Guard Rail and Drainage Facilities. In *Transportation Research Record 1065*, TRB, National Research Council, Washington, D.C., 1986, pp. 38–44.
22. *A Policy on Geometric Design of Highways and Streets*. AASHTO, Washington, D.C., 1984.
23. D. L. Sicking and H. E. Ross. Benefit-Cost Analysis of Roadside Safety Alternatives. In *Transportation Research Record 1065*, TRB, National Research Council, Washington, D.C., 1986, pp. 98–105.
24. R. L. Carstens. Optimizing Economic Returns on Highway Investments. *Transportation Engineering Journal*, ASCE, Vol. 102, No. TE 4, 1976, pp. 665–672.
25. L. D. Chapman. Investing in Region Highway Networks. *Transportation Engineering Journal*, ASCE, Vol. 99, No. 2, 1973.
26. O. Gulbrandsen. Optimal Priority Rating of Resources Allocation by Dynamic Programming. *Transportation Science*, Vol. 1, 1977.
27. B. A. Hutchinson. Programming of Regional Highway Investments. *Transportation Engineering Journal*, ASCE, Vol. 98, No TE 3, 1972.
28. R. R. Knox, K. M. Theodore, and W. J. Yuskus. Programming Highway Improvements in New Funding Environments. In *Transportation Research Record 599*, TRB, National Research Council, Washington, D.C., 1976, pp. 7–12.
29. A. C. Lemer and F. Moavenzadeh. The Analysis of Highway Pavement Systems. In *Highway Research Record 337*, HRB, National Research Council, Washington, D.C., 1970, pp. 78–85.
30. D. Y. Lu and R. L. Lytton. Strategic Planning for Pavement Rehabilitation and Maintenance Management System. In *Transportation Research Record 598*, TRB, National Research Council, Washington, D.C., 1976, pp. 29–35.
31. D. A. Robinson. Highway Maintenance Economics. *Highways and Road Construction*. Vol. 43, No. 1791, 1975.
32. W. W. Rankin and R. J. Oravec. Allocation and Apportionment of Highway Funds. *Transportation Engineering Journal*, ASCE, Vol. 99, No. 2, 1973.
33. Performance Investment Analysis Process. FHWA, U.S. Department of Transportation, 1978.
34. *Road Transport Investment Model*. Supplementary Report 224 UC. Transportation and Road Research Laboratory, Crowthorne, Berkshire, United Kingdom, 1976.
35. J. P. Mahoney, N. U. Ahmed and R. L. Lytton. Optimization of Pavement Rehabilitation and Maintenance Using Integer Programming. In *Transportation Research Record 674*, TRB, National Research Council, Washington, D.C., 1978, pp. 15–22.
36. M. A. Zegeer, K. R. Agent, and R. L. Rizenbergs. Economic Analyses and Dynamic Programming in Resurfacing Project Selection. In *Transportation Research Record 814*, TRB, National Research Council, Washington, D.C., 1981, pp. 1–8.
37. B. Colucci-Rios. Development of a Method for Establishing Maintenance Priorities for the Pavement Management System in Indiana. Ph.D. thesis. School of Civil Engineering, Purdue University, Lafayette, Ind., 1984.
38. R. K. Kher and W. D. Cook. PARS, the MTC Program, and Financial Planning in Pavement Rehabilitation. *Proc., North American Pavement Management Conference*, Toronto, Ontario, Canada, Vol. 2, March 18–21, 1985.
39. M. Y. Shahin, S. D. Kohn, R. L. Lytton, and W. F. McFarland. Pavement M&R Budget Optimization Using the Incremental Benefit-Cost Technique. *Proc., North American Pavement Management Conference*, Toronto, Ontario, Canada, Vol. 2, March 18–21, 1985.
40. M. J. Markow, B. D. Brademeyer, J. Sherwood, and W. J. Kenis. The Economic Optimization of Pavement Maintenance and Rehabilitation Policy. *Proc., 2nd North American Conference on Managing Pavements*, Toronto, Ontario, Canada, Vol. 2, November 2–6, 1987.
41. T. F. Fwa, K. C. Sinha, and J. D. N. Riverson. Highway Routine Maintenance Programming at Network Level. *Transportation Engineering Journal*, ASCE, Vol. 114, No. 5, 1988, pp. 539–554.
42. K. J. Feighan, M. J. Shahin, and K. C. Sinha. A Dynamic Programming Approach to Optimization for Pavement Management Systems. *Proc., 2nd North American Conference on Managing Pavements*, Toronto, Ontario, Canada, Vol. 2, November 2–6, 1987.
43. L. G. Byrd and K. C. Sinha. Concepts of Integrating Maintenance Management in Pavement Management. *Proc., 2nd North American Conference on Managing Pavements*, Toronto, Ontario, Canada, Vol. 2, Nov. 2–6, 1987.
44. K. Ksaibati and K. C. Sinha. Development of a Routine Pavement Maintenance Data Base System. In *Transportation Research Record 1109*, TRB, National Research Council, Washington, D.C., 1987, pp. 36–41.
45. M. J. Markow. Concepts, Methods, and Applications Relating to Pavement Maintenance and Rehabilitation. *Proc., North American Pavement Management Conference*, Toronto, Ontario, Canada, Vol. 3, March 18–21, 1985.
46. R. A. Ritcher. Integrated Information Systems for Better Data Management. *Public Roads*, Vol. 50, No. 1, 1986, pp. 11–14.
47. A. Stein, T. Scullion, D. R. Smith and S. Cox. A Microcomputer Based Pavement Rehabilitation and Management System. *Proc., 2nd North American Conference on Managing Pavements*, Toronto, Ontario, Canada, November 2–6, 1987.
48. F. L. Mannering, W. P. Kilareski and D. R. Luhr. Interactive Data Base for Pavement Management. *Proc., North American Pavement Management Conference*, Toronto, Ontario, Canada, March 18–21, 1985.

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

Dredged Material: Its Potential for Ice Control Sand Replacement

M. William Newstrand

Every year the St. Paul District of the Corps of Engineers dredges huge volumes of sediment from the Mississippi, St. Croix, and Minnesota rivers in Minnesota. That dredged material is deposited in established corps upland disposal sites. The corps makes the material available for public and private use at no cost. A study was conducted to analyze the acceptability of the material and the cost benefits for the Minnesota Department of Transportation (Mn/DOT) and the corps, with Mn/DOT's use of the dredged material as road ice control sand. The findings were as follows: (a) Mn/DOT could realize considerable savings through the use of dredged material as ice control sand; the savings would be significant even with the purchase or lease of a portable screener; (b) field tests demonstrated that the material was of the same or better quality as commercially supplied sand and that it is effective for ice control; and (c) this use of the dredged material helps retard the rate of filling of corps disposal sites, which helps reduce corps operations costs.

Every year the St. Paul District of the U.S. Army Corps of Engineers dredges huge volumes of sediment from the Mississippi, Minnesota, and St. Croix rivers in Minnesota. Most of the dredged material is deposited in upland disposal sites where it is available for any beneficial use. The Minnesota Department of Transportation (Mn/DOT) buys thousands of yards of sand each year for ice control on the roads in the same areas where the corps deposits the dredged material. If the dredged material from the river could be used for ice control purposes it would produce a twofold benefit: Mn/DOT's maintenance costs would go down and the corps would fill its costly disposal sites at a reduced rate.

Environmental protection regulations in Minnesota place restrictive parameters on dredged material disposal site locations. In each pool of the river in the St. Paul District of the corps, there are at the most only one or two approved primary and one or two secondary sites. The restricted number of disposal sites in each pool forces the corps to transport the dredged material considerable distances, which adds to dredging costs.

Transportation of the dredge material becomes even more costly with the need to move to the secondary sites. Reducing the rate of filling the primary sites by using the material would help control Corps of Engineers' costs. That becomes more important with each renewed effort to charge channel maintenance costs to commercial navigation users of the river.

The use of dredged material as ice control sand is an established practice with some of the Minnesota and Wisconsin river city and county road agencies. Those organizations use roller sanders, which spread the sand by gravity over a single highway lane. Mn/DOT uses sanding trucks, which pour the sand on a rapidly revolving disc to create coverage of two or three lanes. The revolving disc also creates fairly high velocity projection of pebbles or pieces of wood or metal that might be in the sand. For that reason it was assumed that a screening machine would be necessary for removing the larger pebbles and other potential projectiles from the dredged material.

The study's main areas of concern, then, were to determine if the material was usable and if the savings realized by its use would cover the cost of a screening machine.

Eight existing Corps of Engineers disposal sites were sampled to determine if the dredged material they contained would meet Mn/DOT standards for ice control sand. The locations of the sites are shown in Figure 1. Samples of dredged material were taken from the sites and sieve analyses were made of the samples. The results were compared with the results of sieve tests of commercially supplied road sand in the three Mn/DOT districts that border the rivers. In most instances the results showed that the dredged material not only satisfied Mn/DOT specification requirements but was of the same or better quality as purchased sand. Only one location on the Mississippi contained material that was unusable. Sand from Disposal Location 8, at Brownsville, proved to be either too fine or too silty. Table 1 presents the results of the sieve tests. The table shows Mn/DOT requirements and the percentages of the material that passed through each size screen.

The existing corps disposal sites provide a potential supply for truck stations in Mn/DOT's Maintenance Districts 5 and 6, as shown in Figure 1. At present, there are no functioning sites in Mn/DOT District 9. However, planned dredging will require a site near Lock and Dam 2, in Hastings, which could supply truck stations in that district. Sand quality in the Hastings area, as determined from random samples of older dredgings, appears to be acceptable.

All of the corps' disposal sites would provide continuous supplies of dredged material well in excess of Mn/DOT's needs. Mn/DOT's needs in the river districts would average about 40,000 yd^3 annually and the corps dredges an average of 900,000 yd^3 of materials each year. However, dredging volumes do fluctuate and surpluses from one year might be usable in following years. All of the beneficial users, including Mn/DOT, will probably not strain the supplies available from the corps.

The study's second phase involved determination of size requirements and the relative benefits of leasing or purchasing a portable screener. It was determined that a portable screener was most acceptable. None of the three Mn/DOT districts would need a screener for more than a few weeks each year to allow time to screen a winter's supply. Portability would

Ports and Waterways, Minnesota Department of Transportation, Transportation Building, Room 810, St. Paul, Minn. 55155.

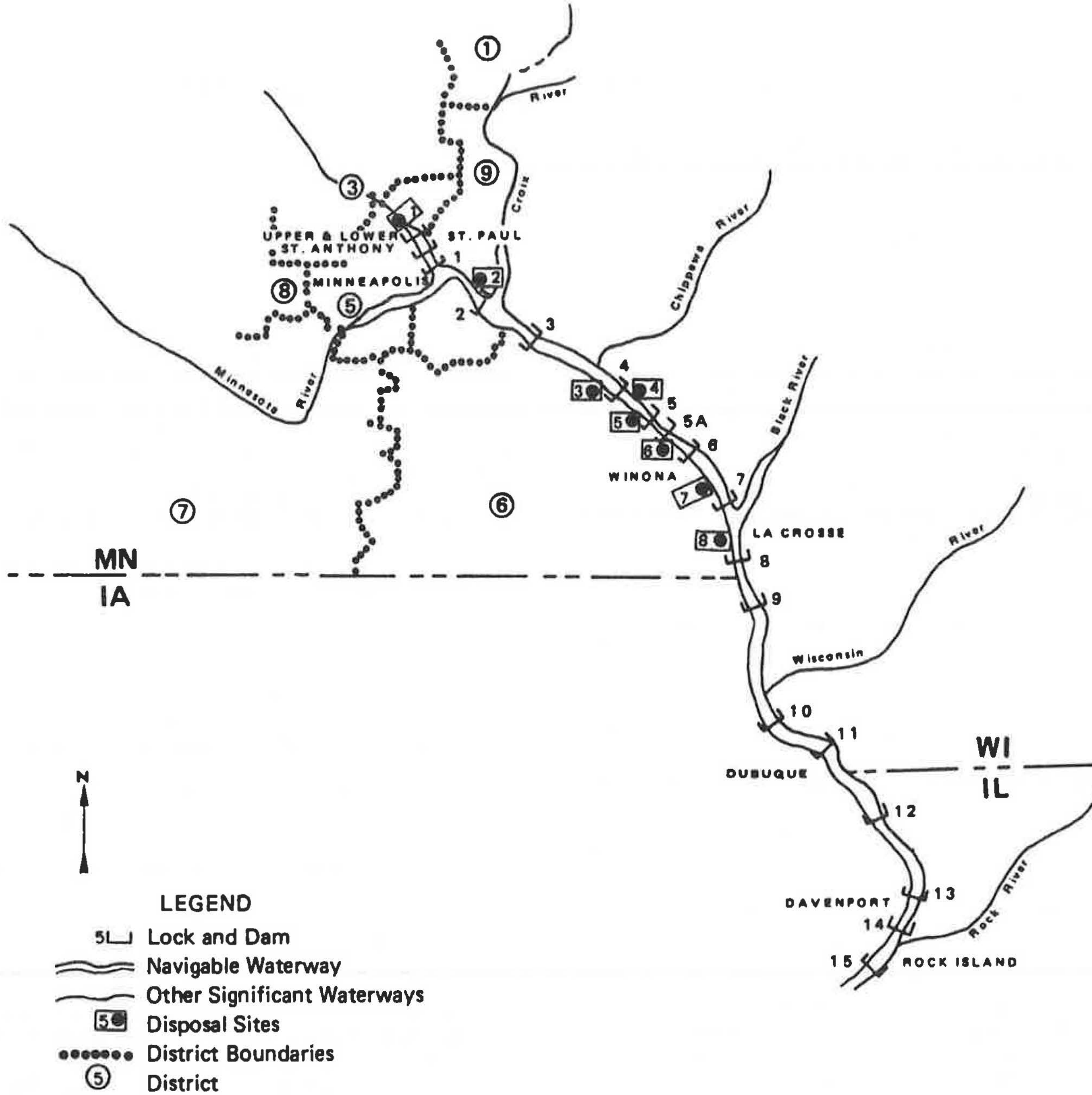


FIGURE 1 Upper Mississippi River.

allow use by each river district, in turn, and even allow movement to Duluth should tests of dredged material in that harbor prove the material usable for ice control purposes.

Results of the screener analysis showed that Mn/DOT could most effectively use a screener with a capacity of 100 tons per hour. Analysis showed that leasing would cost $20,340/year for the anticipated 10-year life of the machine, and purchase of the machine would cost $9,340 for each of the 10 years, including anticipated maintenance. The analysis of screener needs and costs included a determination of the numbers and sizes of screens needed, volumes of material that would be screened, and the number of probable screener operating days in each of the districts.

The final study analysis included a review of truck, material, and labor costs for existing sanding operations and a determination of changes in those costs that would result from the use of dredged material. That analysis demonstrates the potential for substantial savings for Mn/DOT's ice control program in the three districts.

Fixed costs were determined from operating records in each district. A fixed cost multiplier (dollars per load-mile) was calculated separately for each of the three districts because of their operational differences.

One of the variables that changed from district to district was truck size, which made significant differences in fixed costs. At present, District 6 uses both 6- and 12-ton trucks. An average of 9 tons was used in computing the initial fixed costs and operating costs with the addition of a screener. In

TABLE 1 SIEVE TEST RESULTS—PERCENTAGE OF DREDGED MATERIAL PASSING EACH SCREEN

Screen Size	Comm'l Supplier					Corps of Engineers Disposal Sites								Mn/DOT
	A	B	C	D	E	1	2	3	4	5	6	7	8	Standards
1/2"						100	100	100	100	100	100	100		100
3/8"						99	99	100	100	100	99	100		100
#4	100	100	100	100	100	98	99	98	99	99	96	100		95-100
#10	27	90	89	85	82	95	97	96	96	97	92	100		
#20	8	71	60	60	57	86	87	84	77	82	78	97	100	
#40	2	37	50	22	26	40	37	51	35	31	38	76	97	
#80	1	5				1	2	2	1	1	2	3	23	
#100	1	4	3	5	4	1	1	1	0.4	0.5	1	2	16	
#200	0.4	1.6	1.1	1.7	1.5	0.3	0.4	0.5	0.2	0.3	0.7	0.4	5.1	3.0 maximum

Districts 5 and 9, 12-ton trucks are currently in use, so all computations for these districts were based on 12-ton truck use.

For the purpose of costs determination, an average operational day of 6 hr, to allow for necessary nonoperating functions, was used in each district. To compute the dollars per load-mile factor, the number of loads per day one truck would carry was needed. This was determined by using an average of 0.1 hr (6 min) for loading and weighing and 0.083 hr (5 min) for unloading. Screening added 0.1 hr (6 min) to a 9-ton load and 0.133 hr (8 min) for a 12-ton load. There was no significant difference in loading, weighing, and unloading times between the two truck sizes. Travel time was developed for each travel pattern and added to the handling time to produce total load time. This was divided into the 6-hr workday to get loads per day, which in turn was used to produce dollars per load-mile.

In reviewing the results of the analysis, District 6 could save $35,371/year (purchase screen), or $26,232/year (lease screen), using 12-ton trucks for moving the dredged material. Combining Districts 5 and 6, a savings of $49,225/year (purchase) or $38,805/year (lease) could be realized. If all three districts were involved there could be a $84,813/year (purchase) or $73,669/year (lease) savings. Savings for the three districts in total are based on the assumption that the new disposal site near Hastings will have usable dredged material, as would appear to be the case from samples of residue from previous dredging in the area. Because only one screener would be leased or purchased for use in the three districts, the relatively small differences between leasing and purchasing in Districts 5 and 9 by themselves are shown only for comparison.

A field test was made of the ice control effectiveness of dredged material. The material was screened with a small screener currently in use for District 6 maintenance activities. The machine has limited capacity but was able to supply enough sand for a single crew's use during the field test, which ran through the winter of 1985 to 1986.

For the field tests the screened dredged material was mixed with salt and rice rock. The most acceptable mix was 75 percent dredged sand, 10 percent salt, and 15 percent rice rock. Rice rock, which is residue from a local concrete mixing plant operation, was added to enhance the average grain size of the mix. It is the size of rice grains. The 10 percent salt element keeps the storage piles from freezing.

An unexpected finding of the field tests was that the dredged material mixture tended to cake less around the augers in the truck boxes than does commercially supplied sand. This is probably because of the smaller percentage of fines in the river sand, as is shown on Table 1. This pleased the maintenance workers who spent less time with the truck stopped while they worked to free the augers in bad weather.

A side benefit, which was not fully evaluated in this study, was the production of pea rock from the screening process. Pea rock is required in the bituminous patching mix used by Mn/DOT maintenance workers. It has become increasingly costly to purchase pea rock and cheaper substitutes do not have the same properties. Although the quantity of pea rock obtained from the screening would probably not be large, it is a welcome and unexpected windfall.

A final indication of the effectiveness of dredged material as ice control sand was the response of the local aggregate suppliers in District 6. They dropped their prices from $2.60 to $1.00/yd for the 1986 to 1987 season. Because of this dramatic reduction in District 6 costs, Mn/DOT has delayed acquisition of a screener. Even with free sand, the costs of processing and handling exceed the $1.00/yd commercial price. Without the inclusion of District 6, the program—including the purchase or lease of a screener—would not be effective in Districts 5 and 9.

Publication of this paper sponsored by Committee on Inland Water Transportation.

Intercity Bus Stops: Essential Connectors for a Viable Rural System

MARY KIHL

The paper is based on the assumption that reliable, secure bus stops are essential both to maintaining existing ridership and to enticing new riders either from among small town residents or from new feeder networks. The expectation is that unless adequate bus stops are provided and regularly served, potential rural riders will not feel confident to venture out to take the intercity bus. The December 1984 *Intercity Bus Terminal Study* defines an adequate bus station as one that "provides a place to purchase tickets, obtain some schedule information and wait in a sheltered area, perhaps with access to food service and/or rest rooms." Using these criteria as a guide, the current study takes another look at rural bus stops in Iowa, a state well known for its rural orientation. A telephone survey was conducted of a random sample of 43 commission agents in June 1987. Overall, it was found that the majority of agents regard their bus station activities as a type of "community service" operated in addition to another business. They served few passengers and received little financial benefit. Consequently more than 25 percent of the stops surveyed did not meet the established criteria. A fuller recognition of the importance of bus stations in the overall plans for increasing ridership in rural areas is needed.

In a day when deregulation is an accepted modus operandi and profit making is an obvious indicator of success, rural bus service appears to be an anachronism. Since the 1982 Bus Regulatory Reform Act, intercity bus companies have divested themselves of numerous rural routes and reduced the number of stops in many small communities, opting instead for the efficiency that comes with interstate highway through travel and charter service (*1–4*). At the same time, the continuing migration of rural youth toward better employment opportunities in suburbia and exurbia is leaving rural America with a dwindling and increasingly elderly population base (*5*). The majority of those who continue to live in small towns and rural areas have always equated mobility with the family automobile or pickup truck.

Nevertheless, in the face of these overwhelming trends there is a small but significant segment of the population that is not independently mobile. These residents are tied to rural America not only by tradition and sentiment but by fixed incomes and personal investment in homes with limited resale value. This group includes not only the small number of elderly residents who never did drive but also an increasing number of the very elderly who are no longer confident in driving long distances or who have lost their licenses because of physical frailty. They are joined by youth and low-income families with limited personal means of mobility (*6*, p. 9). Together these people do not constitute a sufficient market to entice private bus companies to serve them in the sparsely populated rural area. Nevertheless they do constitute a need for service. For example, a recent study conducted in the northern tier of counties in Nebraska found that 1,300 people were totally dependent on a regional intercity bus for their connection to the broader world. Unfortunately, the carrier had incurred a debt of $114,000/year in order to continue to serve them (*6*, p. 15).

Design Research Institute, Iowa State University, Ames, Iowa 50011.

How to serve the intercity travel need of these rural residents in the face of rising costs has been the focus of a number of news articles and scholarly papers, as well as of a number of public and private experiments. The news articles (*7–9*) have decried the fact that "you can't get there from here anymore," scholarly papers have been devoted to an analysis of the "new vanishing American," the captive bus rider. One recent study of the demand for intercity buses by the elderly on a route in California found that ridership by the elderly on intercity buses was low—about 3.3 percent of the passengers per vehicle-service-hour. What was surprising was not the small number but that only a tiny number of riders were "captive." The rest of the riders were indistinguishable from the elderly who did not ride the bus (*10*, p. 2). The high relative costs of providing service in rural areas have also inspired scholarly papers such as that by Hansen et al. (*11*), who assess the relative high unit costs for service in rural areas of Wisconsin.

Policy analysts who have considered approaches to bolstering the intercity system through increasing ridership have largely emphasized public-private cooperation as a means of blending both public service and private operational efficiency. Feeder systems have long been advocated as a manifestation of this type of public-private cooperation. With rural public transit services retrieving rural residents from small towns and rural areas and transferring them to intercity buses at preestablished stops, the partnership would seem to benefit both the residents' need for longer-distance transportation and the intercity buses' need for increased ridership. This is, of course, the logic behind the new Greyhound Rural Connection Service (*12*).

The Rural Connection Service, which was inaugurated shortly over a year ago, is now operating in 12 states. The program provides for a formal linkage between Greyhound and either public or private rural providers. Passengers are provided with joint ticketing, assured transfers, and the opportunity to make trips across the state or country. The cooperating rural systems benefit from commissions paid by Greyhound Lines based on the distance the respective passengers travel on Greyhound. As of December 1988 there were rural connection programs operating in Alabama, Iowa, Kentucky, Michigan, Nebraska, New York, North Carolina, Oregon, South Carolina, Tennessee, Texas, and Virginia. However, only seven of these programs have been operating for more than a few months, and it is far too soon to judge their ultimate effectiveness (*6*, p. 13; *12, 13*).

A parallel program, the Greyhound Shuttle, goes one step farther by allowing Greyhound commission agents to lease vehicles from Greyhound Lines and to operate them in rural areas or small towns as connectors to Greyhound's intercity system. The program, which is just getting under way, is currently being tried in Sandusky, Ohio (*14*). To date few of these feeder operations have yielded large numbers of additional riders, but the scattered populations in rural areas would make that an unrealistic expectation. The one feeder program that has generated large numbers of riders is the bus-train program in California where population densities are relatively higher than in other states that have tried feeder programs. In California bus-train service has continued to expand over the last 6 years, particularly in regard to the bus link. Three new routes were added in April 1986 and some earlier routes readjusted. Total ridership on these feeders is now close to 250,000 (*15, 16*).

Recognizing that intercity bus travel cannot continue to survive in rural areas unless there are major and consistent efforts to increase ridership, the author of this paper has focused on a frequently overlooked but fairly basic factor in generating ridership for intercity buses—adequate bus stations. The paper is based on the assumption that reliable, secure bus stops are essential both to maintaining existing ridership and to enticing new riders either from among small town residents or from feeder networks. The expectation is that unless adequate bus stops are provided and regularly served, potential rural riders will not feel confident to venture out to take the intercity bus. Similarly, feeder systems without well-publicized connecting points are doomed to be underused. This point was demonstrated by a 1985 UMTA-sponsored 4-I project in Iowa. This program involved five different forms of feeders ranging from taxi to connecting bus service. All linked with Jefferson Lines, a regional intercity bus operator. Over the 6 months of operation, the program did not generate a sufficient number of riders for several reasons, one of which was that potential riders did not trust the system, especially for return trips (*17*, p. 37). They were not confident where and when they would be picked up. The problem was exaggerated when one stop had to be changed three times in 6 months.

A bus route, like any other type of system, must have connectors in order to function. Yet too often the focus has been on route configuration and timing with far less attention to the means of encouraging potential riders to access the system. Fortunately, some states are beginning to recognize the importance of investing in rural bus stops. For example, the state of California has introduced a clean-up, fix-up loan program for local bus stop operators to help them improve safety and their image (*18*). The state of Michigan is also expanding its terminal building program to include building weather-protected passenger shelters in rural areas, recognizing that "dilapidated facilities can discourage the use of intercity buses" (*17*).

In December 1984 the authors of the Intercity Bus Terminal Study (*19*) reported on the need for increased attention to urban bus terminals, but advised against providing any federal assistance for constructing terminals in nonurbanized areas. This was a role to be left to the private carriers. They concluded that "in the majority of states, the private sector solution wherein a private carrier arranges for bus facilities either directly or through an agent who provides retail store space, has been considered adequate (*19*, pp. 87–88). In the study, a distinction was drawn between a terminal as a facility with the primary purpose of furnishing passengers with transportation services and a bus station that sells bus services as a secondary business while its primary business may be that of a retail store, motel, or gas station (*19*, pp. 10–11). Nevertheless, the authors did go on to provide a useful definition of an ideal bus station—one located close to the passengers' origin or destination—one that "provides a place to purchase tickets, obtain some schedule information and wait in a sheltered area, perhaps with access to food service and/or rest rooms" (*19*, p. 10). Such a station should certainly not be beyond the expectations of rural travelers.

However, in 1980 when the researchers of a U.S. Department of Transportation (USDOT) study, took a more indepth look at 374 rural bus stop facilities in Oklahoma, Maryland, Oregon, and Mississippi, they found that 53 percent of the stops were unsheltered, and an additional 6 percent were sheltered but in poor condition. At flag stops they observed that prospective passengers literally got out and waved down the bus even in bad weather when visibility was limited (*20*, p. 1-13-14). Nevertheless, in this prederegulation study some positives were noted including the fact that 95 percent of the stops were within 1 mi of a community center and that most passengers had vehicles available to transport them to bus stops (*20*, p. 81-8-16).

Six years after deregulation, the author of the current study is taking another look at rural bus stops in the light of continuing cutbacks in intercity bus service and in light of the overall decline in bus ridership. The target area for this study is the state of Iowa, a state well-known for its rural orientation and a state considerably affected by the loss of stops since deregulation. Because there is no standardized source of data on rural bus stops and the passengers they serve, the approach used was to survey commission agents. This approach unfortunately excluded the review of a number of flag stops because many of these are not associated with a specific location or telephone. However, the focus was to be on bus stops that could function as "bus stations" in reassuring prospective riders and informally encouraging people to take the bus.

Names and addresses of the commission agents for two of the major bus companies serving Iowa—Greyhound and Jefferson Lines—were obtained from the *Greyhound Lines Directory of Sales Location* (*21*) and the *Jefferson Transportation Group Agency Directory* (*22*), respectively. A sample of 43 bus stations were selected randomly. However, a large number of stops were designated as "flag" by Greyhound (approximately one-third of all Greyhound stops) and had no further information listed in the directory. Consequently, the sample included a larger proportion of Jefferson Line stops. Both carriers serve several of the major centers from the same terminal. Information available from the Jefferson directory as to hours of operation, name of agent, and length of tenure as agent was recorded as were the names and addresses associated with the sample of Greyhound stops. A structured follow-up telephone interview was then conducted with each of 37 operators who could be contacted. The telephone interview questions appear in the appendix. The study found no significant difference between the responses of Jefferson and Greyhound agents.

Repeated efforts to reach five additional stops failed even when calls were made at times when the printed schedule indicated that a bus was to stop. One other store owner noted that he had not seen the bus for 6 months, although he was still listed as commission agent. Information obtained from the schedules and printed directories was, however, included for the unattended stops to represent the full picture of bus stops in Iowa.

The population of the towns associated with the sample of stops ranged from 500 to over 20,000, thereby representing the full range of Iowa's population centers. Distribution was as follows: 0 to 500 (2.4 percent), 501 to 2,000 (23.3 percent), 2,001 to 5,000 (21.4 percent), 5,001-20,000 (16.7 percent), and over 20,000 (26 percent). The latter group included terminals in Des Moines, Cedar Rapids, Ames, Iowa City, and Mason City. The strong representation of larger population centers is in part a reflection of the trends associated with deregulation and in part an indication of the absence of the Greyhound flag stops in the sample. Of these stops, 33.3 percent were situated along Interstate highways with the rest along primary state and federal roads.

The type of service provided by these stops ranged from full (21.4 percent), including handling of both passengers and baggage in a dedicated facility, to flag stops, listed by Jefferson, with no ticket sales (23.8 percent). The largest proportion (42.9 percent) offered full service as a consignment in another business. Experience as a commission agent varied from 3 weeks to well over 15 years: 21.4 percent serving less than 2 years, 21.4 percent serving 2 to 5 years, 14.3 percent serving 6 to 10 years, and 19 percent serving more than 15 years. What was impressive was the overall longevity of service among the consignees. In fact, all but one of the newer consignees said that the predecessor had been in the same building. All but one of the respondents also indicated a determination to remain as a commission agent, thereby serving the public. Hence, overall, these stops represented more stability than had been anticipated, and the agents were in a position to comment effectively on changes in the bus service since deregulation.

The overwhelming majority of the commission agents (62.2 percent) reported that only one or two buses stopped a day (usually one in each direction). Thirteen percent of the stops were served by 3 to 4 buses a day—usually 2 in each direction; an additional 13.5 percent reported 5 to 9 buses a day; and 10.8 percent said that they had over 10 buses a day. The latter two categories were in the larger cities. However, the pattern is not consistent because two of the towns with a population of more than 20,000 reported only two stops a day.

The number of tickets sold by these stops is again relatively predictable. As shown in Table 1, the majority (66 percent) of the stops that sold tickets sold less than 25 tickets a week. In fact, 27.3 percent of the stops reported that they did not sell tickets because that was done on the bus. Few reported any type of peaking in sales and 28.6 percent noted a decrease in sales over the winter.

Most respondents were reluctant to share information regarding the dollar value of tickets sold. In fact, only 16 respondents were willing to suggest a figure. Of these, 18.8 percent said that ticket sales were less than $100 a month, 31.3 percent indicated sales levels at $100 to $500, and 50 percent (again in the larger population areas) indicated sales of more than $500 a month. Given the small number of responses, little can be determined from these figures except confirmation of the fact that commissions are not generally very large.

Respondents indicated that 40 percent of all travelers purchased tickets to travel within the state. An additional 53 percent, however, noted travel outside of in addition to within Iowa. In fact, half of their sales were for points outside the state. In a given week, people still travel from small towns in Iowa to Florida, Chicago, and Detroit by bus, for example.

TABLE 1 NUMBER OF TICKETS SOLD BY TOWN POPULATION SIZE

Town Population	Number of Tickets Sold per Week: None	0-5	6-10	11-25	26-50	51-100	Over 100	Row Total
0-500	1							1 3.0
501-2000	6	3	1	1				11 33.3
2001-5000	1	1	2	2				6 18.2
5001-20,000			1	3	2			6 18.2
Over 20,000	1			1	2	2	3	9 27.3
Totals	9 27.3	4 12.1	4 12.1%	7 21.2	4 12.1	2 6.1	3 9.1	33 100.0

A closer look at the type of customers that the intercity bus attracts in Iowa largely mirrors other national reports. Most are seniors and women. In fact, 78 percent of the stops reported primarily senior riders, and 61 percent indicated that the majority of riders were women. An indication of the level of dependency on bus travel of some residents comes from the report that 86.7 percent of the stops have regular riders.

Package handling efforts generally mirrored the low volume of ticket sales. Although 81 percent of the stops reported handling packages, 29 percent indicated handling less than one package a week. An additional 38 percent reported handling 2 to 10 packages a week. However, as is the case with the passengers, there is a small number of shippers who are reliant on bus service. Among the bus stop operators, 83.3 percent reported serving regular shippers. In fact, they were able to identify by name the local shippers relying on bus service. The products shipped are varied but include such items as auto parts, construction parts, flowers, agricultural products, medical supplies and blood, newspapers, television tapes, and bicycles. The common element is that these items are oddly shaped or perishable and need fast, reliable service. Packages also are sent primarily within Iowa as reported by 46.2 percent of the respondents. However, 19.2 percent of them reported sending packages well beyond the borders of Iowa. The rest reported shipments primarily to Iowa and its neighboring states.

The study has thus far reconfirmed the findings of others, that bus service is meeting a need for a small group of people who are familiar with it and are dependent on it for their outlet to the broader world. These people are willing to adjust their schedules and overlook inconveniences in order to travel or ship from one place to another by bus.

However, if bus companies are to become economically viable, they will need to attract new riders. Publicity campaigns like those being carried on by Jefferson Lines in which civic groups and town officials are mobilized to support continued bus service through news articles and town meetings are clearly a positive step (*6*, p. 14). Greyhound's new Rural Connection plan promises more local publicity as well. However, a more fundamental image problem needs to be addressed—the issue of the stops themselves.

Symptomatic of some of the problems encountered by potential riders is the fact that more than 10 percent of the stops listed in the respective directories were unreachable by telephone after several tries during different times of the day. At four additional stops the manager indicated that he or she knew nothing about the bus except that it stopped outside. They were not even familiar with the schedule. Thus, at 20 percent of the stops for which telephones and addresses were provided, no information on bus service would be available to potential riders. This does not even begin to account for the Greyhound flag stops for which no contact numbers are available. Approximately 55 percent of the original sample of Greyhound stops fell into this category.

As indicated above, the stops that were contacted ranged from those that would be characterized as dedicated terminals to those that would fit the definition of bus station or bus stop provided in the US DOT/Interstate Commerce Commission (ICC) terminal study (*19*). The latter included motels, convenience stores, gas stations, cafes, and retail stores. The data in Table 2 indicate the proportion of respondents by type of primary business. This sample of bus stations is also compared with that included in the 1984 ICC/USDOT terminal study. Similarities between the two samples are apparent. However, this more rural sample indicates more of a reliance on convenience stores (18 percent) than on gas stations (12 percent) as bus stations. A considerable proportion (14 percent) of the more rural Iowa stations were motel lobbies. Both convenience stores and motels are logical locations for stops. They are usually located out on the highways so routes are not diverted into town and both have extended hours. In fact, convenience stores are frequently open either until midnight or for 24 hours. Motel lobby hours are similar, depending on the motel size and location. Although convenience stores typically have food available with no seating, motel lobbies have seating with no food. Cafes and other restaurants also featured more prominently in the Iowa sample. These offer food and seating but usually with shorter hours. Among all respondents

TABLE 2 TYPE OF ESTABLISHMENT SERVING AS BUS STATION

	Current Study	ICC/DOT Terminal Study
Gas Station	12%	29%
Convenience Store/Grocery	18%	5%
Motel/Hotel	14%	NA*
Retail	14%	15%
Pharmacy	2%	0%
Restaurant	12%	8%
Other		17%
Depot	28%	26%
	100%	100%

*Motel may have been included in "Other" category.

TABLE 3 SERVICES PROVIDED BY RESPONDING BUS STATIONS

Type of Service	Iowa Survey (proportion of respondents providing service)	ICC/DOT Study (proportion of respondents providing service)
Ticket sales	79%	94%
Package service	74%	92%
Seating	73%	89%
Food	38%	51%
Possibility of transfer to another bus	15%	8%
Taxi/limo service nearby	35%	60%
Free parking for travelers	78%	66%

73 percent indicated that there was a sheltered waiting area available for bus passengers, but 27 percent reported that this was not the case.

The proportions of those stations responding to the survey that provide key services are summarized in Table 3. Again a comparison is provided with the 1984 national survey (*19*). The Iowa survey represented a large number of stations in towns with populations well under 15,000, the definition for small towns in the 1984 ICC/USDOT survey. These small Iowa stations reflected both the positives and negatives of small town facilities. There was less service geared exclusively to bus passengers, but there was more free parking. The concept of bus transfer was also reflected in some of the larger cities in the Iowa sample.

Of the Iowa survey respondents, 73 percent indicated that they were open when the buses arrived. At 27 percent of the stops, however, the bus arrived after closing or before opening hours. Hence, passengers still had to wait outside. Although almost all reported that the bus is within 15 min of schedule, waiting outside would be difficult, especially in the winter. When asked how the passengers arrived at the bus stops, 78 percent of the respondents indicated that the majority of their passengers drove their own cars and parked them at the stops, and 59 percent indicated that some passengers were also dropped off by others. Usually this drop-off was by private vehicle. Only 9 percent (*3*) of the respondents noted that passengers used public transportation to reach the stops. This may be explained in part by the paucity of public transportation opportunities in most rural communities. At one stop in a larger town some passengers came by taxi, and at another they came by city bus. At only one stop were passengers reported as arriving by public van. Among the respondents only 12.5 percent observed passengers walking to the stop. These findings correspond rather closely to those of earlier studies.

Nevertheless, the considerable drop-off traffic might well be some indication of a potential market for a feeder system. In fact, the station operators were asked their opinion on whether they thought that such a system might work in their area. Among those responding, 51.7 percent said that they thought it would be worth a try because of the potential to attract more rural riders, especially in northwest Iowa where there no longer is any intercity bus service. Several commented on the long distances that passengers must travel to reach these remaining bus stops. Some respondents, however, were skeptical because of the previous experience with the Jefferson bus feeder pilot project mentioned above. They emphasized the need for publicity if any such effort were to succeed. Several also mentioned the concern that low densities would mean long trips in a feeder van, which might discourage potential riders. An opinion survey of bus stop operators is certainly not an adequate marketing tool by which to test the feeder van concept, but it is an indication of a potential market that has not yet been addressed. In fact, two of the respondents reported that they went out personally and picked up regular customers on call.

The effort to personally retrieve passengers is symptomatic of the service orientation of a large proportion of the station operators. Thirty-eight percent of the respondents noted that they were continuing as commission agents primarily because they felt that the service was needed in the community. The enthusiasm with which they greeted this service opportunity, however, varied from "I love the work" to "someone has to do it." Only one respondent indicated that she experienced any financial benefit from serving as commission agent.

It is certainly true that a bus stop is a needed service, but it can also become far more than that. It is, after all, an arm of a private company. As such, it needs to be part of the system engaged in attracting increased ridership. Where agents have assumed responsibility for assisting in attracting ridership, their efforts have frequently proven to be successful. A regular feature in *Bus Ride* magazine applauds the dedication of commission agents like Bob and Dolly Johnson who have their "hands in just about every aspect of terminal operation" (*23*, p. 62) or Jan and Jim Ward who have worked to "avoid the typical bus stop look" and "have done much to enhance the image of bus travel in their region" (*24*, p. 60). The agents featured, however, are usually associated with a dedicated bus station or terminal. On the other hand, Vermont Transit, an intercity carrier in New England, is dedicated to assist

TABLE 4 CHANGES IN RIDERSHIP BY POPULATION SIZE

Town Population	Ridership Decreased	Ridership Increased	Ridership Stayed the Same	No Response	Row Total
501-2000	3	5	1		9 30.0
2001-5000	2	4	1		7 23.3
5001-20,000	1	2		2	5 16.7
Over 20,000	3	1	2	3	9 30.0
Totals	9 30.0	12 40.0	4 13.3	5 16.7	30 100.0

agents like their Iowa counterparts—those for whom bus service is simply an additional duty in conjunction with their livelihood. They have identified two liaison agents who assist in networking time-saving ideas that have proven effective and that can benefit all of them. They also feed concerns back to the company's sales manager (*25*, p. 60). This idea of liaison agents might well be replicated elsewhere.

Fortunately, a number of the Iowa respondents noted an increase in ridership within the last 3 years. Forty-one percent of those reporting an increase were from towns with a population of between 500 and 2,000 people, and an additional 33 percent of those reporting increases were from towns with populations of 2,001 to 5,000 as indicated in Table 4. This growth in ridership would not constitute any major shift from the perspective of the bus companies involved because the total volume of ticket sales is so low. No station in a town of under 5,000 in population reported selling more than 25 tickets a week. Nevertheless the trend is encouraging. More needs to be done to move more dramatically in that direction, and bus stations can play an important part. Scheduling information must be available at the stops, and telephones must be handled so that prospective riders are reassured as to connections. Radio connections between buses and the agents can keep agents informed of late schedules. Bus companies will need to work with commission agents to ensure that not only are the stops made during reasonable times of the day but that the station is open during such stops.

Waiting areas are, of course, ideal at bus stations but difficult to arrange in convenience stores or retail shops. Nevertheless, some secure place out of the weather needs to be provided. One optional aspect in the earlier definition of the "ideal bus station" was access to food and rest rooms. The former, fortunately, is currently available within walking distance of 81 percent of the responding bus stops, and the latter is also available in all but 30 percent of the stops, the retail establishments. Motels and cafes serve these needs especially well as highway stops.

The potential for better use of bus stations to encourage ridership certainly exists. The cost for increased hours of operation and providing more consistent scheduling information would be minimal as would care in selecting convenient, reliable locations for bus agencies. Any such costs incurred would be reimbursed by increased ridership. What is needed, in the overall plans for increasing ridership in rural areas, is a full recognition of the importance of the bus station on the part of the companies and the commission agents alike.

APPENDIX: Telephone Interview

Commission Agent:
Address:

Telephone number:

1. How long have you served as a commission agent?

   If 1 year or less, where was it before?

   Do you plan to continue as a commission agent?

   Why?

   Why not?

2. How many buses stop at your location in a day?

   Has that changed within the last 2 years, or since 1983?

3. Is your establishment open when the bus stops?

   Does your station serve more than one bus company?

   Which ones?

   Is there a nearby city bus or taxi stop?

4. Is there a regular waiting area?

Is food available in the station?

Within walking distance?

Are restrooms available for passengers?

5. Within an average given week, how many tickets do you sell?

In a peak week?

During a week in winter?

Approximately what are your average ticket sales per month?

Using last week as an example, would you say the bus was usually on time?

Within 15 minutes?

Within 30 minutes?

Later?

6. Has there been a significant change in ridership within the last 2 years?

Since you have become a commission agent?

7. What type of people use the service?

Are they regular customers?

What is the average age of your customers?

Seniors? Young people?

Mostly men? Mostly women?

8. How do your customers come to the stop?

By car? If so, is there parking?

Dropped off?

Taxi?

Local public van?

Walk?

Other?

Is the stop within walking distance of the shopping area in town?

Do you know if it used to be?

There has been some talk about linking rural public vans or taxis, with regular Greyhound service in order to bring in more passengers from rural areas. Do you think that might work in your area?

Why?

Why not?

No opinion.

9. Where do people travel most often?

10. Do you handle packages?

How many in a given week?

Does this vary throughout the year?

What type of packages do you handle?

Are your regular shippers from a certain company?

Where are the packages going?

REFERENCES

1. *A Report to the President and the Congress of the United States, Part II, Implementation of the Bus Regulatory Reform Act of 1982: The Impact on Older Americans and Effect on Intercity Bus Service.* Motor Carrier Ratemaking Study Commission, Washington, D.C., May 15, 1984.
2. F. Fravel. Intercity Bus Service Changes Following the Bus Regulatory Reform Acts of 1982. In *Transportation Research Record 1012.* TRB, National Research Council, Washington, D.C., 1985, p. 38–47.
3. C. Oster and K. Zorn. *The Impacts of Regulatory Reform in Intercity Bus Service.* Indiana University, Bloomington; U.S. Department of Transportation, Sept. 1984.
4. J. Kott. The Decline of Intercity Bus Service in Illinois. Presented at the 66th Annual Meeting of the Transportation Research Board, Washington, D.C., Jan. 1987.
5. J. Kasarda. *Population and Employment Change in the U.S.: Past, Present, and Future.* Presented at the 2020 Futures Conference, Washington, D.C., June 1988.
6. *Final Report on the North Central Regional Symposium on Rural Intercity Passenger Transportation.* Des Moines, Iowa, Office of Transportation, U.S. Department of Agriculture, 1987.
7. W. Petrowski. Passenger Bus Service on Steady Decline. *Des Moines Register*, Des Moines, Iowa, Jan. 25, 1987.
8. S. Carter. Small Towns Look for Bus Alternatives. *Des Moines Register*, Des Moines, Iowa, Oct. 7, 1988.
9. W. Petrowski. Cutbacks Peril Transit Service. *Des Moines Register*, Des Moines, Iowa, April 23, 1988.
10. D. Sperling and R. Goralka. Demand for Intercity Bus by the Rural Elderly. In *Transportation Research Record 1202.* TRB, National Research Council, Washington, D.C., 1988, pp. 106–113.
11. E. Hansen et al. Assessment of the User Benefits of Intercity Bus Service. In *Transportation Research Record 1125.* TRB, National Research Council, Washington, D.C., 1987, pp. 78–88.
12. *The Greyhound Rural Connection Program Manual.* Greyhound Lines, Inc., Dallas, Tex., Nov. 1988.
13. *The Rural Public Transportation Program, Project Supporting Information.* Internal report. First Tennessee Human Resources Agency, Johnson City, n.d.
14. *Greyhound Shuttle Service Program Manual.* Greyhound Lines, Inc., Dallas, Tex., April 1988.
15. L. Franks. Role of Feeder Buses in Supporting AMTRAK Serv-

ices in California. In *Transportation Research Record 1177*. TRB, National Research Council, Washington, D.C., 1988, pp. 40–47.
16. *Report on California Intercity Bus Transportation*. California Department of Transportation, Sacramento, 1987.
17. F. Fravel, R. E. Menzer, H. Weinblat, and J. Burkhardt. *Innovative Funding for Intercity Modes*. Office of Technology and Planning Assistance, U.S. Department of Transportation, July 1987.
18. D. Dean. California's Intercity Bus-Rail Program. Presented at the 67th Annual Meeting of the Transportation Research Board, Washington, D.C., Jan. 1988.
19. *Intercity Bus Terminal Study*. U.S. Department of Transportation, Dec. 1984.
20. *Intercity Bus, Rail, and Air Service for Residents of Rural Areas*. International Business Services, Inc.; U.S. Department of Transportation, Jan. 1980.
21. *Greyhound Lines Directory of Sales Locations*. Greyhound Lines, Inc., Dallas, Tex., March 15, 1988.
22. *Jefferson Transportation Group Agency Directory*. Jefferson Transportation Line, Minneapolis, Minn., June 1987.
23. *Bus Ride*, May 1988.
24. *Bus Ride*, Jan. 1988.
25. *Bus Ride*, Oct. 1987.

Publication of this paper sponsored by Committee on Intercity Bus Transportation.

Application of California Bus Accident Data in the Study of Intercity Bus Passenger Safety

JOAN AL-KAZILY

It is well documented that seat belts can save lives in automobile accidents, and some people consider the lack of passenger restraints on buses to be a safety hazard. However, many technical experts argue against seat belts because lap/shoulder belts cannot be installed on buses. The effectiveness of lap belts alone is questioned, and there is evidence that they may actually induce injury. Arguments for and against seat belts on buses are reviewed in this paper, which focuses on intercity coaches. The potential effectiveness of lap belts on intercity coaches was assessed by examining statistics and reports for severe bus accidents in the California Highway Patrol "other bus" (nonschool bus) category. The potential effectiveness of lap belts was assessed after classifying accidents by type because lap belts are not considered effective in head-on or rear-end collisions. Lap belts were judged to have potential effectiveness in 15 to 25 percent of the 1975 through 1984 accidents. Two problems were encountered in applying the available data. First, buses were not classified by body type in the data base and, second, many accidents occurred in the "hit object" classification where the direction of impact was not specified. To facilitate future study it is recommended that statistics for bus accidents identify the bus by body type rather than by function and that records for hit object accidents identify the direction of impact on the bus and the depth of penetration by the object.

This paper is based on a study of the need for passenger restraints on intercity buses (*1*). In that study the existing body of knowledge on the effectiveness of seat belts on buses and arguments for and against the installation of seat belts on buses were reviewed. In addition California bus accident records and reports were analyzed and a subjective evaluation of the likely effectiveness of seat belts, had they been available and in use, was made.

During the analysis of the California accident records, difficulties were encountered. The classification of buses for the accident records placed all "nonschool buses" in a category called "other buses." The "other bus" category included intercity buses, transit buses, farm labor buses, and miscellaneous types of buses owned and operated by private groups. In this paper, the author presents a discussion of the controversy regarding seat belts for buses, describes how the data for intercity buses were obtained and used, discusses the problems encountered in using the available data, and presents some conclusions that have been drawn from the study.

BUS SAFETY RECORD

Accident statistics show that buses are one of our safest modes of transportation. The American Bus Association reports 0.04 passenger fatalities per 100 million vehicle-miles for buses in 1982, compared with 0.08 for railroads, and 1.10 for automobile transportation in the same year (*2*). The low bus passenger fatality rate is confirmed by Bureau of Motor Carrier Safety (BMCS) data for the period 1975 to 1983, which shows an average of 16.6 bus passengers killed each year in the United States (*3*). During the same period an average annual 35,000 million passenger-miles were traveled, resulting in an average of 0.047 passenger fatalities per 100 million passenger-miles.

This good safety record for commercial bus carriers of passengers is well documented. Although the types of buses used by the commercial bus carriers are not specifically mentioned in the references used, the implication is that the buses are intercity coaches.

A similarly good safety record is documented for school buses. School buses, however, are the center of a controversy regarding the need for seat belts, and this subject has been studied by many groups over several decades. In the late 1960s the interior and body of the old-style school bus were determined to be hazardous to passengers, and in 1976 a school-bus-occupant protection rule, Federal Motor Vehicle Safety Standard (FMVSS) 222, was issued. This rule, which took effect April 1, 1977, introduced the use of a concept known as compartmentalization, a type of passive occupant protection developed from work done at the University of California, Los Angeles (*4*). This type of protection works by containing children within a structurally sound passenger compartment with fully padded, high-back seats and high padded barriers for front seats. The NHTSA believes that FMVSS 222 "sets requirements . . . which provide children a high level of protection, without the need to buckle-up" (*5*). School buses on the road today are often referred to as prestandard and poststandard buses.

SEAT BELT CONTROVERSY

Legislation requiring installation of seat belts in automobiles was first enacted in 1964, and the first FMVSS for seat belts was issued in 1966. In the United States three-point lap/shoulder belts are now required on front outboard seats of automobiles, and lap belts are required for other seating locations. Some European countries require lap/shoulder belts for rear outboard seats.

The prevention of fatalities and reduction of injuries through the use of seat belts in automobiles is well documented. The preference for lap/shoulder belts in front seats was quickly

California State University, 6000 J Street, Sacramento, Calif. 95819.

established because severe head and facial injuries were sustained by lap belted passengers whose heads and faces impacted with the front dashboard. The use of lap belts for rear seats of automobiles in the United States, however, was continued.

Recently, the usefulness of lap belts in providing protection has been thrown into serious doubt by a 1986 National Transportation Safety Board (NTSB) report (*6*), which documents lap-belt-induced injuries in 26 frontal crashes of automobiles and vans. Lap-belt-induced injuries occurred to the abdomen and also the head of many of the passengers.

The conclusion that can be drawn from the available data is that lap/shoulder belts are preferred over lap belts. The data assembled by the NTSB do not lead to any conclusion regarding the use of lap belts versus no seat belt. Lap belts may prevent fatalities and injuries in accidents other than head-on collisions, and the question becomes one of net benefits.

As a result of the well-documented evidence of the lifesaving and injury-reducing capabilities of seat belts in automobiles, parents of schoolchildren began calling for seat belts on school buses as far back as the 1960s. Research into the problem of passenger protection on school buses led to issue of the 1977 FMVSS known as compartmentalization. In addition to requiring improvements to bus bodies and seats, this standard required the installation of lap/shoulder belts for the driver's seat. This enables the driver to maintain control of the bus during an accident. Parents continue to press for passenger seat belts, and there are now approximately 78 school districts with lap-belt-equipped large school buses. Some of the buses are new and others are poststandard school buses retrofitted with lap belts. (Retrofitting prestandard school buses with lap belts is not considered feasible.) The state of New York recently became the first state to enact legislation requiring the installation of lap belts on all new school buses.

In addition to the argument that seat belts save lives, proponents of lap belts on school buses argue that there is educational value in providing the belts. The use of safety belts on buses, they argue, will teach children good safety habits that will continue into their adolescent and adult driving years.

In addition to the primary argument that the lap belts do more harm than good, there are several arguments used by those who oppose the installation of lap belts on school buses. They argue that buses are already safe; lap belts are too costly (costs exceed benefits); and belts cannot be safely anchored, can be misused or abused, increase liability costs, and are so inconvenient that people will not use them.

The controversy regarding the need for seat belts on school buses continues. However, a recent (1987) study of poststandard school buses conducted by the NTSB (*7*) resulted in the conclusion that, overall, passengers in the 43 school bus accidents that were studied in detail would have received no net benefit from the use of lap belts. (Note: only lap belts are seriously considered for buses because of technological and cost factors that inhibit the installation of lap/shoulder belts.) This study did not include consideration of the possibility of lap-belt-induced injuries that have been found to occur in automobiles and vans (*6*).

In its 1987 study, NTSB found that the 1977 federal school bus standards providing for "compartmentalization" worked well in the crashes investigated (*7*, p. 97). They also found that the federal school bus standards requiring increased side panel and roof strength appeared to have been successful in eliminating the structural failure responsible for many of the ejections in prestandard buses. Further improvements were recommended for joints of the interior maintenance access panel and floor panel and for seat cushion attachments.

The poststandard school bus has undoubtedly improved passenger protection. Unfortunately many prestandard school buses continue to be used by school districts and private social organizations.

In comparison with the prestandard school bus, the intercity coach affords better passenger protection because of the heavier bus body and padded seats with high seat backs. This is not the case, however, with the transit bus, which often has low seat backs with exposed metal bars. Transit buses, designed for city use, are today being used on freeways at speeds that can result in severe accidents. The passenger protection afforded by many transit buses in such an accident would be very poor. Some transit districts with high freeway mileage are using coach-type buses, but many transit districts use the typical transit bus on the freeway. Improvement of the typical transit bus seat is necessary and is being evaluated.

In recent years the minibus and van-type bus have been gaining in popularity. Passengers in smaller vehicles are subjected to greater crash forces. This was taken into account when the 1977 FMVSS standards were being set for school buses. Type II buses (under 10,000 lb gross vehicle weight) constructed after April 1, 1977 are required to be equipped with lap belts at each seating position. Recent evidence has shown that the performances of rear-seat lap belts in frontal collisions of automobiles and vans is very poor (*6*). Thus the use of lap belts in minibuses may need to be reevaluated.

Passenger protection provided by the interior of buses on the road today clearly varies with the type and age of the bus. Arguments exist both for and against the installation of lap belts on school buses. Transit bus seats need improvements to provide passenger protection when the buses travel at higher speeds on the freeway. Lap belts on minibuses and van-type buses may place passengers at risk in head-on collisions. This paper, however, deals with intercity motor coaches, which have no lap belts for passengers but which have high-backed, padded seats and a strong body. This type of construction provides passive protection for passengers in the event of accidents. Nevertheless, in view of the fact that intercity buses are used for long-distance travel, often at high speed and often on mountainous roads, careful consideration of passenger protection is important.

Clearly the controversy regarding the need for seat belts on buses will continue. Because the types of buses provide for passenger safety in different ways, a data base that reflects the body type of buses is needed.

DEFINING THE INTERCITY BUS

Buses can be classified by body type, function, and mode of operation. The term "intercity bus" refers to function in the sense that it means a bus that travels between two cities. A transit bus is a bus that is used by commuters to travel to and from work. A transit bus may, however, also travel between two cities, as may a school bus, a minibus, and a van-type bus. A school bus has a distinctive body shape and is constructed on a truck chassis. A bus of this type may, however, be used by private social groups or to transport farm laborers. On the other hand, a transit bus or a commercial coach may be used to transport school children.

The California Department of Transportation (Caltrans) has grouped buses by body type for the purpose of classification counts (*8*). Body types defined by Caltrans are motor coach, transit bus, minibus, and truck-type bus (school-type bus, which is built on truck chassis).

For accident records, California statewide vehicle classification distinguishes between school buses and other buses. In this context classification as a school bus is based on the legal definition. School children may also be transported to special activities and after school activities in buses that are not legally classified as school buses. For this reason the California Highway Patrol (CHP) introduced (in 1977) the school pupil activity bus (SPAB) classification. An SPAB may be a motor coach, transit bus, minibus, or even a school-type bus, which was not, at the time, legally classified as a school bus.

The CHP classifies buses as commercial, farm labor, school bus, SPAB, and (since 1983) "youth" bus. School buses are further subdivided into public, private, and contractual. This classification is used only for CHP-reported accidents and is not, therefore, applicable to all accidents in the California data base.

The "other bus" category used for California statewide accident reporting includes motor coaches, transit buses, minibuses, and (before 1977) SPABs. After CHP introduced the new classification, SPAB buses were included in the school bus category of the statewide classification. For the purpose of the study on which this paper is based, the term "intercity bus" was used to mean full-size motor coaches used for long-distance travel, including pleasure trips. The classification of accidents in the available data was not compatible with this definition.

TABLE 1 1975 THROUGH 1984 STATEWIDE "OTHER BUS" ACCIDENTS

YEAR OF COLLISION	KILLED	SEVERE INJURY	VISIBLE INJURY	COMPLT-PAIN	TOTAL INJURED
1975	2	36	208	935	1179
1976	31	42	219	1031	1292
1977		16	170	936	1122
1978		20	207	1055	1282
1979		35	273	1048	1356
1980	1	15	185	1097	1297
1981	4	36	144	766	946
1982	16	12	157	826	995
1983	3	35	250	963	1248
1984	5	28	243	1114	1385
TOTALS	62	275	2056	9771	12102
AVERAGES	6	28	206	977	1210

EXTRACTING THE DATA

Ten years of accident records (1975 through 1984) for the "other bus" category were provided on magnetic tape by the CHP. These data were from the Statewide Integrated Traffic Records System (SWITRS). There were 13,325 records in this category; 4,821 involved at least one victim. The data base classifies victim condition as fatality, severe injury, other visible injury, and complained of pain. There were 62 deaths, 275 severe injuries, and 2,056 with other visible injuries in the records for "other bus." The data are summarized in Table 1. These data include victims on the bus and in other vehicles.

The most severe accident in the "other bus" category occurred in May 1976 and is known as the "Martinez" accident. In this accident 29 passengers were killed, 19 severely injured, and 4 received other visible injury. The bus was a school-type bus carrying school children but was not legally classified as a school bus. Since that time the CHP has introduced the SPAB classification for use in CHP-reported accidents, and SPAB buses are now classified as school buses in the statewide classification. Had this accident occurred after 1977 it would have been included in the school bus category. Excluding the Martinez accident, the number of passengers killed and severely injured in the "other bus" category is 33 and 256, respectively.

From the "other bus" accident records, 88 severe accidents were identified. A severe accident is defined as one involving one or more bus passenger deaths, or one or more bus passengers severely injured, or five or more visible injuries to bus passengers, or a combination of any of these three scenarios. Pertinent data for these 88 accidents were extracted and produced on hard copy for examination and analyses. A sample of the data extracted is shown in Figure 1.

In addition to these aggregate accident records, the CHP made available several major accident investigation team (MAIT) reports. It was necessary to request these reports individually by accident date and location. In order to do this, specific accidents were selected from the 88 previously identified as severe. Ten MAIT reports were provided (no reports were available for accidents before 1980).

It turned out that there were no catastrophic accidents involving intercity buses in California during the 1975 through 1984 period. Since that time, however, there has been one severe accident. Occurring on May 30, 1986, in Sierra Nevada, this accident resulted in 21 deaths, 16 severe injuries, and 4 moderate injuries. The bus ran off the road, rolled down a steep embankment, and landed in the Walker River. Passengers were thrown around inside the bus, and many were ejected into the river. Clearly, a single severe accident such as this has a large effect on the average incidence of fatalities.

DATA ANALYSIS

Classification by Collision Type

In order to evaluate the need for and potential effectiveness of lap belts on intercity buses, the 88 severe accidents were classified by collision type. These are hit object, overturned, head-on, broadside, rear-end, sideswipe, and other automobile/pedestrian. The other party (or fixed object) involved in the collision was also recorded. The detailed MAIT reports were analyzed for bus type, direction and severity of impact, and seating positions of passengers killed and injured.

The 88 severe accidents isolated for detailed study involved 56 bus passengers killed, 187 bus passengers severely injured, and 777 bus passengers with other visible injuries (including the Martinez accident). Because all accidents with one or more bus passenger fatality or severe injury were included in

```
COLLISION SEGMENT ***************************************

COLLISION NUMBER ON THIS FILE                             87
JURISDICTION (REPORTING NCIC NR.)                       9835
COLLISION DATE (YYMMDD)                               750820
COLLISION TIME (HHMM)                                   0845
BADGE NUMBER                                           07257
DISTRICT WITHIN JURISDICTION                            0000
COLLISION LOCATION 00=UNINCORPOR.                       3600
COUNTY (CALTRANS)                                        SBD
CALTRANS DISTRICT 00=NOT STATE HWY                        08
STATE ROUTE 000=NOT STATE HWY                            040
LOCATION TYPE                          RAMP (OR COLLECTOR)
INJURY, FATAL, OR TOW-AWAY                               YES
COLLISION SEVERITY                   OTHER VISIBLE INJURY
NUMBER OF VICTIMS KILLED                                  00
NUMBER OF VICTIMS INJURED                                 13
NUMBER OF VICTIMS                                         13
NUMBER OF PARTIES                                         02
COLLISION TYPE                                      REAR-END
MOTOR VEH. OF 1ST CONTACT INVOLVED      OTHER MOTOR VEH.

PARTY SEGMENT ***************************************************

BUS 1, PARTY NUMBER                       1            OTHER PARTIES
EXTENT OF INJURY             COMPLAINT PAIN        PARTY        STATEWIDE
VICTIMS KILLED                           00       NUMBER     VEHICLE TYPE
VICTIMS INJURED                          10
STATEWIDE WEH. TYPE               OTHER BUS

BUS 2, PARTY NUMBER                       2
EXTENT OF INJURY                  NO INJURY
VICTIMS KILLED                           00
VICTIMS INJURED                          03
STATEWIDE WEH. TYPE               OTHER BUS

VICTIM SEGMENT ********************************************************************************************

VICTIM NUMBER                1         2         3         4         5         6         7         8       9        10
VICTIM TYPE          PASSENGER PASSENGER PASSENGER PASSENGER PASSENGER PASSENGER PASSENGER PASSENGER  DRIVER PASSENGER
EXTENT OF INJURY     VIS. INJ. VIS. INJ. VIS. INJ. VIS. INJ.      PAIN VIS. INJ. VIS. INJ. VIS. INJ.    PAIN      PAIN
VICTIM IN PARTY          BUS 1     BUS 1     BUS 2     BUS 1     BUS 1     BUS 1     BUS 1     BUS 1   BUS 1     BUS 1

VICTIM NUMBER               11        12        13
VICTIM TYPE          PASSENGER PASSENGER PASSENGER
EXTENT OF INJURY          PAIN      PAIN      PAIN
VICTIM IN PARTY          BUS 2     BUS 1     BUS 2

VICTIM NUMBER
VICTIM TYPE
EXTENT OF INJURY
VICTIM IN PARTY

VICTIM NUMBER
VICTIM TYPE
EXTENT OF INJURY
VICTIM IN PARTY

VICTIM NUMBER
VICTIM TYPE
EXTENT OF INJURY
VICTIM IN PARTY

VICTIM NUMBER
VICTIM TYPE
EXTENT OF INJURY
VICTIM IN PARTY

VICTIM NUMBER
VICTIM TYPE
EXTENT OF INJURY
VICTIM IN PARTY
```

FIGURE 1 Sample of data extracted from the Statewide Integrated Traffic Records System (data extracted from six California Highway Patrol reports of accidents involving seven intercity buses).

these 88 accidents, the remaining 6 deaths and 88 severe injuries are assumed to have occurred to passengers of other vehicles. An unknown number of the 2,056 other visible injuries also occurred to passengers of other vehicles. For the purpose of this study the 88 severe accidents were considered to be the data base for other bus accidents in which lap belts may have been effective.

Classification by collision type (see Tables 2 through 8) was undertaken because lap belts are considered to be effective in accidents involving passenger ejections and passengers being thrown about inside a bus. These events can occur when a bus is impacted from the side and especially in roll-over accidents. On the other hand, the effectiveness of lap belts in head-on and rear-end collisions is questionable. As can be seen from the data, 4 were killed and 19 severely injured in head-on and rear-end collisions, whereas 7 were killed and 61 severely injured in broadside, sideswipe, and roll-over accidents. The majority of deaths and severe injuries (16 and 78, respectively, and excluding the Martinez accident) occurred in the hit object category of accidents.

For "hit object" accidents the direction of impact is not known. This makes it impossible to draw any conclusions regarding the likely effectiveness of lap belts in these accidents. The importance of the direction of impact has been recognized by the U.S. Department of Transportation in its Fatal Accident Reporting System (*9*). The distribution of accidents by direction of primary impact has been reported for automobiles, motorcycles, and trucks for many years, and starting in 1986 this is also done for buses.

As mentioned earlier 10 MAIT reports were obtained for this study. Accidents for which MAIT reports were obtained

TABLE 2 COLLISION TYPE: HIT OBJECT

OTHER PARTY	KILLED	SERIOUS	VISIBLE	MAIT
FIXED OBJECT	2	14	6	
FIXED OBJECT	1		24	07/07/84
FIXED OBJECT			8	05/09/84
FIXED OBJECT			13	
FIXED OBJECT		2	9	03/20/83
BUS	3	7	58	
FIXED OBJECT		1	6	
FIXED OBJECT		15	27	
FIXED OBJECT		1	8	
PASS CAR			11	
TRUCK	10		1	10/08/82
PASS CAR		3	8	
PASS CAR			6	
PASS CAR			6	
PASS CAR		3	10	
FIXED OBJECT		6	10	
FIXED OBJECT		4	11	
FIXED OBJECT		4	9	
PASS CAR			7	
FIXED OBJECT	29	19	4	05/12/76
FIXED OBJECT		18	18	

SUMMARY: 21 ACCIDENTS 45 KILLED
97 SERIOUS INJURIES
260 OTHER VISIBLE INJURIES

TABLE 3 COLLISION TYPE: OVERTURNED

OTHER PARTY	KILLED	SERIOUS	VISIBLE	MAIT
NON COLLISION	1	7	4	
NON COLLISION			6	
NON COLLISION		3	12	
NON COLLISION	3		7	10/17/82
NON COLLISION		8	8	
NON COLLISION	1	10	16	01/11/81
NON COLLISION			11	
MULTIPLE			15	
NON COLLISION		1	17	

SUMMARY: 9 ACCIDENTS 5 KILLED
29 SERIOUS INJURIES
96 OTHER VISIBLE INJURIES

TABLE 4 COLLISION TYPE: HEAD-ON

OTHER PARTY	KILLED	SERIOUS	VISIBLE	MAIT
PASS CAR			14	
PASS CAR			4	
PASS CAR	2	7	4	08/08/81
PASS CAR			5	
PASS CAR		2	17	
PICK-UP + CAR		4	1	
TRUCK			8	
PASS CAR		1	9	
TRUCK/TRAILER	1		18	
PASS CAR		2	5	

SUMMARY: 10 ACCIDENTS 3 KILLED
16 SERIOUS INJURIES
85 OTHER VISIBLE INJURIES

are identified in Tables 2 through 8. The MAIT report accidents involved 51 bus passenger deaths, 77 severe injuries, and 168 other visible injuries, thus accounting for 91 percent of the deaths, 38 percent of the severe injuries, and 22 percent of the other visible injuries sustained in the 88 accidents.

As indicated earlier the worst accident during the analysis period, the Martinez accident, was sustained by a school-type bus listed with "other bus" because it was not, at the time, legally classified as a school bus. Analysis of the MAIT reports revealed that three of the accidents involved minibuses or van-type buses and one involved a transit bus (see Table 9). As seen from this table, nonintercity buses accounted for 45 deaths, 26 severe injuries, and 24 other visible injuries. Intercity buses accounted for 6 deaths, 51 severe injuries, and 144 other visible injuries. The bus type is unknown for accidents resulting in the remaining 5 deaths, 109 severe injuries, and 609 other visible injuries.

TABLE 5 COLLISION TYPE: BROADSIDE

OTHER PARTY	KILLED	SERIOUS	VISIBLE	MAIT
PASS CAR			5	
PASS CAR		2	11	
PICK-UP			6	
PASS CARS	1	2	8	
PASS CARS			7	
PASS CAR			8	
PICK-UP W/TRAIL		3	9	
PICK-UP W/TRAIL			5	
PASS CAR			5	
PASS CAR		5	19	06/22/80
PASS CAR			5	
TRUCK			7	
PASS CAR		1	9	
PASS CARS		2	3	
PASS CARS		3	4	
PASS CAR			6	
TRUCK W/TRAIL		2	4	
PASS CAR			8	
BUS			13	
TRUCKS W/TRAIL		4	16	
PICK-UP			8	
PICK-UP	1		1	
PICK-UP			5	
PASS CAR			11	
PASS CARS		4	1	
PASS CAR			5	

SUMMARY: 26 ACCIDENTS 2 KILLED
28 SERIOUS INJURIES
189 OTHER VISIBLE INJURIES

TABLE 6 COLLISION TYPE: REAR-END

OTHER PARTY	KILLED	SERIOUS	VISIBLE	MAIT
BUS			5	
BUS		1	4	
BUS			6	
PICK-UPS			8	
PASS CAR		1	5	
TRUCK	1		1	
TRUCK W/TRAIL			6	
PICK-UP W/TRAIL		1	4	
MULTIPLE			17	
PASS CAR			5	
BUS			7	

SUMMARY: 11 ACCIDENTS 1 KILLED
3 SERIOUS INJURIES
68 OTHER VISIBLE INJURIES

TABLE 7 COLLISION TYPE: SIDESWIPE

OTHER PARTY	KILLED	SERIOUS	VISIBLE	MAIT
PASS CAR			5	
TRUCK W/TRAIL		1	4	
TRUCK W/TRAIL			5	
TRUCK W/TRAIL			9	
TRUCK W/TRAIL		1	5	
TRUCK W/TRAIL		1	6	
TRUCK + CARS		1	5	

SUMMARY: 7 ACCIDENTS 0 KILLED
4 SERIOUS INJURIES
39 OTHER VISIBLE INJURIES

TABLE 8 COLLISION TYPE: OTHER

OTHER PARTY	KILLED	SERIOUS	VISIBLE	MAIT
PEDESTRIAN			6	
PICK-UP		1	7	
TRUCK W/TRAIL			8	
ANIMAL		8	19	

SUMMARY: 4 ACCIDENTS 0 KILLED
9 SERIOUS INJURIES
40 OTHER VISIBLE INJURIES

Reliability of Data

Classifying unknown bus types as intercity buses results in totals of 11 deaths, 160 severe injuries, and 753 other visible injuries being attributed to intercity bus passengers during 1975 through 1984 (see Table 9). As shown in Table 10, the BMCS reports 11 deaths and 711 injuries to passengers in California during the 1975 through 1983 period (*3*). The BMCS data appear to be compatible with the CHP data. Closer analysis, however, reveals discrepancies in the number of deaths reported on a year-by-year basis as shown in Table 11.

These discrepancies may arise from differences in bus classification. In 1982, for example, a total of 16 deaths are reported by the CHP (see Table 1); 13 of these have been attributed to minibus accidents (see Table 9). Only three deaths, occurring in accidents involving unknown bus types, have been attributed to intercity buses. The BMCS reports 10 deaths in California in 1982. Presumably, then, the CHP minibus was a "motor carrier of passengers," whereas the other buses were not. Thus, the category "motor carrier of passengers" may not be compatible with the category "intercity bus." Existing data bases do not classify buses by body type.

Lap Belt Effectiveness

In considering the need for lap belts on intercity buses the question is how many, if any, of these fatalities and severe injuries would have been prevented by the use of lap belts. A subjective analysis of the accident reports and available information about lap belt effectiveness resulted in estimation of 15 to 25 percent effectiveness with full use of the lap belts. Analysis of the likely effectiveness of lap belts was hampered by the lack of knowledge of the direction of impact in the hit object category, which accounted for a large proportion of the passenger deaths and injuries. No estimation of possible lap-belt-induced injuries was made.

TABLE 9 CHP DATA SHOWING SUMMARY OF THE 88 SEVERE ACCIDENTS IN THE OTHER BUS CATEGORY IN CALIFORNIA (1975 through 1984)

ACCIDENT DATE & DESCRIPTION	KILLED	SEVERELY INJURED	OTHER VISIBLE INJURY
NON INTERCITY BUSES			
05/12/76 MARTINEZ, HIT OBJECT	29	19	4
10/08/82 SMALL VAN, HIT OBJ., EJECTION	10	0	1
08/08/81 SMALL VAN, HEAD ON, FIRE	2	7	4
10/17/82 SMALL VAN, OVERTURNED	3	0	7
5/09/84 TRANSIT BUS, HIT OBJECT	1	0	8
SUB-TOTAL	**45**	**26**	**24**
INTERCITY BUSES			
06/22/80 BROADSIDE, ROLLOVER	0	5	19
01/11/81 OVERTURNED	1	10	16
03/20/83 HIT OBJECT, 2 BUSES, MULTIPLE IMPACT	3	7	58
07/16/83 HIT OBJECT, OFF ROAD	0	15	27
07/07/84 HIT OBJECT, OFF ROAD, AIRBORNE	2	14	24
SUB-TOTAL	**6**	**51**	**144**
OTHERS (BUS TYPE UNKNOWN)			
HIT OBJECT	0	42	138
OVERTURNED	1	19	73
HEAD-ON	1	9	81
BROADSIDE	2	23	170
REAR-END	1	3	68
SIDESWIPE	0	4	39
OTHER	0	9	40
SUBTOTAL	**5**	**109**	**609**
GRAND TOTAL	**56**	**186**	**777**

TABLE 10 BMCS DATA SHOWING ACCIDENTS OF MOTOR CARRIERS OF PASSENGERS IN CALIFORNIA

		Drivers		Passengers	
Year	Accidents	Killed	Injured	Killed	Injured
1975	40	0	2	0	26
1976	52	0	6	1	89
1977	62	0	6	0	60
1978	40	0	4	0	42
1979	62	0	10	0	175
1980	62	0	6	0	49
1981	82	0	10	0	85
1982	66	0	6	10	75
1983	60	0	2	0	110
Total	526	0	52	11	711
Average	58.4	0	5.8	1.2	79

TABLE 11 COMPARISON OF BMCS AND CHP YEARLY DATA SHOWING BUS PASSENGER FATALITIES

	BMCS (passenger motor carriers)	CHP (intercity buses)
1975	0	2
1976	1	2
1977	0	0
1978	0	0
1979	0	0
1980	0	1
1981	0	1
1982	10	3
1983	0	0
1984	0	2
Total	11	11

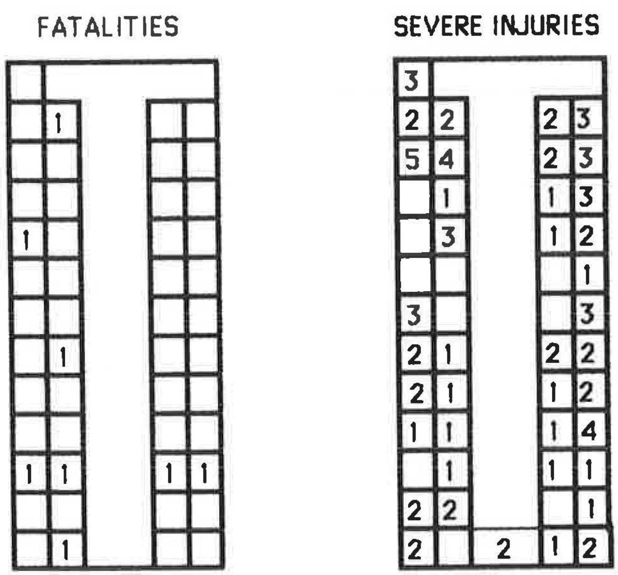


FIGURE 2 Deaths and severe injuries by seat location in intercity buses.

A March 1987 report from NTSB (*7*) suggests that even this low estimate of effectiveness is optimistic. In the NTSB study, 43 poststandard school-type bus accidents were investigated immediately after their occurrence. The study concluded that lap belts would have resulted in no overall net benefit to the passengers of the buses involved in the accidents. This conclusion should not be generalized and cannot be transferred to intercity buses.

In the original work (*1*) on which this paper is based, some thought was given to the greater need for seat belts at certain seating locations on the bus. The passenger seating charts for the accidents were studied, and the frequency of occurrence of deaths and injuries in the various seating locations are presented in Figure 2. Front seats and back bench seats are frequently mentioned as being more dangerous than other locations. This was not borne out by the available data. Most buses did not have back bench seats, and as can be seen from Figure 2 deaths and serious injuries were scattered throughout the vehicles. Fatalities and serious injuries occurred more frequently on the left side of the bus. As seen from Figure 2 the second row on the left of the bus incurred the highest number of serious injuries.

The location of fatalities and serious injuries on the bus is influenced by the location and direction of impact of the collision. Intrusion of the other vehicle or object into the bus has been found to be the most frequent cause of death or serious injury. This is one of the reasons why the effectiveness of lap belt use in buses is estimated to be low. Seat belts are not effective when death or injury results from intrusion of another vehicle or object into the bus.

CONCLUSIONS

Intercity bus accidents in California resulted in approximately 11 deaths and 160 severe injuries during the 1975 through 1984 period. Six deaths and 51 severe injuries are documented in MAIT reports. The total numbers of deaths and severe injuries are approximate (probably an overestimation) because the data sources (CHP SWITRS and BMCS) do not classify intercity bus as a specific category.

For the purpose of analysis of lap belt effectiveness, buses must be classified by body type. The intercity bus or coach has a body type that is different from the transit bus or the minibus. Fleets of motor carriers may include minibuses; hence, BMCS data may include minibuses as well as intercity buses (motor coaches). The California SWITRS classifies all non-school buses as "other bus," which includes transit buses, minibuses, and farm labor buses, as well as intercity buses. (In CHP-reported accidents, commercial buses are separated from farm laborer buses, but this is not a statewide classification.)

The effectiveness of lap belts in reducing the number of deaths and severe injuries was subjectively estimated at about 15 to 25 percent with full use of the belts. In light of more recent studies by the NTSB, this is now considered to be overly optimistic. Furthermore, the potential for lap-belt-induced injuries to passengers who otherwise would be uninjured (or have minor injuries) exists. This has been documented for small vehicles but not for large buses.

The California data base for 1975 through 1984 did not include any serious accidents. In 1986 such an accident occurred and the bus rolled over, down an embankment, and into a river. Passengers were ejected and swept away in the river. Seat belts may have been effective in preventing some of the deaths in this case, and serious accidents such as this one draw attention to the fact that buses do not have seat belts.

During the conduct of this work, safety problems related to minibuses and transit buses have become evident. Minibuses (Type II buses) used to transport school children are equipped with lap belts. The potential for lap-belt-induced injuries in head-on collisions of small vehicles has been documented and is a matter for serious concern. Transit buses, designed for operation at low speeds on city streets, are now traveling at higher speeds on urban and interurban freeways. Seats in many of these buses are low backed with exposed metal bars similar to the prestandard school bus seats. Transit buses operating on freeways should be equipped with padded seats and high seat backs.

Future study of passenger safety on buses would be facilitated if accident data bases would classify buses by body type, namely, school-type buses, intercity buses (motor coaches), transit buses, minibuses, and van-type buses. It would also be helpful if statistical records would include data on direction of impact and depth of penetration for the "hit object" class of accidents.

ACKNOWLEDGMENTS

This work has been carried out under a grant from the California Department of Transportation. Don Dean was most helpful in providing background material for the study. Accident data were provided by the California Highway Patrol. Christian Morand and Christopher Bradfield, students at California State University, Sacramento, provided valuable assistance in data analysis and research.

REFERENCES

1. J. Al-Kazily. *Investigation of the Need for Passenger Restraints on Intercity Buses.* Bus Transportation Branch, Division of Mass Transportation, California Department of Transportation, Sacramento, Dec. 1986.
2. *1983 Annual Report.* American Bus Association, Washington, D.C.
3. *Accidents of Motor Carriers of Passengers.* Bureau of Motor Carrier Safety, Washington, D.C., 1975–1983.
4. A. Severy, M. Brink, J. D. Baire. *School Bus Passenger Protection.* Paper 670049. Automotive Engineering Congress, SAE, Warrendale, Pa., 1967.
5. *Safety Belts in School Buses.* NHTSA, U.S. Department of Transportation, June 1985.
6. *National Transportation Safety Board Safety Study: Performance of Lap Belts in 26 Frontal Crashes.* NTSB/SS-86/03. Washington D.C., 1986.
7. *National Transportation Safety Board Safety Study: Crashworthiness of Large Post Standard School Buses.* NTSB/SS- 87/01. Washington D.C., 1987.
8. *Bus Classification Count.* Bus Transportation Branch, Division of Mass Transportation, California Department of Transportation, Sacramento, 1986.
9. *Fatal Accident Reporting System.* NHTSA, U.S. Department of Transportation (Annual).

Publication of this paper sponsored by Committee on Intercity Bus Transportation.

A Step-by-Step Procedure for Roadway Network Improvement Priority Setting

FAZIL T. NAJAFI

This study was initiated as a response to the need of the city of Gainesville, Florida, to develop methods to prioritize the allocation of funds for roadway improvement projects. Because funds are limited, only the highest priority projects can be funded immediately. The uncertainty of federal highway funding programs and change in public attitude toward transportation investment costs are driving factors in forcing decision makers to devise systems for priority setting to allocate limited funds for needy improvement projects. In this paper, the author provides an overview of the traditional allocation mechanisms and then focuses on a step-by-step roadway improvement prioritization procedure that has been devised for the city of Gainesville, Florida. In the step-by-step procedure, (a) roadway network improvement criteria are identified, (b) the city's roadway network system is divided into segments of homogeneous characteristics, (c) numerical point ratings are assigned to each roadway segment based on roadway sufficiency ratings derived from an overall roadway condition, and (d) cost per segment deficiency improvement is calculated for funding allocation. In addition, a simple computerized improvement ranking procedure is developed to rank and identify signalized intersections as candidates for improvement. A similar program is also developed for sidewalks. In general, the models are simple and easily understood by public officials, and they are practical tools ready for implementation by city, county, or state officials. The models are flexible to accommodate variable standards and modifications that are useful to city, county, state, and federal projects.

During the last decade, the transportation investment decision environment has grown steadily more complex. The traditional process for deciding whether or not to build has been complicated by a number of newly important criteria. For example, capital improvement programs must now frequently be evaluated on the basis of issues such as regional equity, efficient use of available funding assistance, statutory constraints, community and environmental impacts, and even general public acceptability. Responding to any of these issues within a short time frame and with limited resources is a difficult task for decision makers. Therefore, analytical models are needed to allocate limited resources to transportation projects that can satisfy essential project needs. The development of a step-by-step procedure for roadway network improvement priority setting was initiated in response to a request from the city of Gainesville, Florida. The project is part of an overall effort on the part of the city to apply a simplified procedure to allocate limited funding on a priority basis to improve roadway networks, sidewalks, and signalized intersections.

Department of Civil Engineering, University of Florida, 345 Weil Hall, Gainesville, Fla. 32611.

The developed procedure for allocating funds to roadway segments is based on deficiency ratings derived from overall roadway conditions.

The city of Gainesville is a medium-size city with a population of 85,000 people located in the north central part of Florida. The city has 772 lane-miles of arterial, collector, and local roads. The funding sources for the improvement of these roadway network systems come from federal, state, and local revenues. In the past, the allocation of funds for roadway improvement was based on the traditional allocation mechanism, which lacked a systematic prioritization procedure.

The following procedure of systematic steps was developed for Gainesville:

1. Criteria are identified through established standards and by the city's experienced public works staff and engineering and planning divisions, relevant to roadway improvement deficiency (e.g., safety, surface condition, base, drainage, pavement width, level of service, and so on).
2. The roadway network system is divided into homogeneous segments.
3. A total deficiency point value is assigned to each roadway segment.
4. Cost estimates are prepared for the improvement of each roadway segment.
5. Tables are prepared for the present and future roadway network improvement program.

The step procedure provides city officials with the benefit of being able to apply the models for the allocation of limited funds into projects in a systematic fashion. The procedure is flexible and could also be implemented by other cities, counties, or states. The computerization of the system enables decision makers to obtain fast results. In general, it is a simple procedure that can be understood and easily followed.

LITERATURE SEARCH

In the past, transportation improvement priority-setting goals were generally centralized, made either by the state's transportation planning or by each of the state's districts with review and approval at the state level. Funds were allocated on the basis of project needs. Needs were defined relevant to project deficiency in level of service, capacity, or structural quality. In others, lists of projects were generated on a more ad hoc basis. Once such a list was generated, adjustments were made to account for anticipated impacts, community opposition, and environmental effects, and for the consideration of political realities of building these projects. The final list of selected projects would then be made public. In the last decade, citizen participation in the earlier stages of the planning became essential to the overall transportation planning process. Typically, the state agency still retains responsibility for overall system planning and developing alternative programs for review and evaluation by the public. The integration of community and environmental impacts and participation and interaction with a wide variety of interest groups are also part of the overall planning and evaluation process.

Most evaluation systems in use are patterned after a numerical rating system first developed by the Arizona Highway Department in 1946 (*1–3*) describing the highway's "sufficiency." The sufficiency rating method assigns a point score to each section of road, based on its actual condition and its ability to carry load in a safe and efficient manner.

The U.S. Navy Public Works Center model of a priority scheme for the selection of pavement sections needing major repair used a benefit-cost optimization technique. The center developed a pavement condition technique and numerically ranked roadways as primary, secondary, and tertiary. The parking area and roadway network systems were rated as good, fair, poor, very poor, and failed. The conclusion of the repair-when-needed strategy represented the best in terms of maximizing network benefits and minimizing cost (*4*).

The state of Kentucky used an adequacy rating procedure based on certain fixed-point scales for highway construction projects (*3*). One of the major advantages of this procedure included computerization, which allowed coding of numbers from simplified forms without reference to charts, tables, and graphs.

Bower (*5*) cited that in urban areas, in general, traditional allocation mechanisms were based on population. Safety was among the factors included in improvement priority settings.

A demand-responsive approach to highway maintenance and rehabilitation is used by many states. Table 1 presents

TABLE 1 EQUIPMENT USED TO MEASURE PAVEMENT CONDITION PARAMETERS (*6*)

	ROUGHNESS	DEFLECTION	SKID RESISTANCE	DISTRESS
ALASKA	Mays Ride Meter	Falling Weight Deflectometer		Rutting: Measured Cracking, Patching: Visual
ALBERTA	PCA Car Roadmaster	Benkelman Beam and Dynaflect		Visual
ARIZONA	Mays Ride Meter	Dynaflect	Mu Meter	Visual/ Measured
CALIFORNIA	PCA Car Ridemeter	Dynaflect or Deflectometer	K. J. Law, Inc. Skid Tester	Visual/ Measured
CERL				Visual
DENMARK	Servo-accelero-meter Mounted in car	Falling Weight Deflectometer		
FLORIDA	Mays Ride Meter	Dynaflect	ASTM Skid Trailer	Visual/ Measured

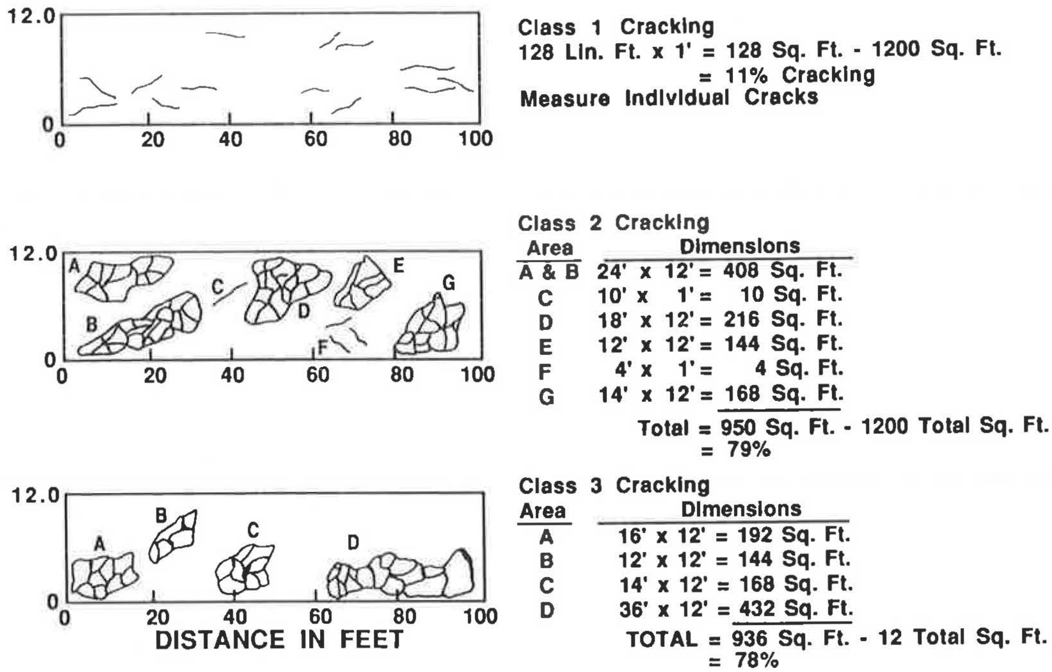


FIGURE 1 Florida method for cracking measurements (*6*).

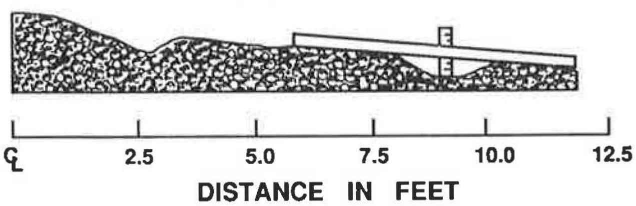


FIGURE 2 Florida method for rutting measurements (*6*).

equipment used to measure pavement condition parameters (*6*). Figures 1 and 2 present the Florida Department of Transportation methods for cracking and rutting measurements (*6*).

In 10 of the 13 states consulted in an NCHRP project (*7*, *8*), the determination of transportation priorities was identified as a major concern.

GAINESVILLE ROADWAY NETWORK SYSTEM'S MODEL FOR PRIORITIZATION OF CAPITAL IMPROVEMENT

To obtain the greatest benefits from the allocation of limited funds to roadway improvement projects, a systematic and simple model for each element of the system is needed. Formulation of models is time-consuming and costly. A model must accurately reflect the structure or behavior of a real-life counterpart. There should be a close correlation between the model and its corresponding reality.

In the model formulation process, the analyst's main concern is how accurately the model fits the problem at hand, including considerations of physical, economic, political, social, and governmental objectives, as well as community goals. The model must be simple and understandable because lay elected decision makers are reluctant to rely on more sophisticated models that they do not understand. Simple models with a reasonable degree of accuracy are generally acceptable for application. In selecting a model related to roadway improvement priority settings, one needs to establish evaluation criteria such as

- Theoretical soundness;
- Rationale for priority settings;
- Multiyear constraint capability;
- Sensitivity and assumptions;
- Multimodel capability;
- Demonstrated use and ability to be convincing;
- Simplicity;
- Accuracy;
- Quality of ideas;
- Cost;
- Time period required;
- Data requirements;
- Individual knowledge needed; and
- Group knowledge needed.

In some instances decision makers are seeking a quick response to a difficult question. Then, time becomes an important factor in selecting a model to generate results in the most cost-effective manner.

As a result of reviewing the city's budgetary constraints and the growing demand for roadway improvement projects, a simplified practical procedure is developed to rank and prioritize projects on the basis of established needs. The city's roadway network system is divided into homogeneous segments, categorized and ranked on the basis of improvement criteria established for the allocation of funding. For the deficiency rating assignments, AASHTO and *Highway Capacity Manual* (HCM) standards are used along with the professional judgments of the city's experienced staff from public works and the planning and traffic divisions. For instance, roadways carrying heavier traffic volume require higher standards of construction and rehabilitation as compared to roadways carrying less traffic volume. Qualifying deficiency points are accordingly assigned to each identified roadway segment (Table 2).

Safety

The first rating category is related to "safety" (Table 2). In this category, rated items are (a) accident rate, (b) hazards, (c) stopping sight distance, (d) passing sight distance, (e) traffic control, and (f) horizontal alignment.

In Table 2, the first item under safety is accident rate. Assignment of relative weights to each accident occurring on a roadway segment over the past 5 years varies according to severity of the accident. Property damage accidents result in one deficiency point, whereas personal injury accidents are four and fatal accidents are six deficiency points. Mercier and Stoner (*9*) cited that the score for a given road segment uses the following relationships:

$$\text{Rating} = 11 - (N/L)$$

where,

N = sum of all deficiencies,
L = length of the road segment in miles,
11 = maximum score, and
0 = minimum score (negative scores are recorded as 0).

The second item rated under safety is the roadway segment hazards (Table 2). Deficiency points are assessed for each

TABLE 2 ROADWAY NETWORK SUFFICIENCY RATING CRITERIA

Rating Category	Item Rated	Max. Point
1. Safety		
(45 points)	a. Accident Rate	11
	b. Hazards	9
	c. Stopping Sight Distance	8
	d. Passing Sight Distance	5
	e. Traffic Control	6
	f. Horizontal Alignment	6
	Sub Total	45
2. Roadway Segment Conditions		
(26 points)	a. Base	9
	b. Wearing Surface	9
	c. Drainage	8
	Sub Total	26
3. Service		
(20) points	a. Level of Service (HCM65) volume capacity on a roadway segment	6
	b. Pavement Width	9
	c. Shoulder Width	5
	Sub Total	20

hazard not included in any other rating element. They are

- Narrow structures (less than 20 ft);
- Structure with poor approach alignment;
- Railroad crossing at grade without automatic signals;
- Abrupt or severe grade changes; and
- Other fixed structures extending into the traveled way.

Rating scores are based on the average number of hazards per mile of roadway using the following formula:

$$\text{Rating} = 9 - 2\,(N/L)$$

where,

N = number of hazards encountered,
L = length of road segment in miles, and
2 = perceived weighted severity index of the effect of the hazards on driving safety (maximum score is 9 and minimum is 0 with negatives recorded as 0).

Other items rated under the safety category are (a) stopping sight distance, (b) passing sight distance, (c) traffic control, and (d) horizontal alignment. These items were rated on the basis of existing established standards and engineering judgments. The item with a maximum point value as given in Table 2 is an indication of no defect, whereas a defective item is assigned a point value of 0.

Roadway Segment Conditions

The second rating category is "roadway segment conditions," which includes base, wearing surface, and drainage (Table 2). The identified roadway segment base was rated as follows:

Excellent	8 to 9	No evidence of base failure
Good	6 to 7	Minor base failures, which are correctable by spot repairs
Fair	5	Frequent base failure, which causes reduction in traffic speeds and should be considered for reconstruction
Poor	1 to 4	Severe base failure, which makes reconstruction necessary

In the evaluation of the city's roadway surface condition and drainage problems, the Laser Road Surface Tester (LRST) is used. The LRST uses a combination of 11 laser cameras in conjunction with on-board computers to record various elements of a surface condition. The 11 lasers are mounted on the front of a van capable of collecting roadway surface data (e.g., rut depth, crack, distance, speed, and so on) with an accuracy of ±0.1 of measuring range. The LRST data are analyzed, evaluated, and then incorporated into "roadway segment conditions" for improvement priority consideration.

The city of Gainesville hired the owner of the LRST, a consultant named Infrastructure Management Services (IMS) from Arlington Heights, Illinois. The consultant used LRST with a four-man crew including one from Gainesville for a period of 3 months at a cost of $137 per lane-mile. It took the city about 3 months to collect and incorporate the data into the city's roadway network improvement priority program.

Service

A third general type of scale is represented under the "service" category. For instance, capacity of a segment was based on the criteria established in the 1965 *Highway Capacity Manual* (*10*) having six levels of service from A to F. Furthermore, where the segment included signalized intersections, the improvement was weighed on the basis of 1985 HCM (*11*) criteria (Table 3).

Under the service category related to pavement width, the following design guide was used:

Excellent	9	Width of pavement that meets or exceeds the width specified in the appropriate design standards
Good	6 to 7	Width of pavement that is within 2 ft less than the design standard
Fair	5	A "tolerable" width of pavement, which is 2 to 4 ft less than the design standard
Poor	1 to 4	A not tolerable width of pavement, which falls short of design standard by 4 ft or more

Table 4 presents an example of a summary of each roadway sufficiency rating, segment length, and improving cost and a final priority rank. A candidate with a minimum point value is selected first for improvement. For instance, in Table 4, the first candidate for improvement is roadway segment C. The maximum total roadway sufficiency rating for this segment is 61 points. The total points are calculated on the basis of information given in Table 2. A similar table is prepared for roadway Segment C and a maximum point value is cal-

TABLE 3 LEVEL OF SERVICE IN RELATION TO STOPPED DELAY PER VEHICLE AT SIGNALIZED INTERSECTION (*11*)

Level of Service (HCM 85)	Stopped Delay per Vehicle (s)
A	< 5.0 (sec.)
B	5.1 to 15.0
C	15.1 to 25.0
D	25.1 to 40.0
E	40.1 to 60.0
F	< 60.0

TABLE 4 AN EXAMPLE OF ROADWAY NETWORK SUFFICIENCY RATING AND ROADWAY SEGMENT'S FINAL RANK FOR IMPROVEMENT

Segment at	RNSR	Length (mile)	$/length	Final Rank*
A	89	1.3	56,622	9th
B	75	1.2	159,571	4th
C	61	1.5	77,211	1st
D	65	1.0	102,949	2nd
E	72	1.4	123,539	3rd
.	.	.	.	.
.	.	.	.	.
.	.	.	.	.

Segment: Road Segment Identifier

RNSR: Roadway Network Sufficiency Rating

Length: Road Segment Length in Miles

$/Length $/mile to Remove Segment Deficiency

* The final ranking was based on the criteria set in Table 2 (Roadway Network Sufficiency Rating Criteria). A total point value was calculated for each roadway segment. A segment with a minimum point was the first candidate for improvement. The cost/length is only calculated as an indication of how much it would cost to improve a candidate segment.

culated for each of the items shown in Table 2. The subtotal of each rating category (safety, roadway segment conditions, and service) is added and a maximum of 61 points is obtained for this segment. Tables similar to Table 2 are prepared for each roadway segment and a total maximum point value is calculated.

IMPROVEMENT PRIORITIZATION AND RANKING PROCEDURE AT SIGNALIZED INTERSECTIONS

Gainesville also suffers from the lack of funds to improve the city's signalized intersections.

The city's intersections were evaluated and ranked on the basis of consideration for both severity rate and level of service (Tables 5 and 6). A simple computer software program was developed by K. Green of the city's traffic division and the following data were incorporated:

- Number of accidents per intersection;
- Number of fatalities per intersection;
- Number of injuries per intersection;
- Number of property-damage accidents per intersection;
- Property damage total in dollars per intersection; and
- Level of service based on stopped delay per vehicle.

From the raw data, two rates are calculated. These are

$$\text{accident rate} = (tot * 1{,}000{,}000)/(365 * adt)$$

$$\text{severity rate} = [(5.8 * fat) + (2 * per) + (prop)] * 1{,}000{,}000/(365 * adt)$$

where,

- *tot* = total number of accidents for the intersection per year,
- *adt* = average daily traffic (24-hr period),
- *fat* = number of fatalities for the intersection per year,
- *per* = number of personal injuries for the intersection per year, and
- *prop* = number of property accidents for the intersection per year.

The 1985 HCM level-of-service criteria for the average

TABLE 5 AN EXAMPLE OF RANKING THE SIGNALIZED INTERSECTIONS FOR IMPROVEMENT IN GAINESVILLE, FLORIDA

ACCIDENT RATE			SEVERITY RATE			ACCIDENTS			PROPERTY DAMAGE			LEVEL OF SERVICE	
SIG*	RATE	RANK	SIG	RATE	RANK	SIG	NO.	RANK	SIG	$	RANK	SIG	POINT
412	2.908	1	415	3.857	1	121	35	1	128	58,935	1	412	2
411	2.611	2	305	3.727	2	610	33	2	415	54,600	2	415	2
415	2.282	3	411	3.481	3	127	29	3	130	46,000	3	411	4
610	2.264	4	412	3.356	4	336	25	4	106	45,450	4	610	3
306	2.130	5	610	2.676	5	117	24	5	113	43,700	5	117	3
336	1.890	6	336	2.495	6	122	23	6	336	42,220	6	121	4
127	1.825	7	508	2.413	7	628	23	6	612	37,425	7	628	4
117	1.768	8	127	2.390	8	612	21	7	619	35,580	8	508	4
122	1.726	9	117	2.210	9	415	20	8	117	35,395	9	127	2
628	1.717	10	123	2.202	10	123	20	8	628	31,950	10	723	5
121	1.651	11	122	2.177	11	619	20	8	610	30,400	11	130	4
123	1.631	12	324	2.167	12	326	19	9	123	29,170	12	319	3
324	1.589	13	628	2.090	13	130	19	9	412	27,800	13	336	3
335	1.539	14	612	2.001	14	329	18	10	121	25,195	14	324	4
508	1.508	15	625	1.942	15	113	17	11	215	24,625	15	335	5
319	1.412	16	121	1.887	16	410	16	12	335	24,100	16	113	4
410	1.409	17	224	1.847	17	108	16	12	329	22,925	17	612	3
340	1.390	18	517	1.758	18	133	15	13	325	22,955	19	619	4
507	1.366	19	106	1.716	19	213	14	14	324	21,960	19	122	5
612	1.356	20	507	1.706	20	412	13	15	327	21,775	20	106	4

* SIG (Signal) - For identification purpose each intersection is being designated with a number.

stopped delay per vehicle was also incorporated (Table 3). Each intersection is then ranked in five separate categories and given a number for its position in that category. The five ranking categories are accident rate, severity rate, total number of accidents, property damage in dollars, and level of service based on stopped delay per vehicle (Table 5).

The final ranking is based on the total points an intersection received when the five-category rankings were totaled. The lower the ranking total, the higher the candidate's chances for improvements (Table 6). For instance, in Table 5 signal number 412 has the ranking description shown in Table 7.

In Table 6, signal Number 412 is ranked fifth as a candidate for improvement. Other signalized intersections are ranked accordingly.

There are many methods that can be used objectively to improve a low-ranking intersection. Among these techniques are

- Adding exclusive turn lanes (left and right turn lanes); and
- Applying signal timing optimization software (e.g., HCM 65, Circular 212, HCM 85, Signal Optimization Analysis Package "SOAP 84," Traffic Network Study Tool 7-version "TRANSYT-7F," PASSER II-87, PASSER III-88, Highway Capacity Software (HCS) version 1.4, and so on).

Installation of the new timing plans in Gainesville produced by TRANSYT-7F enhanced the average total time improvements of an intersection by 10 percent meaning an estimated annual benefit per intersection of about $23,935. The safety results of those improved intersections will be the subject of future investigations.

SIDEWALK IMPROVEMENT PRIORITIZATION AND RANKING PROCEDURE

Gainesville has a large number of existing streets that have either inadequate or nonexistent sidewalk facilities. The cost to construct sidewalks on all of these streets far exceeds the city's current funding capability. A new sidewalk installation work plan, including budget priority and ranking procedure, is established on the basis of (a) pedestrian service demand factor, and (b) pedestrian environmental demand factors.

Pedestrian Service Demand

Because the pedestrian service demand information is qualitative, determination of a numeric value for pedestrian service demand for a given street section is based on weighted

TABLE 6 AN EXAMPLE OF THE FINAL RANKING OF THE SIGNALIZED INTERSECTIONS FOR IMPROVEMENTS

FINAL RANK	SIG. NO.	DESCRIPTION	RANK TOTAL*
1	415	NE 39 Ave/Waldo Rd	16
2	127	W Univ Ave/NW 34 St	21
3	610	SW 2 Ave SW 13 St	25
3	336	Mall Ent/NW 13 St	25
4	117	W Univ Ave/NW 6 St	34
5	412	NE 23 Ave/NE 15 St	35
6	628	SW 16 Ave/SW 13 St	43
7	121	W Univ Ave/NW 13 St	46
7	123	W Univ Ave/NW 18 St	47
8	612	SW 2 Ave/SW 34 St	51
9	324	NW 16 Ave/NW 2 St	65
10	335	NW 23 Ave/NW 16 Terr	70
11	113	Univ Ave/Main St	70
12	619	SW 8 Ave/SW 13 St	71
12	122	W Univ Ave/NW 17 St	72
13	130	Newberry Rd/NW 8 Ave	72
13	411	NE 12 Ave/NE 9 St	72
14	319	NW 8 Ave/NW 43 St	78
15	106	E Univ Ave/SE 15 St	85
16	340	NW 39 Ave/NW 34 St	82
17	329	NW 16 Ave/NW 34 St	89
18	625	Archer Rd/Center Dr	91
19	410	NE 16 Ave/Waldo Rd	99
20	208	SE 4 Ave/S Main St	100

* The lowest total number ranking candidate is selected first for improvement.

TABLE 7 RANKING DESCRIPTION OF SIGNAL NUMBER 412

Signal Number 412	Variable	Rank
Accident rate	2.908	1
Severity rate	3.356	4
Number of accidents	13	13
Dollar value of property damage	$27,800	15
Level of service	—	2
	Subtotal	35[a]

[a]See Table 6.

TABLE 8 WEIGHTED FACTORS FOR PEDESTRIAN SERVICE DEMAND VARIABLES

Variable	Weight Factor
Regional transit service route (RTS)	3
School bus route (SCH BUS RT)	5
School bus stop (SCH BUS ST)	4
Shopping centers (SHP CR)	2
Recreational and park areas (REC & PRK)	5
Public buildings (PUB BLDG)	2
Connection to major arterial system (CAS)	4

factors. The weighted factors used by the city engineering department for each applicable pedestrian service demand variable are given in Table 8.

The determination of the weight factor assigned to each variable is based on the anticipated number of pedestrian traffic. For example, the weight factor for Variable 5, recreational and park areas, is higher than Variable 1, RTS route, because of the higher anticipated pedestrian traffic associated with the recreational and park areas as compared to an RTS route and because the percentage of children in the pedestrian traffic is expected to be higher for recreation and park areas than RTS routes.

The numeric value for pedestrian service demand is the summation of the applicable weighted factors for the given street section. If a street section is close to a park (weight factor is 5), close to a shopping area (weight factor is 2), and connected to a major arterial (weight factor is 4), then the pedestrian service demand value is 11, which results from the summation of these three weight factors.

Pedestrian Environmental Demand

Unlike the pedestrian service demand value, the derivation of the pedestrian environmental demand value involves the quantitative interaction of the two variables.

The value for a given street section is computed by initially checking the existence of sidewalks. This information is evaluated over the entire length of the street section.

Next, the average daily traffic (ADT) volume information is factored into the calculations to yield a final environmental value. The threshold limit for sidewalk consideration is an ADT of 1,000 or greater. ADT of 1,000 is defined by the city ordinance as the ADT value that separates a residential street classification and a minor collector street classification. A given street section must have an ADT of at least 1,000 in order to obtain an environmental value.

Total Sidewalk Demand

The total sidewalk demand for a given street section is a summation of the pedestrian service demand value and the pedestrian environmental demand value.

As stated earlier, a significant portion of the sidewalk needs assessment data base was derived from the roadway pavement management data base. The roadway pavement management program divided the city into six study areas. The sidewalk needs assessment study is likewise divided into six areas.

TABLE 10 WEIGHTED FACTORS FOR TOTAL SIDEWALK DEMAND

Variable	Weight Factor
School bus route (SCH BUS RT)	5
Regional transit service route (RTS)	3
School bus stop (SCH BUS ST)	4
Shopping centers (SHP CR)	2
Recreational and park areas (REC & PRK)	–[a]
Public buildings (PUB BLDG)	2
Connection to major arterial system (CAS)	4
(See Table 9, Row 1, Column 12) Subtotal	20

[a]Factor not present.

The result of the analyses is a priority listing of the street sections to be considered for new sidewalks (Table 9). For instance, in Table 9 the pedestrian service demand need total of 20 (Row 1, Column 12) is calculated as follows: The streets from West University Avenue to Northwest 7th Avenue have the characteristics given in Table 10 (starting from Column 5, Table 9, the value of 1 signifies the presence of the respective factor, and the value of 0 indicates that the factor is not present).

The pedestrian environmental demand total is calculated by giving quantitative values to the existence of sidewalks over the entire length of the street section. The ADT is another consideration over each particular roadway segment. As a result of consideration of these two factors over the entire section of this roadway segment, a total of 71 points are calculated for pedestrian environmental demand value. A total of 91 points (Row 1, Column 15, Table 9) results from adding both pedestrian service demand and environmental demand values. The remaining items in Table 9 are calculated accordingly.

TABLE 9 AN EXAMPLE OF TARGET STREETS FOR NEW SIDEWALK CONSTRUCTION

STREETS FROM	TO	WDTH (FT)	DIST (FT)	SCH BUS RT	RTS BUS RT	SCH BUS ST	SHP CR	REC & PRK	PUB BLDG	CAS	NEED TTL	NEED RANK	ADT	TTL	RANK
W Univ Ave	NW 7 Ave	31	1,946	1	1	1	1	0	1	1	20	60	11,000	91†	1
W Univ Ave	NW 8 Ave	28	2,683	1	1	1	1	0	1	1	20	61	11,000	78	2
SE 15 St	SE 17 St	22	925	1	1	1	0	0	0	1	16	265	6,600	72	3
S Main St	SW 11 St	20	3,468	0	1	1	0	1	0	1	18	108	5,666	65	4
SE 12 St	SE 15 St	18	1,456	1	1	1	0	0	0	1	16	266	5,600	62	5
.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.

NOTES: * The value of "1" in columns 5 to 11 signifies the presence of the respective factor and the value of "0" in columns 5 to 11 signifies the factor is not present.

† The higher the total (column 15), the better the chances are for improvement

SCH BUS RT - School Bus Route
RTS BUS RT - Regional Transit Bus Route
SCH BUS ST - School Bus Stop
SHP CR - Shopping Centers
REC & PRK - Recreational & Park
PUB BLDG - Public Building
CAS - Connection to Major Arterial System
ADT - Average Daily Traffic

Evaluation of the results of the analyses indicated that the priority listing for sidewalks, both in a given study section and on a citywide basis, fairly accurately reflect the relative needs of the community.

CONCLUSIONS AND RECOMMENDATIONS

In determining the improvement deficiency of the city's roadway network system, the following general steps were developed:

1. Based on AASHTO and HCM standards and the engineering judgments of the city staff, certain criteria were identified to evaluate the overall improvement conditions (e.g., Table 2).
2. Based on the criteria in Step 1, the city's roadway network system was divided into homogeneous segments. If a level of service or a segment pavement's condition changed significantly, it was broken down into two or more homogeneous segments.
3. A total point value was calculated for each segment in order to examine and rank a segment's candidacy for improvement.
4. Dollar per segment was calculated to remove the segment's deficiency.
5. A careful check was made for locating errors in judging a segment's weight and ranking. An estimate of the top-ranked projects was made, to be undertaken given the available budget.
6. A significant usage of the rankings was established as the starting point for developing a road repair work plan for the next planning period.

Often a decision maker looks for a simple and numerical method to rank several projects to see how many can fit into a limited budget for improvement during a specified planning horizon.

Roadway improvement priority consideration is relevant to the end results of a comprehensive study and analysis of a project's components for establishing order of needs for final selection of each project for improvement. The heuristic presentation of a project's need should help agencies to allocate the available limited funds to those projects identified on a priority basis, particularly when requests for additional funds are made to the state or the federal government. Such an approach should also be helpful in convincing the funding agencies to provide the necessary funding.

It is proper for agencies (city, county, district, state, and federal) to allocate limited funds to projects on the basis of project priority. The priority model developed for Gainesville, Florida, is a starting point for developing roadway repair work plans, sidewalk improvement, traffic improvement, safety and signal improvements, new construction, restoration, and rehabilitation. The benefit derived from this ranking procedure enables the city to identify those critical projects that need improvements. It is a simple and practical approach to rank a project on a priority basis. The developed step-by-step overview should work well if the criteria are identified with accurate data. The quality of subjective assignment of values could also be enhanced by the accuracy of data and consideration of the judgment of experienced city staff. In addition, the quality of the evaluation matrix can be further enhanced by incorporating community goals, preference, impact criteria, and so on. Additional research is needed to establish more systematic scoring criteria with input from community groups and local, state, and federal governments. Similar investigation in other states should provide researchers with information on allocation schemes as a basis for comparing and improving existing methods.

REFERENCES

1. K. Moscowitz. Numerical Ratings for Highway Sections as a Basis for Construction Programs. *Bulletin 17*, HRB, National Research Council, Washington, D.C., 1948, pp. 28–39.
2. W. E. Willey. Arizona's Experience with Sufficiency Ratings. *Bulletin 53*, HRB, National Research Council, Washington, D.C., 1952, pp. 3–7.
3. C. V. Zegeer and R. L. Rizenbergs. Priority Programming for Highway Reconstruction. In *Transportation Research Record 698*, TRB, National Research Council, Washington, D.C., 1979, pp. 15–23.
4. D. R. Uzarski and M. I. Darter. Comparing Different Strategies from Selecting Pavement Sections for Major Repair. In *Transportation Research Record 1060*, TRB, National Research Council, Washington, D.C., 1986, pp. 61–69.
5. D. Bower. Statewide Systems Level Allocation of Highway Resources: Case Study of Colorado. Presented at 67th Annual Meeting of Transportation Research Board, Washington, D.C., 1988.
6. *Demand-Responsive Approach to Highway Maintenance and Rehabilitation, Volume 2: Optimal Investment Policies for Maintenance and Rehabilitation of Highway Pavements*. Report DOT/OST/P-34/87/054. University Research Program, U.S. Department of Transportation, June 1985.
7. T. F. Humphrey. Evaluation Criteria and Priority Setting for State Highway Programs. *NCHRP Synthesis of Highway Practice 84*: TRB, National Research Council, Washington, D.C., Nov. 1981, 32 pp.
8. J. A. Swanson. General Comments on Sufficiency Rating Procedures. *Bulletin 53*, HRB, National Research Council, Washington, D.C., 1952, pp. 7–11.
9. C. Mercier and J. Stoner. Sufficiency Ratings for Secondary Roads: An Aid for Allocation of Funds? Presented at 67th Annual Meeting of the Transportation Research Board, Washington, D.C., 1988.
10. *Special Report 87: Highway Capacity Manual—1965*. HRB, National Research Council, Washington, D.C., 1965, p. 397.
11. *Special Report 209: Highway Capacity Manual*. TRB, National Research Council, Washington, D.C., 1985.

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

Socioeconomic Methodology for Rural Road Construction

J. Greenstein, L. Berger, and H. Bonjack

In many South American countries, such as Ecuador, Peru, and Bolivia, rural development has been held back by a lack of accessibility to many potentially rich agricultural areas. As a result, these areas are now being used for subsistence farming only rather than for more mechanized farms that could produce substantial amounts of agricultural surplus. It is apparent that road improvement could increase agricultural production and substantially reduce the user costs because the better road surfaces would encourage the use of motorized vehicles rather than animals or river boats. The better economic returns possible from the existing land would lead to an increase in the area under cultivation and eliminate the potential loss from crop deterioration resulting from a lack of access during harvest season or damage to fragile crops because of rough road surfaces. The economic analysis requires not only a determination of the costs and benefits, but an evaluation of such economic indicators as net present value, first year rate of return or internal rate of return, and optimum schedule for construction. The economic indicators, when evaluated jointly with such social factors as population density and level of education, are used to predetermine both the socioeconomic justification and the priorities for rural road construction.

Pacific Rim countries of South America, such as Ecuador, Peru, and Bolivia have three major climatic zones: tropical or mountainous with subtropical conditions, tropical or mountainous with arid conditions, and semiarid zones. In general, the subtropical zones, including the west coast of Ecuador, possess the richest agricultural areas and produce such export commodities as bananas, coffee, cocoa, rice, vegetables, and shrimp. However, the economic growth of these areas has been substantially hindered by poor accessibility, which has substantially increased the vehicle operating costs and traffic hazards.

A socioeconomic methodology that examines the relationships between road accessibility, agricultural production, and economic and social indicators for rural improvement has been developed that evaluates the benefits of investments from road construction in such rural areas. Socioeconomic analysis of road construction for rich agricultural areas is best executed in two stages (*1,2*). The first stage, which is a threshold analysis, determines the most economical alternative for each given traffic volume. The second stage is the socioeconomic analysis that evaluates the benefits obtained from reduced transportation costs and reduced losses in the value of agricultural products being transported to local or international markets. Although the investments are made only in the road sector, other benefits derived from better accessibility include a reduction in the rate of illiteracy and a resettlement of the population closer to good transportation facilities. Most of the rural areas in South America are not as rich as the western provinces of Ecuador (*1,2*), and, consequently, they require additional investments to justify road construction now (*2,3*). These complementary investments in rural agriculture, when combined with the investment for road construction, can often generate sufficient economic benefits to justify the entire program.

The authors' experience in road planning in the developing world indicates that this concept of socioeconomic evaluation can be successfully used in virtually every tropical, subtropical, or arid zone that possesses a potential for agricultural growth. This specific methodology was used in 1986 for the planning and construction of over 1,600 km of rural roads in the mountainous and eastern Amazonas regions of Ecuador.

Louis Berger International, Inc., 100 Halsted Street, P.O. Box 270, East Orange, N.J. 07019-0270.

ENGINEERING CLASSIFICATIONS OF RURAL ROADS

In the Pacific Rim countries of South America, nine main types of rural roads have been identified (Table 1). Type 1 is designated for dirt roads built with limited engineering input using either labor-intensive methods or limited use of a motorgrader. During the rainy season, these dirt roads are frequently impassable from 1 to 6 months, depending on whether they are in semiarid or subtropical areas, and also depending on whether good or poor drainage conditions exist. The life expectancy of these earth roads is likewise a function of the surface California bearing ratio (CBR). Prior experience has demonstrated that roads with a subgrade CBR of 4 to 7 can carry, respectively, 400 to 3,000 equivalent standard axle loads (ESALs) of 8,200 kg. Failure of these earth roads is defined as rutting to a depth of 10 to 15 cm (*4*).

Road Types 2 and 3 are composed of compacted silty sand constructed to widths of from 4 to 6 m, respectively. The thickness of the surface course on these roads varies between 10 and 30 cm, and the design CBR varies from 7 to 9. These roads are capable of carrying between 3,000 to 11,000 ESALs for Type 2 roads and approximately 5,000 to 20,000 ESALs for Type 3 roads (*4*).

Road Types 4 and 5 are constructed with a gravel or laterite surface, from 12 to 35 cm thick. The roads are built 4 to 6 m wide, respectively, are usually designed to carry between 25,000 to 50,000 ESALs, and have a life expectancy of approximately 7 years before rehabilitation (*3, 4*).

Roads 4E and 5E are stone roads (*empedrado* in Spanish) requiring minimum maintenance. These roads have a life expectancy of from 20 to 30 years before strengthening or

TABLE 1 BASIC ENGINEERING PROPERTIES OF RURAL ROADS

	Road Type																	
	7		6		5		5E		4E		4		3		2		1	
	Terrain[a]																	
Property	L	M	L	M	L	M	L	M	L	M	L	M	L	M	L	M	L	M
Design speed (km/hr)	60	40	60	40	50	25	50	25	50	25	50	25	50	25	50	30	30	20
Minimum horizontal radius (m)	120	50	120	50	80	30	80	30	80	30	80	30	80	30	80	30	25	12
Pavement width (m)	6.0		6.0		6.0		5.0-6.0		3.0-4.0		4.0		6.0		4.0		3.0-4.0	
Shoulder width (m)	2 x .0.6		2 x 0.6		-		-		-		-		-		-		-	
Pavement materials	Base, CBR >80, DBST		Base, CBR >60		Subbase CBR>20		Stone		Stone		Subbase CBR>20		Compacted subgrade, CBR 7-9		Compacted subgrade, CBR 7-9		Natural subgrade, CBR 4-7	

[a] L = level; DBST = double bituminous surface treatment; M = mountainous.

rehabilitation is necessary. They vary in width from 3 to 4 m for Type 4E and 5 to 6 m for Type 5E (Table 1).

Road Types 6 and 7 are normally about 7.2 m wide with Type 6 being free of asphalt surfacing and Type 7 with an asphaltic surface treatment. Types 6 and 7 are designed to carry from 200,000 to 400,000 ESALs and have a design life of approximately 10 years (*2,3,5*). For Type 6 and 7 roads, pavement failure is defined as rut depth of 5 to 7 cm for road Types 7 and 6, respectively.

PRINCIPLES OF THE ECONOMIC METHODOLOGY

The major conclusion reached from the rural road studies carried out in Ecuador between 1984 and 1986 (*2,3*) was that the optimization of rural investment can only be obtained when the most economic type of roadway and the optimized complementary agricultural investments are both made simultaneously. Benefits achieved are as follows:

- Reduced transport costs by the substitution of economical motor vehicles replacing animal transport or river boats;
- More effective use of agricultural land by converting it from subsistence farming to commercial production;
- Increased yield per unit area through the introduction of more modern farming equipment, fertilizers, pesticides, and other technical assistance;
- Raising of crops with much higher economic value because perishables for the domestic market can be grown in place of long-life more stable crops; and
- Because of all-weather accessibility, ability to harvest the crops when they are ready for market, regardless of the weather conditions at that season of the year.

When these factors are able to generate more income and benefits than the total expenditures required during the lifetime of the road, or when the first year rate of return and other economic indicators indicate returns exceeding 12 percent, the road investment is normally considered justified by international financing agencies.

DETERMINATION OF MOST ECONOMIC TYPE OF ROAD

The least-cost type of road for each level of traffic is determined by analyzing the relationship between the total transportation cost and the traffic volume (*1–3*). The total transportation cost for a given road includes construction, maintenance, and reconstruction expenditures and vehicle operating cost (VOC) during the economic lifetime of the road, which is normally 15 to 20 years (*2,3*). During this service period, most of the benefits of the complementary agricultural investment can be developed and the construction justified (*2,3*).

The conclusions of this road screening or threshold analysis (*1–3*) are summarized as follows, and the engineering properties of these roads are shown in Table 1.

Road Type (min. transportation cost)	*Traffic Volume (vehicles per day)*
1	5–25
4 or 4E	26–100
5 or 5E	101–200
7	over 200

According to these tabulations, when the traffic volume is less than 200 vehicles per day, paved roads are not feasible and gravel or stone roads are constructed to provide all-weather accessibility.

ANALYSIS OF ECONOMIC TRANSPORTATION EXPENDITURES

The main objective of road planning is to determine the optimum level of construction and maintenance effort that will result in the lowest possible transportation expenditures during the lifetime of the road. In order to properly determine transportation expenditures it is necessary to carry out a precise unit cost analysis of the construction, maintenance, reconstruction, and vehicle operating costs (*1–3*). The unit cost analysis was carried out in both economic and financial terms to eliminate any cost distortions resulting from taxation or subsidies.

Construction Costs

The construction cost of a new road depends on such factors as topography and climate, availability of construction materials, and availability and cost of equipment and local labor. Table 2 presents representative economic costs or rural roads in Ecuador per km in 1985 and 1986. For example, the economic construction cost of a gravel road (Type 4) is $50,000, $65,000, and $105,000 for level, hilly, and mountainous terrain, respectively. The financial cost in Ecuador in 1985 was approximately 10 to 12 percent less, because of subsidies in petroleum products. The portion of foreign exchange is approximately 30 to 40 percent of the total cost. Economic construction costs of bridges for rural roads in Ecuador in 1985 and 1986 are given in Table 3 (*3,6*). These are one-lane solid concrete bridges 5.0 m wide.

Maintenance and Reconstruction Costs

The maintenance and reconstruction cost analysis includes both the determination of the annual periodical and emergency work quantities for each maintenance activity and the results of the unit cost analysis. The work quantities necessary to maintain and reconstruct the roads and the unit prices used to calculate the maintenance and reconstruction costs are shown in Table 4 (*7*).

VOC

A detailed analysis of VOC is usually needed to justify investment in rural road construction or upgrading (*1–3*). For this type of analysis in South America, the recommendations given elsewhere (*8,9*) were adjusted for the representative vehicles and the nine rural road types defined in Table 1. The economic VOCs of these representative vehicles in optimum road conditions were $0.40, $0.35, and $0.20/km for truck, bus, and pickup, respectively (*1–3*).

COMPLEMENTARY RURAL INVESTMENT COSTS

As previously mentioned, rural road construction can be justified economically in rich agricultural areas without the need for complementary rural investments (*1,10*). On the other hand, in most rural areas of Ecuador, Peru, and Bolivia, complementary agricultural investment is essential to justify such road projects. In these countries, much of the rural areas is already farmed by traditional agricultural methods.

In a study carried out in 1985 and 1986 in nine provinces in Ecuador (Chimborazo, Pastaza, Esmeraldas, Cotopaxi, Tungurahua, Canar, Bolivar, Pichincha, and Loja), it was concluded that between 0 and 15 percent of the potential agricultural areas are not yet used with an average of 7.2 percent (*3*). In other words, 92.8 percent of the potential agricultural area was already used by traditional agricultural methods. The construction of all-weather roads will usually speed up the use of this additional 7.2 percent, which will obviously increase agricultural production by approximately 7 percent.

This increase in production may be insufficient to justify road construction, so additional agricultural benefits are needed. These benefits can be achieved if the traditional agricultural production methods are upgraded to semitechnical or technical production methods. These advanced methods can be introduced only if all-weather accessibility exists (*2,3*). It was concluded from this study that both road construction and agricultural development (a complementary investment) are necessary to economically justify rural investment.

TABLE 2 ECONOMIC CONSTRUCTION COSTS OF RURAL ROADS IN ECUADOR, 1985–1986 (× $1,000/km)

Terrain/Road Type	1	2	3	4	4E	5	5E	6	7
Level	1.1	42	47	50	56	59	69	77	95
Hilly	1.1	57	65	65	71	77	87	99	130
Mountainous	1.1	96	112	105	111	123	140	171	185

TABLE 3 ECONOMIC CONSTRUCTION COSTS OF RURAL ROAD BRIDGES IN ECUADOR, 1985–1986 (× $1,000/km)

	Cost (x $1,000/lineal meter) 1985-1986		
	Span (Meters)		
Type of Cost	≤30	31-60	761
Deck Only	0.6	0.9	1.2
Entire Bridge	1.4	2.0	2.6

TABLE 4 ECONOMIC COSTS OF MAINTENANCE AND RECONSTRUCTION OF RURAL ROADS IN ECUADOR (1985–1986)

Road Type	Maintenance Cost (x $1,000/year/km) by Terrain			Reconstruction Costs (x $1,000/operation/km)	Average Period of Reconstruction (Years)
	Level	Hilly	Mountainous		
1	0.90	0.95	1.00	1.0	0.5
2	1.00	1.10	1.15	1.1	2
3	1.60	1.65	1.70	2.0	3
4	2.00	2.20	2.50	4.5	7
4E	1.00	1.05	1.10	-	-
5	2.30	2.40	2.60	6.0	7
5E	1.50	1.55	1.60	-	-
6	3.50	3.80	4.10	6.0	7
7	4.50	5.00	5.50	15.0	10

DEFINITION OF AGRICULTURAL BENEFITS ACHIEVED THROUGH ROAD CONSTRUCTION

The economic impact of road construction in agricultural areas was previously analyzed by means of the producer-surplus approach (*10*), which related a large portion of the agricultural benefits to the increase in the area under cultivation as a result of the introduction of new roads. It was concluded that this approach may be insufficient to economically justify rural road construction (*2,3*). In such cases other sources of rural benefits were also explored (*2,3*). These benefits are defined as economic value added. Five sources of economic benefits were identified for the purpose of economic analysis and justification of road construction:

- Improvement in the agricultural exploitation system;
- Savings in transportation costs;
- Cultivation of new agricultural areas;
- Elimination of losses in existing crops caused by lack of access; and
- Elimination of losses to existing crops because of damages when transported over roads with rough surfaces.

An analysis of each of these five economic benefits is presented in the following sections.

IMPROVEMENT IN THE AGRICULTURAL EXPLOITATION SYSTEM (AD_{ex})

Three major exploitation systems were identified: traditional, semitechnical, and technical. The traditional system is characterized mainly by the use of the family work force; seeds are from the last harvest, and neither fertilizers nor technical assistance is used. Production rates are low and a large portion of the harvest serves for local subsistence. A total of approximately 72 percent of the cultivated areas in the seven provinces studied was identified as traditional (*2,3*). The semitechnical system is characterized by the use of machinery for land preparation, application of fertilizers in selective form, and the use of improved seed. The farmer uses limited technical assistance and credits extensively. Yields are varied and the harvest is frequently mechanized. Approximately 27 percent of the area studied was identified as semitechnical or partially mechanized in 1985. The technical system is totally mechanized, capital-intensive, and characterized by total control of seed quality and the use of fertilizers and chemical elements. The farmer makes extensive use of technical assistance and credits; yields are high and the harvest is frequently mechanized. Approximately 1 percent of the studied area was identified as technical in 1985.

Based on a detailed analysis it was concluded that the main constraints to improving the agricultural system (from traditional to semitechnical) are the lack of adequate infrastructure (principally, all-weather roads for market access), the use of inputs (such as improved seed and fertilizers, which should be brought in from outside the zone), and the introduction of technical assistance. In order to estimate the value added by changing the exploitation system, a production function was developed (*2,3*) for about 60 main agricultural products (e.g., coffee, cacao, banana, citrus fruit, potatoes, garlic, onions, tomatoes, and so on) in the area studied. For each product a production function relating production cost, yields, and exploitation system was developed.

A typical characteristic of the production function is shown in Figure 1, which describes the relationship between the yields and production costs in the traditional, semitechnical, and technical exploitation methods. Under the traditional method, production cost per ha is defined in Figure 1 as C_0, C_1, and C_2, and yields per ha are defined as R_0, R_1, and R_2 for traditional, semitechnical, and technical exploitation systems, respectively. The C and R values were determined for all 60 products and the three levels of exploitation. Representative yield/cost values are given in Table 5. For example, the production cost of cacao is C_0 = \$87/ha and yield is R_0 = 5 qq/ha. One ha equals 10,000 m^2 and one qq equals 100 lb. For the same product—cacao—the production cost and yield in the semitechnical method is C_1 = \$139/ha and R_1 = 9 qq/ha. The unit price (UP) was \$21/qq in 1985. In this case the value added for production of cacao in the traditional exploitation method is defined as

$$AD_0 = (UP = \$21/\text{qq})\ (R_0 = 5\ \text{qq/ha}) - (C_0 = \$87/\text{ha}) = \$18/\text{ha} \qquad (1)$$

where

AD_0 = economic value added in dollars per ha in the traditional method and
UP = unit price of the product (in this case cacao).

By investing and improving the production system from the traditional to the semitechnical exploitation method, the value added (AD) is increased from \$18 to \$50/ha (Table 5). The new value added is calculated as follows:

$$AD_1 = (UP = 21)\ (R_1 = 9) - (C_1 = 139) = \$50/\text{ha} \qquad (2)$$

where AD_1, C_1, and R_1 are the value added production cost and yield of cacao in the semitechnical method. Because the change in production costs of cacao from the traditional to the semitechnical exploitation system is $C_1 - C_0 = 139 - 87$ = \$52/ha (Table 5), one may conclude that the annual benefits of this investment are $[(AD_1) - (AD_0)]/[(C_1 - C_0) = (50 - 18)/52 = 0.62$, or 62 percent of annual profit. In the case of coffee the marginal value added is $AD_1 - AD_0 = 49 - 10$ = \$39/ha. The annual profit is $(AD_1 - AD_0)/(C_1 - C_0) = 39/(151 - 110) = 0.95$, or an annual profit of 95 percent.

These two examples appear to indicate that a high rate of return can be achieved by improving the agricultural production method. This economic return has a significant value when compared to the investment in road construction. For example, say that new road construction will provide all-weather accessibility to 500 ha/km. Say that the influence area is cultivated with 40 percent cacao and 60 percent coffee. The value added by improving the traditional farming method to a semitechnical one can be determined according to Equations 1 and 2 and Table 5, namely, for cacao $[(AD_1 = 50) - (AD_0 = 18)]$ (500 ha) (0.4) = \$6,400/year/km and for coffee $[(AD_1 = 49) - (AD_0 = 10)]\ 500 \times (0.6)$ = \$11,700/year/km. Total annual benefit or value added per km is 6,400 + 11,700 = \$18,100/year/km. This high annual benefit can usually be achieved during an approximately 5- to 10-year transition period in which the traditional agricultural production system is transferred into the semitechnical method.

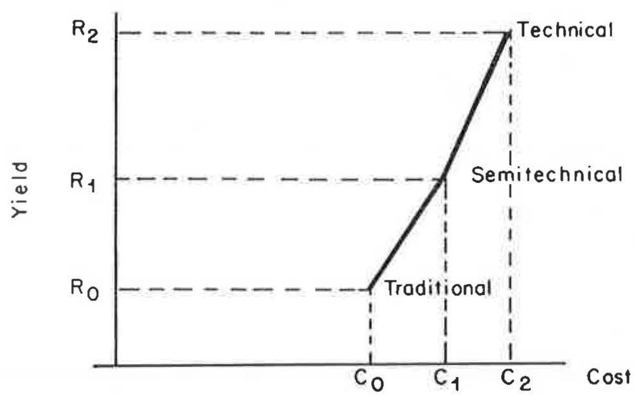


FIGURE 1 Typical characteristic of production function.

REDUCTION IN TRANSPORTATION COSTS (AD_{tr})

Savings on transportation costs in rural South America are usually obtained in two ways: by reducing (a) the VOC by using roads with better surface conditions (*1,3,8,9*), and (b) the cost of transporting agricultural products by using motorized vehicles on new roads instead of animals in areas where roads do not now exist (*2,3*). A rural fleet in such countries as Ecuador and Bolivia would typically consist of 80 percent pickups, 15 percent buses, and 5 percent medium-size trucks. The representative VOC per kilometer for these vehicles in optimum road conditions is \$0.20, \$0.35, and \$0.40/km,

TABLE 5 ANNUAL COSTS, YIELDS, PRODUCTION METHODS, AND VALUE ADDED OF REPRESENTATIVE AGRICULTURAL PRODUCTS (CHIMBORAZO, ECUADOR, 1985)

Name of Product	Traditional Cost* (CO) (\$/ha)	Traditional Yield (RO) (qq/ha)	Semitechnical Cost (C1) (\$/ha)	Semitechnical Yield (R1) (qq/ha)	Technical Cost (C2) (\$/ha)	Technical Yield (R2) (qq/ha)	Unit Price (\$/qq)	Value Added (US \$/ha) Traditional (AD0)	Value Added Semitech. (AD1)	Value Added Technical (AD2)
Cacao	87	5	139	9	+	+	21	18	50	+
Coffee	110	6	151	10	+	+	20	10	49	+
Bananas	315	269	672	581	+	+	1.7	134	315	+
Citrus Fruits	481	137	875	272	+	+	9	752	1,573	+
Potatoes	608	160	903	240	1,003	360	7	512	777	1,517
Garlic	1,543	64	2,055	120	3,576	244	50	1,657	3,945	7,624
Onions	1,312	120	1,931	200	3,686	352	21	1,208	2,269	3,706
Tomatoes	+	+	1,200	320	2,027	570	14	+	3,280	5,953

*1 quintal (qq) equals 100 lb.
+Technical agricultural technology was not yet used for this product.
(1 ha - 1 hectare)

respectively. The representative VOC per kilometer of this rural fleet is therefore 0.80 • 0.20 + 0.15 • 0.35 + 0.40 • 0.05 = \$0.23/km of rural road (in optimum conditions). The representative VOC in normal (not optimum) and in very poor road conditions is \$0.30 and \$0.46/km, respectively (*2,3*). In other words, very poor accessibility is considered to be road surface conditions that result in an increase of 100 percent in the VOC as compared to the VOC under optimum conditions. A VOC higher than \$0.46/km indicates that the road is practically not accessible.

The transportation of agricultural production in South American rural areas is usually done by pickup or light trucks that carry up to 40 qq, which is equal to 4,000 lb per vehicle. The transportation cost (TC_v) in normal road conditions is therefore $TC_v = (VOC) = \$0.3/\text{km})/40\text{ qq} = \$0.75 \times 10^{-2}$ qq/km. This vehicle transportation unit cost is only one-fifth to one-sixth of the cost of animal transport by mules. This unit cost relationship is given in Equation 3:

$$TC_a = (5 - 6) \qquad TC_v = 0.037 - 0.045 \tag{3}$$

where

TC_a = transportation cost (\$/qq/km per animal in 1985) and
TC_v = transportation cost (\$/qq/km per vehicle in 1985).

The benefit or value added of transportation (AD_{tr}) equals the savings in VOC by (a) using better road surfaces, and (b) reducing the cost of transporting goods by vehicle instead of by animal.

The transportation value added is defined in Equation 4:

$$AD_{tr} = [(VOC_b - VOC_a)\, ADT \cdot M_a \cdot 30 + \sum (TC_a - TC_v)_j\, (R_j \cdot A_j \cdot N_j)]\, L \tag{4}$$

where

AD_{tr} = annual value added related to savings in transportation costs,
VOC_b and VOC_a = VOC (per kilometers) before and after road construction,
ADT = average daily traffic,
M_a = number of months with accessibility,
L = length of road,
TC_a and TC_v = transportation cost of unit product (qq per km) of animal and vehicle, respectively,
R_j = agricultural production (per ha per product j),
A_j = influence area of road (ha) cultivated with product j, and
N_j = percentage or portion of product transfered by animals.

The following example explains how to determine the transportation value added: $L = 10$ km of rural road provides limited accessibility to 20,000 ha cultivated with 60 percent cacao and 40 percent coffee ($j = 2$). The production rates of cacao and coffee are $R_1 = 5$ and $R_2 = 6$ qq/ha (Table 5). The existing road can provide accessibility during $M_a = 6$ in the dry season only. During this time of year, the $ADT = 20$ vehicles per day. The VOC per kilometer before and after road construction is \$0.16/km. During the dry season 67 percent of the agricultural product is transferred mainly by pickups. The other 33 percent ($N_j = 1/3$) is transferred by animals during the rainy season. The transportation cost difference of unit product, $TC_a - TC_v = \$0.34$/qq/km. Equation 4 shows the value added by transportation AD_{tr} resulting from the construction of this road to a level that can provide all-weather accessibility. According to Equation 4 the annual benefits per km resulting from savings in transportation costs equal \$1,800/km.

It is worthwhile mentioning that in such rural tropical areas as the Amazonas zone in Ecuador, the Selva of Peru, and the eastern zone in the provinces of Beni and Santa Cruz in Bolivia, the use of combined land and river transportation is common. Using river transportation instead of new roads results in a significant reduction in construction costs to only about 5 to 10 percent. This small investment is needed for constructing docks, parking lots, facilities for loading and unloading, and the like. On the other hand, user transportation costs for river transportation are significantly higher (*2,3*).

The following analysis can explain this conclusion. A representative boat used in Ecuador for river transportation has a 40-hp engine and can carry 15 qq or 15 persons. The transportation cost of such a boat was \$0.65/km in 1985 and 1986, which is two to three times more than the VOC on a rural road, mainly because the degree of friction between the water and the boat significantly increases the energy needed per unit weight and unit distance as compared to the energy needs of a motor vehicle that uses a typical rural road in normal conditions. In addition, the average motor vehicle used in rural areas can carry twice the load of a boat. Therefore, the unit cost of transporting 1 qq by boat is $TC_{bo} = [(0.65/\text{km})/15]$ (qq per boat) $= \$4.3 \times 10^{-2}$/qq/km. The annual value added using river transportation AD_{riv} is the present value of the savings in construction, maintenance, and reconstruction costs of a new road as compared to the increase in user costs resulting from using river transportation over land transportation. AD_{riv} is defined in Equation 5:

$$AD_{riv} = 0.9 \cdot (CC) + \sum_{1}^{17} (MC + RC) + \sum_{1}^{17} [TC_v\,(ADT_1 + ADT_2) - TC_{bo}\,(ADT_1 + 2ADT_2)] \cdot 365 \tag{5}$$

where

ADT_1 = number of passenger vehicles carrying up to 15 persons per vehicle and is approximately equal to number of boats and
ADT_2 = number of vehicles used to transport agricultural products that carry 40 qq and are equal to twice the number of boats.

(Note: $ADT_1 + ADT_2 = ADT$ is the total average daily traffic.) CC, MC, and RC denote the construction, maintenance, and reconstruction costs, respectively. The construction is usually done in the first year and the maintenance and reconstruction expenditures take place during the economic service lifetime of the road, which is approximately 17 years (*2,3*). TC_v and TC_{bo} denote the transportation costs for a vehicle and for a boat, \$0.23/km and \$0.65/km, respectively. If AD_{riv} is greater than zero, it is feasible to use a river as part of the rural transportation system. For example, say that the construction cost of road Type 4 is $50,000/km (Table 2). The average annual maintenance cost is $2,000/km and the average annual reconstruction cost is 4,500/7 = $700/km (Table 4). The average ADT is 80 vehicles per day ($ADT_1 = 50$ and $ADT_2 = 30$).

Is it feasible to use a portion of 15 km of the river Napo in the Ecuadoran Amazonas zone instead of constructing a new gravel road parallel to the river? According to Equation 5, the value added of river transportation AD_{riv} equals $AD_{riv} = 0.9 \cdot 50{,}000 + (2{,}000 + 700)17 + 17\,[(TC_v = 0.23)\,(ADT = 80) - TC_{bo} = 0.65)\,(50 + 60)]\,365 < 0$. Conclusion: because AD_{riv} is less than zero, it will be more feasible to build a new road instead of using the river to transport goods and passengers. On the other hand, if the ADT is equal to or less than 20 vehicles per day and includes mainly passenger cars ($ADT_1 = 20$ and $ADT_2 = 0$), AD_{riv} calculated according to Equation 5 achieves a positive value, which indicates that it is not feasible to construct a new road at this stage and that it will be more economical to use the river as a link in the rural transportation network until the traffic volume increases to a level that will result in a negative value of AD_{riv} according to Equation 5.

INCREASE IN AREA UNDER CULTIVATION (AD_l)

The value added from the increase in area under cultivation is relatively small (between 0 and 15 percent) in such countries as Ecuador; therefore, the maximum new cultivated area can be 15 percent of the influence area of the road, which is 0.15 • 500 ha/km or 75 ha/km of road. For example, in the case of a cacao plantation (Table 5), $AD_l = 75$ ha $[(UP = 21)\,(R_0 = 5) - (C_0 = 87)] = \$1{,}350$/km of road length.

ELIMINATION OF LOSSES IN EXISTING CROPS CAUSED BY LACK OF ACCESS (AD_{ac}) AND POOR SURFACE CONDITIONS (AD_{sc})

Accessibility (AD_{ac})

The accessibility value added includes the benefits of eliminating the lack of accessibility to market and of having a better agricultural product as a result of improved road surface conditions (*1*). When a road in an agricultural area is inaccessible (e.g., during the rainy season), the following losses, damages, or disturbances occur: (a) transferring crops to the local market is impossible, and (b) seeding is inefficient.

Surface Conditions (AD_{sc})

Some agricultural products, such as tomatoes, avocados, bananas, strawberries, custard apples, papayas, and plantains suffer significant damage transported over roads with poor surfaces. This type of damage (or quality loss) was analyzed in Ecuador (*1–3*). More explanation of AD_{ac} and AD_{sc} is given elsewhere (*1*) and is not repeated here.

SOCIOECONOMIC ANALYSIS

Economic Analysis

The economic analysis includes the calculations of (a) the road construction costs, and (b) the transportation and agricultural costs and benefits during the lifetime of the road and the determination of such economic indicators as the net present value (NPV), first year rate of return (FYRR), optimum schedule of construction, and internal rate of return (IRR). The net benefit stream is defined as follows:

$$B_t = AD_{ex} + AD_{tr} + AD_l + AD_{ac} + AD_{sc} - [CC + MC + RC] \qquad (6)$$

where

B_t = net benefit in year t,
AD_{ex} = value added resulting from improvement in the agricultural exploitation system in year t (defined in Equations 1 or 2),
AD_{tr} = value added resulting from reducing transportation costs in year t (Equation 4),
AD_l = value added caused by an increase in the cultivated area in year t,
AD_{ac} = value added caused by improved accessibility to markets in year t,
AD_{sc} = value added caused by improved surface conditions in year t,
CC = construction cost at the year of construction,
MC = annual maintenance cost at year t in the case of a new road and difference in annual maintenace expenditures after and before improvement of an existing road, respectively, and
RC = annual expenditures for pavement reconstruction in the case of a new road and the difference in annual expenditures for pavement reconstruction after and before road improvement, respectively, in the case of an existing road.

The stream of economic benefits was calculated for 17 years and a sample of the results is given in Table 6, which presents the value of cost and four economic indicators for four representative rural roads in the Ecuadoran province of Chimborazo. For example, a new road (Number 97-0) was constructed to carry low-volume traffic (i.e., 15 vehicles per day). It is a gravel road (Type 4), 4.0 m wide and 5.4 km long. The estimated construction cost of the entire project was $200,000 (1985). The total value of benefits achieved during 1986 was $39,000, which includes $13,000 and $26,000 for transportation and agricultural benefits, respectively. The net present value at a discount rate of 12 percent is $543, the first year rate of return is 14.4 percent, the optimum year of construction is 1 (1985), and the IRR calculated for an economic lifetime of 17 years was 36.4 percent.

Social Consideration

South American governments and international finance agencies, such as the World Bank and the Inter-American Devel-

TABLE 6 SOCIOECONOMIC ORDER OF PRIORITY FOR RURAL ROAD CONSTRUCTION (CHIMBORAZO, ECUADOR, 1985; × $1,000)

Road No.	Length (km)	ADT	Road Type Existing	New	Const. Cost in 1985 (x $1,000)	Benefits in 1986 (x $1,000) Total	Transportation	Agricultural	NPV (12%)	FYRR (%)	Opt. Year of Construction	IRR (%)	Socio-economic Priority Index (SEPI)
2124-0	4.5	323	3	7	329	515	508	7	3,950	65.0	1	78.1	65.5
97-0	5.4	15	-	4	200	39	13	26	543	14.4	1	36.4	27.7
3184-0	11.4	5	-	4	940	76	18	58	799	6.0	4	21.4	19.3
2501-0	2.4	161	4E	5	124	16	6	10	303	10.4	2	33.3	16.1
2317-0	3.7	90	2	4	249	33	22	11	135	8.1	2	17.7	15.3

opment Bank, specify that the results of the economic evaluation must be analyzed together with social factors. Because the period of rural road planning is limited to approximately 1 year and always has budget limitations, maximum use is given to analyzing existing published data rather than carrying out new field surveys. The only readily available social data in Ecuador, Dominican Republic, or Bolivia are population density and rate of illiteracy. It is obvious that the higher the population density, the greater the need for transportation to local markets, public institutions, health and educational facilities, and commercial centers. That is to say, for any given investment, the social benefits to be achieved by rural road construction will be greater for a higher population density. The population index (PI) defined in Equation 7 represents this social factor. In other words the higher the PI, the larger the population that is benefited from a given construction dollar value.

$$PI = \text{population in the road's influence area} \div \text{construction cost} \times C \quad (7)$$

where C denotes a constant equal to $5,000. Another social index (*1–3*) is the education index (EI) defined in Equation 8:

$$EI = (RI)\,(PI) \quad (8)$$

where RI, as a percentage, is the rate of illiteracy in the population of the influence areas of rural roads. This percentage was determined for the influence area of each rural road. In order to analyze the economic index together with the social indexes the following empirical socioeconomic priority index (SEPI) was derived (*1*):

$$SEPI = 0.700(IRR) + 0.225(PI) + 0.075(EI) \quad (9)$$

As is shown in Equation 9, SEPI is composed of economic considerations (70 percent) and social considerations (30 percent). The relationship between the economic and social indicators can of course be modified according to national or local priorities. For example, the population included in the influence area of road Number 97-0 is 370 persons. IRR = 36.4. According to Equation 7 the population index is PI = 370/(200,000) × 5,000 = 9.25, and the rate of illiteracy is 20 percent or RI = 0.2. The SEPI, as is shown in Equation 9, is SEPI = 0.7 (36.4) + 0.225 (PI = 9.25) + 0.075 (RI = 0.2) · (PI = 9.25) = 27.7. The SEPI values calculated using Equation 9 are shown in Table 6. This socioeconomic indicator was implemented (*1–3*) to determine the priorities of constructing and upgrading 1,600 km of rural roads in seven Ecuadoran provinces (*3*): Chimborazo, Pastaza, Pichincha, Cotopaxi, Esmeraldas, Tungurahua, Canar, and Bolivar. A total budget of approximately $95 million was assigned for this purpose. Of this amount, approximately 58 percent was in local currency and 42 percent in foreign exchange.

SUMMARY AND CONCLUSIONS

- In some rural areas in South America, road construction can be economically justified only if other complementary investments are made in agriculture. These complementary investments allow for upgrading the subsistence farming system to a semitechnical or technical one. The basic goal in improving the agricultural exploitation system is to achieve all-weather accessibility for modern agricultural equipment, technical assistance, and adequate communication with the national and international market.
- Nine types of roads are mostly found in the South American rural areas. Three road types can be used during the dry season only and six types are all-weather roads. The width of the all-weather roads varies between 4.0 and 7.2 m. The pavement is composed of a local gravel (or special stone in mountainous areas) base with or without blacktop. The stone pavement needs almost no maintenance during the first 20 to 30 years of service, whereas other types of all-weather pavements with or without blacktop need rejuvenation or overlay every 7 to 10 years in addition to adequate maintenance.
- The planning for road construction is carried out in two stages. In the first, the most economical type of road is determined for the projected volume of traffic. In other words, once the projected traffic volume is known, the type of road requiring minimum transportation expenditures during its service life can be determined. In the second stage, the investment to improve agricultural benefits is determined. The following benefits are obtained from a combined investment in both road construction and agricultural development: (a) an increase in agricultural production through improvement in the agricultural exploitation system, (b) a reduction in users' costs, (c) an increase in the area under cultivation, (d) the elimination of losses in existing crops caused by lack of access, and (e) the elimination of losses in existing crops because of damages incurred when transported over roads with rough surfaces.

- When traffic volume is less than 200 vehicles per day, paved roads are not feasible and gravel or stone roads are constructed to provide all-weather accessibility.
- The economic analysis includes the calculation of (a) the road construction cost, and (b) the transportation and agricultural costs and benefits. This calculation is done for the lifetime of the road and concludes with the determination of such economic indicators as NPV, FYRR, optimum schedule of construction, and IRR. Table 6 gives an example of the results of the economic analysis.
- The conclusions of the economic evaluation are analyzed together with social factors published by the local authorities. The only readily available social data in countries such as Ecuador or Bolivia are the population density and rate of illiteracy. It is obvious that the higher the population density, the greater the need for transportation to local markets, public institutions, health and educational facilities, and commercial centers. Obviously, for any given investment, the social benefits resulting from rural road construction will be greater for a higher population density and higher rate of illiteracy.

REFERENCES

1. J. Greenstein and H. Bonjack. Socioeconomic Evaluation and Upgrading of Rural Roads in Agricultural Areas in Ecuador. In *Transportation Research Record 898*, TRB, National Research Council, Washington, D.C., 1983, pp. 88–94.
2. *Guidelines for Economic Evaluation of Rural Roads, Ecuador (Guia para Evaluacion Economica de Caminos Vecinales—Ecuador)*. World Bank, Washington, D.C., Nov. 1985.
3. *Technical Assistance to the Rural Road Unit: Final Report*. Loan No. 1882-EC. World Bank, Washington, D.C., 1986.
4. J. Greenstein and M. Livneh. Pavement Design of Unsurfaced Roads. In *Transportation Research Record 827*, TRB, National Research Council, Washington, D.C., 1981, pp. 21–26.
5. J. Greenstein and M. Livneh. Design Thickness of Low-Volume Roads. In *Transportation Research Record 702*, TRB, National Research Council, Washington, D.C., 1979, pp. 39–47.
6. L. Berger, J. Greenstein, and J. Arrieta. Guidelines for the Design of Low-Cost Water Crossings. In *Transportation Research Record 1106*, Vol. 2, TRB, National Research Council, Washington, D.C., 1987, pp. 318–327.
7. L. Berger and J. Greenstein. Simplified Procedures To Manage the Maintenance of Low-Volume Roads. In *Transportation Research Record 1106*, Vol. 2, TRB, National Research Council, Washington, D.C., 1987, pp. 201–210.
8. J. Bank. *Quantification of Road User Savings*. Staff Occasional Paper 2. John Hopkins University Press, Baltimore, Md., 1966.
9. R. Winfrey. *Economic Analysis for Highways*. International Textbook Company, Scranton, Pa., 1969.
10. G. Carnemark, J. Biderman, and D. Bovet. *The Economic Analysis of Rural Road Projects*. Staff Working Paper 241. World Bank, Washington, D.C., 1978.

Publication of this paper sponsored by Committee on Application of Economic Analysis to Transportation Problems.

Local Option Motor Fuel Taxes

THOMAS W. COOPER AND JUDITH A. DEPASQUALE

The availability and potential of local option motor fuel taxes for local highway and transportation programs are described in this paper. Although over half of the states permit local road user taxes, only a few raise significant sums from these charges and fewer still apply them throughout the state. Only Florida has universally (i.e., 63 of 67 counties) adopted the local option motor fuel tax. Florida's local motor fuel taxes supply one-half of county and one-third of municipal funds for highways, and total spending had doubled for counties and has increased by 50 percent for municipalities since 1983. The report includes an overview of highway financing with particular focus on local road user funds for highways. The Florida local option gas tax is extensively described along with its impact on local highway financing. Nearly all counties in Florida have adopted the local option gas tax, and its pervasiveness is attributed to its approval by elected officials rather than the voters. Local highway funding has significantly increased, whereas reliance on general revenues and impact fees has decreased. The local option gas tax moves Florida into the mainstream of state motor fuel taxation, that is, the state tax of 9.7 cents per gallon plus average local tax of 5.2 cents approximates the national average motor fuel tax. However, under Florida's arrangement, local governments control 62 percent of total motor fuel tax revenues, whereas the national average is 29 percent. Given the need for added revenue for state and local road programs, the local option motor fuel tax might be considered by other states to, in part, offset the decline in real federal spending.

The availability and potential of local option motor fuel taxes for local highway and transportation programs are described in this paper. Although over half of the states permit local road user taxes, only a few raise significant sums from these charges and fewer still apply them throughout the state. Except for Hawaii where each island levies a separate gas tax, only Florida has universally (i.e., 63 of 67 counties) adopted the local option motor fuel tax.

Florida's local motor fuel taxes supply one-half of county and one-third of municipal funds for highways, and total spending has doubled for counties and has increased by 50 percent for municipalities since 1983. Given the need for added revenue for state and local road programs, the local option motor fuel tax might be considered by other states to, in part, offset the decline in real federal spending in the immediate years ahead.

This report begins with an overview of highway financing with particular focus on local sources of funds for highways. Next, the Florida local option tax is described followed by its impact on local financing and some policy implications and conclusions.

T. W. Cooper, FHWA, 400 Seventh Street, S.W., Washington, D.C. 20590. J. A. DePasquale, Florida Department of Transportation, 7322 Normandy Boulevard, Jacksonville, Fla. 32205.

OVERVIEW OF HIGHWAY FINANCING

In 1987, all levels of government raised $66.5 billion for highway programs. The federal government provided $14.4 billion; the states $32.8 billion; and counties, cities, and other local entities the remaining $19.3 billion (see Table 1). Federal sources—increasingly supplied by the Highway Trust Fund—accounted for 21.7 percent of total funding for highways in 1987—down from 24.1 percent in 1985 and 26.9 percent in 1984. Federal payments have been static since 1985, averaging less than $15 billion a year. The outlook for the immediate future portends similar levels of funding or even a decline inasmuch as general revenue sharing (a significant source of local government road and street financing) has been repealed and federal aid obligations are not increasing.

State and local governments have been increasing their funding for highways lately, in part, to offset the loss of real federal funding. The states account for one-half of all money raised for highways and look primarily to user fees to supply the bulk of funds. Road user revenues totaled $26.6 billion (86 percent) of state revenue of which motor fuel taxes generated $16.2 billion in 1987. States have been enacting higher motor fuel taxes in recent years. Indeed, 14 states raised motor fuel tax rates in 1987, as did 17 in 1988.

The remaining participant in this public finance triad is the local government. This group is comprised of over 3,000 counties, 16,000 townships, and approximately 20 thousand municipalities and special districts financing highway programs. Providing over $19 billion or 29 percent of the fiscal resources in 1987 for highway programs in the United States, the local government finance share is on the rise, up from 26 percent in 1985. Most local funds, excluding bond proceeds, come from nonuser sources, that is, property taxes, general revenues, and miscellaneous taxes and receipts. Road user charges accounted for only 8 percent of locally levied receipts in 1987.

Given that highway program needs in the future will greatly outstrip presently available revenues, especially in light of a federal program that is likely to remain static or even decline relative to inflation, new sources of funding must be identified by state and local governments. There is evidence that existing highway user taxes are underpriced. For example, the 1987 state motor fuel tax, expressed in real dollars, is below its 1965 level in purchasing power. To maintain parity with 1965, the average current tax rate should be raised by 2 to 4 cents per gallon (depending on choice of index). Motor vehicle registration fees are likewise below their 1965 levels, that is, 44 percent below the 1965 average fee (*1*).

Greater use of these revenue sources offers the potential to significantly increase funding to meet the ever-increasing state and local highway needs. Although attention has been focused on the rapid pace of state motor fuel tax changes

TABLE 1 1987 TOTAL HIGHWAY RECEIPTS AND DISBURSEMENTS FOR ALL UNITS OF GOVERNMENT (IN $ MILLIONS) (6)[1]

DATA COMPILED FROM REPORTS OF FEDERAL, STATE AND LOCAL AUTHORITIES

(MILLIONS OF DOLLARS)

TABLE HF-10
SEPTEMBER 1988

ITEM	FEDERAL GOVERNMENT				STATE AGENCIES AND D.C.	COUNTIES AND TOWNSHIPS	MUNICI-PALITIES	TOTAL
	FEDERAL HIGHWAY ADMINISTRATION		OTHER FEDERAL AGENCIES	TOTAL FEDERAL				
	HIGHWAY TRUST FUND	OTHER FUNDS						
RECEIPTS BY COLLECTING AGENCIES								
IMPOSTS ON HIGHWAY USERS: 2/								
MOTOR-FUEL AND VEHICLE TAXES	11,980	-	-	11,980	24,335	500	400	37,215
TOLLS	-	-	-	-	2,261	65	600	2,926
SUBTOTAL	11,980	-	-	11,980	26,596	565	1,000	40,141
OTHER TAXES AND FEES:								
PROPERTY TAXES AND ASSESSMENTS	-	-	-	-	-	2,350	1,600	3,950
GENERAL FUND APPROPRIATIONS	-	236	895	1,131	1,247	2,600	5,900	10,878
OTHER TAXES AND FEES	-	-	60	60	1,336	325	350	2,071
SUBTOTAL	-	236	955	1,191	2,583	5,275	7,850	16,899
INVESTMENT INCOME AND OTHER RECEIPTS	862	-	433	1,295	1,682	1,000	1,100	5,077
TOTAL CURRENT INCOME	12,842	236	1,388	14,466	30,861	6,840	9,950	62,117
BOND ISSUE PROCEEDS (PAR VALUE) 3/	-	-	-	-	1,927	900	1,600	4,427
GRAND TOTAL RECEIPTS	12,842	236	1,388	14,466	32,788	7,740	11,550	66,544
INTERGOVERNMENTAL PAYMENTS:								
FEDERAL GOVERNMENT:								
HIGHWAY TRUST FUND	-12,618	-	-	-12,618	12,240	205	173	-
ALL OTHER FUNDS	-	-203	-922	-1,125	351	402	372	-
STATE AGENCIES:								
HIGHWAY-USER IMPOSTS	-	-	-	-	-5,781	3,452	2,329	-
ALL OTHER FUNDS	-	-	-	-	-564	319	245	-
COUNTIES AND TOWNSHIPS	-	-	-	-	328	-428	100	-
MUNICIPALITIES	-	-	-	-	267	5	-272	-
SUBTOTAL	-12,618	-203	-922	-13,743	6,841	3,955	2,947	-
FUNDS DRAWN FROM OR PLACED IN RESERVES 4/	238	-	-	238	-9	1	-389	-159
TOTAL FUNDS AVAILABLE	462	33	466	961	39,620	11,696	14,108	66,385
DISBURSEMENTS BY EXPENDING AGENCIES								
CAPITAL OUTLAY:								
ON STATE-ADMINISTERED HIGHWAYS	-	-	-	-	21,222	-	-	21,222
ON LOCAL RURAL ROADS	-	-	-	-	938	3,800	-	4,738
ON LOCAL MUNICIPAL ROADS AND STREETS	-	-	-	-	776	-	3,856	4,632
NOT CLASSIFIED BY SYSTEM	200	21	250	471	-	-	-	471
SUBTOTAL	200	21	250	5/ 471	22,936	3,800	3,856	31,063
MAINTENANCE AND TRAFFIC SERVICES:								
ON STATE-ADMINISTERED HIGHWAYS	-	-	-	-	7,179	-	-	7,179
ON LOCAL RURAL ROADS	-	-	-	-	54	5,800	-	5,854
ON LOCAL MUNICIPAL ROADS AND STREETS	-	-	-	-	39	-	5,770	5,809
NOT CLASSIFIED BY SYSTEM	-	-	151	151	-	-	-	151
SUBTOTAL	-	-	151	151	7,272	5,800	5,770	18,993
ADMINISTRATION AND RESEARCH	262	12	65	339	6/ 2,877	775	975	4,966
HIGHWAY LAW ENFORCEMENT AND SAFETY	-	-	-	-	3,191	550	2,100	5,841
INTEREST ON DEBT	-	-	-	-	1,719	348	649	2,716
TOTAL CURRENT DISBURSEMENTS	462	33	466	961	37,995	11,273	13,350	63,579
DEBT RETIREMENT (PAR VALUE) 3/	-	-	-	-	1,625	423	758	2,806
GRAND TOTAL DISBURSEMENTS	462	33	466	961	39,620	11,696	14,108	66,385

1/ THIS TABLE SUMMARIZES AND CONSOLIDATES DATA REPORTED IN GREATER DETAIL IN THE FA, SF, SB, LF, UF, LB, AND UB TABLE SERIES. DATA FOR FEDERAL AND STATE AGENCIES ARE FINAL; THOSE FOR COUNTIES AND MUNICIPALITIES ARE ESTIMATES SUBJECT TO REVISION WHEN DATA FOR ALL LOCAL UNITS ARE AVAILABLE. TABLES HF-1 AND HF-2 FOR 1986 CONTAIN FINAL DATA FOR ALL UNITS OF GOVERNMENT.

2/ EXCLUDES AMOUNTS ALLOCATED FOR NONHIGHWAY PURPOSES. MOTOR-FUEL AND VEHICLE TAXES ARE ALSO NET AFTER REFUNDS AND COLLECTION EXPENSES. EXCLUDES MASS TRANSIT ACCOUNT OF HIGHWAY TRUST FUND.

3/ ISSUE AND REDEMPTION OF SHORT-TERM NOTES OR REFUNDING BONDS ARE EXCLUDED. INTEREST IS INCLUDED. PREMIUMS AND DISCOUNTS ON SALE OF BONDS ARE INCLUDED WITH "INVESTMENT INCOME AND OTHER RECEIPTS"; REDEMPTION PREMIUMS AND DISCOUNTS ARE INCLUDED WITH "INTEREST ON DEBT".

4/ MINUS SIGNS INDICATE THAT FUNDS WERE PLACED IN RESERVES.

5/ INCLUDES $65.7 MILLION PAID TO TERRITORIES.

6/ INCLUDES $201.8 MILLION OF FEDERAL-AID HIGHWAY FUNDS FOR RESEARCH AND PLANNING.

Source: Highway Statistics 1987,
Federal Highway Administration

during the 1980s, the potential of this levy (and others) as a locally levied road user fee has been largely overlooked.

LOCAL ROAD USER CHARGES

Road user imposts provide a minor share (7 percent for 1986 and 8.5 percent for 1987) of county and city road and street funds. Although road user charges support a significant share of local road programs via shared state user taxes, that is, 30 percent of county and 17 percent of city expenditures nationally (see Table 1), locally levied road user charges generated less than $1 billion in 1986 (see Table 2). Local user taxes are found in over half of the states and consist of local option motor fuel taxes, motor vehicle tag fees and surcharges (see Table 3), and tolls.

Local motor fuel taxes are permitted in 16 states. However, not all states exercise the right. For 1986, local motor fuel taxes were used to fund highways in 10 states. States currently permitting these levies are as follows (*2*):

- *Alabama*. As of August 1988, 18 counties imposed gasoline taxes as follows: 1 or 2 cents per gallon (nine and seven counties, respectively), 1 1/4 cents per gallon (one county), and 3 percent of the selling price (one county). Cities of 5,000 or more population may also impose a gasoline tax. Today, 61 cities levy a tax of 1 to 3 cents per gallon.
- *Alaska*. The city of Bettles has a 2 percent tax on motor fuel.
- *California*. Selected counties, cities, transit districts, and so on may impose a tax of 1 cent per gallon on compressed gas used as motor vehicle fuel, if approved by voters. Additionally, counties, subject to voter approval, may impose a tax on motor fuel in increments of 1 cent per gallon. To date, no locality has imposed these taxes.
- *Florida*. See section describing Florida's local motor fuel taxes.
- *Hawaii*. Road user taxes account for 25 percent of local revenue in Hawaii in 1986. In Hawaii, each county levies its own motor fuel tax, as follows:

County	*Gas/Diesel Tax (cents)*
Honolulu	11.5
Maui	8.0
Hawaii	8.8
Kauai	4.0

- *Illinois*. The city of Chicago levies an added 5-cents-per-gallon tax and Cook County applies a 4-cent tax to gasoline. Legally, any municipality with more than 100,000 inhabitants may, with approval of the voters, impose a tax of 1 cent per gallon on the purchase of motor fuel sold at retail within the municipality. Springfield has a 1-cent tax.
- *Mississippi*. The counties of Harrison and Jackson levy a 2-cent-per-gallon tax on motor fuel; Hancock County has a 3-cent tax.
- *Montana*. Counties may levy a motor fuel tax, in increments of 1 cent, not to exceed 2 cents per gallon sold within the county and used by motor vehicles on public highways. To date, no county has enacted the tax.
- *Nevada*. Local governments are permitted to levy an added gasoline tax of up to 4 cents per gallon. This regional tax is collected by the state in the counties meeting the conditions of the legislation. Currently the following counties have adopted this tax:

County	*Gas Tax (cents)*
Carson City	4
Churchill	2
Clark	4
Douglas	4
Elko	2
Esmeralda	4
Humboldt	4
Lander	4
Lincoln	4
Lyon	4
Mineral	2
Nye	4
Pershing	4
Washoe	4
White Pine	4

- *New Mexico*. Certain counties and cities may adopt a local motor fuel gallonage tax of up to 2 cents if approved by the voters. Class A and H counties as well as municipalities located in these counties have this authority. The state collection mechanism collects the tax for localities.
- *New York*. New York City levies a tax of 1 cent per gallon on fuel containing ½ gram or more of tetra-ethyl lead, tetra-methyl, or other lead alkyls.
- *Oregon*. The following counties levy a local gas tax: Multnomah—3 cents per gallon and Washington—1 cent per gallon.
- *South Dakota*. Second- and third-class municipalities are authorized to levy a motor fuel tax not to exceed 1 cent per gallon. The tax is a road user charge because stationary engines, agriculture equipment and heating, lighting, cleaning, and other commercial uses are exempt. The tax is administered by the state.
- *Tennessee*. Counties, metropolitan governments, and incorporated municipalities that operate public transportation systems may levy a tax on gasoline at the rate of 1 cent per gallon, if approved by the voters.
- *Virginia*. A 2 percent sales tax is imposed on retail sales of motor fuel sold within a county or city operating the heavy rail commuter mass transportation system located in Northern Virginia. In short, the local share of the Metro system (Washington, D.C.) in Virginia is funded from motor fuel taxes.
- *Washington*. Cities of 400,000 or more population have the power to impose an excise tax on motor fuel at a rate not to exceed 2 cents, and the state administers the tax.

Local road user charges, although playing a relatively minor role in highway finance from a national perspective, represent a significant resource for certain localities. A case in point is Florida. No other state relies on local option gas tax receipts as does Florida. Granted, Hawaii and Nevada depend on local motor fuel tax, however, only Florida raises over $200 million/year for county and city road and transit programs. Because of its yield, pervasiveness, and potential as a model, the Florida local option motor fuel tax system is extensively described in detail in the next section.

TABLE 2 1986 LOCAL GOVERNMENT HIGHWAY RECEIPTS (IN $ THOUSANDS) (6)[1]

COMPILED FROM REPORTS OF
STATE AND LOCAL GOVERNMENTS

(THOUSANDS OF DOLLARS)

TABLE LOF-21
AUGUST 1988

STATE	RECEIPTS								
	PROPERTY TAX	GENERAL FUND	LOCAL HIGHWAY-USER REVENUE	TOLLS	MISCEL-LANEOUS	BOND PROCEEDS (PAR)	PAYMENTS FROM		TOTAL
							STATE GOVERNMENT	FEDERAL GOVERNMENT	
ALABAMA	22.425	117.805	22.970	-	25.654	7.449	151.513	11.060	358.866
ALASKA	52.885	38.395	5.292	-	11.728	40.094	51.713	2.876	202.783
ARIZONA	13.100	13.865	-	-	55.000	78.710	300.048	8.000	468.723
ARKANSAS	18.155	4.924	-	-	9.300	-	113.666	24.948	170.993
CALIFORNIA	130.000	965.188	-	15.256	307.336	40.000	643.812	145.000	2.246.592
COLORADO	77.861	99.583	-	797	73.080	767.523	142.706	17.246	1.178.795
CONNECTICUT	-	146.184	-	-	1.550	1.200	25.718	7.348	182.000
DELAWARE	-	12.516	-	-	530	642	2.500	882	17.070
FLORIDA	145.000	106.000	235.000	10.875	141.084	194.813	228.991	25.712	1.087.475
GEORGIA	2.220	257.938	3.532	-	3.180	92.086	19.666	16.757	395.369
HAWAII	-	13.828	13.880	-	27.606	90	23.061	9.262	87.717
IDAHO	29.437	4.312	-	-	5.310	-	44.607	7.946	91.612
ILLINOIS	218.000	149.357	78.000	16.526	111.440	5.625	307.970	20.048	906.966
INDIANA	24.283	42.020	16.937	-	32.669	5.250	270.884	7.772	399.815
IOWA	194.595	11.434	-	1.182	13.525	29.731	255.179	54.781	560.427
KANSAS	150.000	116.261	-	-	26.000	7.885	71.894	7.960	380.000
KENTUCKY	4.600	47.957	3.300	-	7.700	-	83.998	11.445	159.000
LOUISIANA	81.000	159.126	22.080	5.983	108.009	67.395	75.058	34.666	553.317
MAINE	-	101.393	-	-	-	11.705	15.270	5.864	134.032
MARYLAND	19.000	107.737	-	-	22.000	31.000	221.343	128.920	530.000
MASSACHUSETTS	3.100	284.697	-	-	6.500	3.150	96.313	9.825	403.585
MICHIGAN	22.000	401.674	-	557	120.458	4.000	496.250	46.076	1.091.015
MINNESOTA	179.042	355.857	-	230	53.452	157.211	225.252	40.496	1.011.540
MISSISSIPPI	43.247	82.558	2.812	-	2.676	33.988	70.185	38.004	273.471
MISSOURI	67.000	75.378	7.000	2.530	78.356	30.570	100.093	27.084	388.011
MONTANA	35.005	3.398	-	-	42.453	-	21.154	6.971	108.982
NEBRASKA	113.916	18.221	6.345	527	11.361	33.108	96.666	39.315	319.459
NEVADA	2.272	22.622	22.058	-	5.723	-	17.509	12.738	82.922
NEW HAMPSHIRE	-	37.000	34.300	-	-	-	13.666	243	85.209
NEW JERSEY	-	550.000	-	12.054	1.276	-	-	10.718	574.048
NEW MEXICO	4.010	38.557	2.650	-	1.400	-	16.096	7.287	70.000
NEW YORK	420.000	1.148.999	20.000	213.726	292.069	300.000	178.999	42.002	2.615.795
NORTH CAROLINA	2.382	139.748	3.022	-	7.112	11.950	54.703	5.324	224.241
NORTH DAKOTA	38.500	30.456	-	-	5.200	-	33.496	9.048	116.700
OHIO	112.422	213.954	-	-	147.411	30.256	375.844	56.204	936.091
OKLAHOMA 2/	-	-	-	-	-	-	-	-	-
OREGON	44.168	41.446	8.659	1.300	37.408	53.112	90.184	67.872	344.149
PENNSYLVANIA	218.000	374.542	43.000	-	45.000	-	185.933	56.025	922.500
RHODE ISLAND	-	37.149	-	-	-	-	390	1.490	39.029
SOUTH CAROLINA	-	49.804	-	-	25.660	-	17.169	2.896	95.528
SOUTH DAKOTA	16.678	62.714	176	-	1.175	2.368	23.364	4.483	110.958
TENNESSEE	40.300	44.435	22.403	-	7.994	13.736	178.654	3.693	311.215
TEXAS	698.285	654.770	55.815	4.833	457.979	672.793	79.367	75.454	2.699.296
UTAH	-	52.256	-	-	1.978	1.200	33.352	2.661	91.447
VERMONT	34.000	1.500	-	-	-	-	19.135	4.143	58.778
VIRGINIA	11.000	21.653	53.000	10.218	39.834	119.500	117.845	6.999	380.049
WASHINGTON	168.931	50.928	1.708	744	68.365	43.767	173.030	62.301	569.774
WEST VIRGINIA	-	48.914	7	840	1.416	-	-	5.172	56.349
WISCONSIN	200.268	533.384	516	-	-	91.388	180.986	1.410	1.007.952
WYOMING	-	41.442	-	-	33.640	7.842	13.283	2.765	98.972
TOTAL	3.657.087	7.933.881	684.462	298.178	2.478.597	2.991.137	5.958.505	1.198.770	26.198.617

1/ THIS TABLE REPORTS LOCAL GOVERNMENT RECEIPTS AND DISBURSEMENTS FOR HIGHWAYS. IT INCLUDES DATA FOR COUNTIES AND MUNICIPALITIES REPORTED IN TABLES LF-1, LF-2, LB-2, UF-1, UF-2 AND UB-2. EXCLUDES NONHIGHWAY USE OF ROAD-USER IMPOSTS.

2/ DATA NOT ESTIMATED DUE TO INCOMPLETE HISTORICAL DATA.

TABLE 3 1986 LOCAL ROAD-USER TAX REVENUE (IN $ THOUSANDS)[1] *(6)*

STATE	-MOTOR-FUEL TAXES- COUNTY	MUNICIPAL	-MOTOR-VEHICLE FEES- COUNTY	MUNICIPAL	LESS: NON-HWY USE 2]	NET ROAD-USER REVENUE FOR HIGHWAYS
ALABAMA	3675	19295				22970
ALASKA				5292		5292
ARIZONA						
ARKANSAS						
CALIFORNIA						
COLORADO						
CONNECTICUT						
DELAWARE						
DIST. OF COL.						
FLORIDA	146000	73000	16000			235000
GEORGIA			3162	370		3532
HAWAII	7206	12691			6017	13880
IDAHO						
ILLINOIS	60000	75000	6000		63000	78000
INDIANA			6898	10039		16937
IOWA						
KANSAS						
KENTUCKY				3300		3300
LOUISIANA			80	22000		22080
MAINE						
MARYLAND						
MASSACHUSETTS						
MICHIGAN						
MINNESOTA						
MISSISSIPPI	2812					2812
MISSOURI				7000		7000
MONTANA						
NEBRASKA				6358	13	6345
NEVADA	22058					22058
NEW HAMPSHIRE			20000	14300		34300
NEW JERSEY						
NEW MEXICO	2650					2650
NEW YORK				20000		20000
NORTH CAROLINA				3022		3022
NORTH DAKOTA						
OHIO						
OKLAHOMA						
OREGAN	8236	417	6			8659
PENNSYLVANIA			18000	25000		43000
RHODE ISLAND						
SOUTH CAROLINA						
SOUTH DAKOTA			156	20		176
TENNESSEE			9592	19703	6892	22403
TEXAS			55815			55815
UTAH						
VERMONT						
VIRGINIA	34000	26000			7000	53000
WASHINGTON	106	1602				1708
WEST VIRGINIA				7		7
WISCONSIN			295	221		516
WYOMING						
TOTAL	286743	208005	136004	136632	82922	684462 3]

1] Includes estimates
2] Includes mass transportation
3] Equals column 3 of Table LGF-21

FLORIDA'S LOCAL OPTION MOTOR FUEL TAX

Local governments in Florida receive funds from several individual motor fuel taxes. First, the state tax of 9.7 cents per gallon is separated into two components. One part is a variable or indexed tax whereby the rate is determined by the retail price of fuel and the state motor fuel sales tax, that is, 5 percent of an established equivalent minimum price of $1.148 per gallon, or 5.7 cents tax. These monies are retained in the State Transportation Trust Fund. The second part is a fixed rate of 4 cents per gallon. Two cents, or the "second gas tax" or "Constitutional gas tax," is distributed among the 67 counties by formula. The other 2 cents is also destined to local governments, where 1 cent is devoted to the counties and 1 cent to municipalities. These levies are collected statewide and thus constitute the state motor fuel tax. Local option motor fuel taxes, the second group of motor fuel taxes, are discretionary and must be approved by the localities.

During the early 1980s, momentum was growing to dedicate a local revenue source for highways. From 1980 to 1983, voters approved a county 1-cent gas tax for highways in nine counties. The authority had been allowed since 1972, but no county was successful gaining voter approval until 1980, and today only 14 counties have the tax. The local road user tax movement got a major boost from the 1983 state legislation that lowered the state fixed motor fuel tax from 8 to 4 cents per gallon. The reduced 4-cent tax was offered to the counties for their highway and transportation programs. Further, state legislation expanded the option from 4 to 6 cents in 1985, and today 63 of the 67 counties have adopted this tax. Most counties (44) have opted for the maximum 6-cent tax, and 11 of these counties have also approved the "voted" 1-cent tax for a total of 7-cents-per-gallon local tax. The pace of adoption

TABLE 4 FLORIDA LOCALLY IMPOSED GASOLINE AND SPECIAL FUEL TAXES (*6*)

COUNTY	VOTED GAS TAX (1¢)	LOCAL OPTION GAS TAX (¢/Gallon) 1983	1984	1985	1986	1987	1988	SUBTOTAL	TOTAL ¢/GAL	1] NET REVENUE PER ¢ (000)	1] TOT. REVENUE (000s)
ALACHUA	1981	3		3				6	7	$980	$6,857
BAKER					4	2		6	6	$86	$517
BAY				4				4	4	$774	$3,095
BRADFORD		4					2	6	6	$124	$741
BREVARD				4	2			6	6	$1,872	$11,234
BROWARD		4		2				6	6	$5,763	$34,575
CALHOUN								0	0	$69	$0
CHARLOTTE		2		2		2		6	6	$449	$2,695
CITRUS		4				2		6	6	$408	$2,448
CLAY	1981		4			2		6	7	$439	$3,073
COLLIER	1980	2	2	2				6	7	$726	$5,081
COLUMBIA	1981	2		2	2			6	7	$387	$2,707
DADE		4		2				6	6	$8,252	$49,509
DESOTO	1982	4		2				6	7	$125	$878
DIXIE			2		2		2	6	6	$61	$365
DUVAL					6			6	6	$3,840	$23,043
ESCAMBIA					6			6	6	$1,327	$7,963
FLAGLER						4		4	4	$104	$416
FRANKLIN								0	0	$56	$0
GADSDEN				4		2		6	6	$214	$1,283
GILCHRIST				4			2	6	6	$36	$217
GLADES					2		2	4	4	$57	$227
GULF								0	0	$57	$0
HAMILTON						2		2	2	$265	$531
HARDEE		4		2				6	6	$133	$796
HENDRY	1983				2			2	3	$143	$429
HERNANDO		2		4				6	6	$432	$2,593
HIGHLANDS		2	2		2			6	6	$367	$2,202
HILLSBOROUGH	1980	4		2				6	7	$4,482	$31,376
HOLMES						5		5	5	$140	$698
INDIAN RIVER				2	4			6	6	$452	$2,713
JACKSON	1986				5			5	6	$410	$2,459
JEFFERSON						2		2	2	$169	$338
LAFAYETTE		2		2				4	4	$21	$84
LAKE	1983		2	2	2			6	7	$741	$5,187
LEE	1982		4					4	5	$1,557	$7,783
LEON				4		2		6	6	$1,034	$6,204
LEVY		2		2	2			6	6	$172	$1,030
LIBERTY								0	0	$43	$0
MADISON						1	2	3	3	$172	$516
MANATEE	1982	4		2				6	7	$928	$6,494
MARION		2	2	2				6	6	$1,242	$7,453
MARTIN				4	2			6	6	$479	$2,871
MONROE		4		2				6	6	$411	$2,466
NASSAU					2	4		6	6	$350	$2,103
OKALOOSA						5		5	5	$807	$4,033
OKEECHOBEE		4		2				6	6	$209	$1,255
ORANGE		4		2				6	6	$3,898	$23,387
OSCEOLA	1987	4			2			6	7	$620	$4,341
PALM BEACH		2		2	2			6	6	$3,904	$23,422
PASCO		2	2		2			6	6	$1,135	$6,810
PINELLAS				4		2		6	6	$3,815	$22,890
POLK		4			2			6	6	$2,285	$13,712
PUTNAM				4			2	6	6	$325	$1,947
ST JOHNS				4	2			6	6	$595	$3,573
ST LUCIE				4		2		6	6	$736	$4,417
SANTA ROSA					6			6	6	$368	$2,206
SARASOTA	1988	4			2			6	7	$1,215	$8,507
SEMINOLE		4		2				6	6	$1,170	$7,020
SUMTER		2				2		4	4	$636	$2,543
SUWANNEE		1		2				3	3	$264	$793
TAYLOR				4				4	4	$170	$680
UNION			4					4	4	$82	$329
VOLUSIA	1982	2		4				6	7	$1,703	$11,921
WAKULLA		4						4	4	$67	$268
WALTON						5		5	5	$207	$1,036
WASHINGTON				4				4	4	$93	$373
TOTALS										$64,651	$388,711
AVERAGE GAS TAX		1.4	1.7	3.2	4.1	4.8	5.0	5.0	5.2		

1] Based on consumption estimates produced by the Department of Revenue for local government FY 1988-89.

by Florida counties of the voted tax and the local option tax is as follows (N/A = not available):

	Voted (1 cent)	*Local Option (1–6 cents)*
1980	2	N/A
1981	3	N/A
1982	4	N/A
1983	2	30
1984	0	9
1985	0	35
1986	1	22
1987	1	17
1988	6	6

Counties imposing these taxes are listed in Table 4 with the average local gas tax being 5.2 cents per gallon for all 67 counties in 1988. Revenue from these local option taxes is used by counties and municipalities for transportation purposes including public transit, road and street capital outlay, and maintenance and debt service on transportation bonds.

In 1985, state legislation also allowed the formation of Metropolitan Transportation Authorities (MTAs) in the state's largest urbanized areas. Counties operating a regional ground transportation system (MTA) are permitted to levy an additional 1-to-4-cents-per-gallon tax plus a 1-mill property tax. These are over the 6-cent local optional gas tax discussed previously.

The ground swell of support experienced by the county local option gas tax has not been shared by the Metropolitan Transportation Authorities and only marginally for the "voted" gas tax. The lack of acceptance may be as a result of a key tax approval condition. The local option gas tax can be implemented by a simple majority of the county governing body or commission. Conversely, after acceptance by localities, the MTAs' taxing authority and the "voted" gas tax must be approved by the voters. The success rate is evident in the results of several referenda.

The voter approved gas tax, that is, the "voted" gas tax, has been passed in only 14 out of 67 counties. However, no MTA has been successful in gaining voter approval for extra gas taxes for regional transportation projects. A case in point is Orlando. Orlando area voters twice defeated transportation financing in recent years. In 1986, the proposal included a gas tax hike plus a property tax increase. It failed according to some officials because of the property tax feature (*3*). Another attempt was made in 1988 when a sales tax was offered, but it too was defeated by the voters.

The success of the local option gas tax is, in part, because the approval authority rests in the hands of the governing body rather than with the voters. Moreover, there is evidence that the governing body or commission may act in opposition to the will of the voters, as was the case in Walton County. In 1987, the Walton County commissioners approved a 5-cent gas tax 6 months after the voters rejected the measure by a 2 to 1 margin (*4*).

Statewide, each penny gas tax will generate $64,651,000. For FY 1989, the 63 counties will receive an aggregate of over $388 million in local option gas and "voted" taxes (see Table 4). The larger counties, such as Dade County, will receive nearly $50 million/year. Administratively, no major change was necessary to collect local motor fuel taxes.

Local option motor fuel taxes in Florida consist of the "voted" 1-cent, the local option 1-to-6-cent, and the MTA 1-to-4-cent-a-gallon taxes. These state-allowed resources are an outgrowth of the need to secure a dedicated source of revenue for local highway and transportation programs and a means to offset the loss of general revenue sharing funds. Adoption of the local gas taxes was slow until the commission-approved local option tax was enacted (1983).

Voter-approved taxes have been less frequent since then but not ignored as three counties recently approved the "voted" 1-cent tax in addition to adopting the maximum local option tax. The local option gas tax has been successful because of its ease of adoption and flexibility. The "voted" 1-cent tax is difficult to approve and is limited in yield, yet it may be used for any legitimate county or municipal transportation purpose. The MTA tax (1 to 4 cents) may yield more than the "voted" gas tax (but less than the local option gas tax); however, its use is restricted to arterial roads and must be approved by the voters. Based on its pervasiveness, yield, and ease of adoption, the local option gas tax is the clear choice in Florida.

IMPACT OF LOCAL OPTION GAS TAX

A review of county, municipal, and state transportation finance in Florida reveals a shift in the major revenue sources for local highways toward a more user-supported program since the advent of the local option gas tax.

In 1987, counties in Florida generated $643 million for highways. Road user taxes and fees accounted for $360 million of this amount, or 56 percent. Road user revenues consisted of $177 million of shared state motor fuel and motor carrier levies and $183 million of local option gas taxes. The local option gas taxes accounted for 47 percent of county-levied tax receipts (see Table 5). For municipalities, road user charges provided a lesser share of the total municipal road and street programs, that is, $176 out of $484 million, or 36 percent. The local option gas tax share of locally imposed taxes is likewise smaller for municipalities (31 percent) (see Table 5). The trend since the early 1980s, however, reflects a greater reliance on user financing for local road programs. Table 5 shows that county and municipal programs depended overwhelmingly on nonuser sources (more than 95 percent) before the local gas tax option. Since then, gas tax receipts have supplied one-half of county local revenue and nearly one-third of municipal local resources. Also noteworthy is the growth in spending—up 135 percent for counties and 52 percent for municipalities from 1983 (see Figure 1).

The Florida Department of Transportation made a survey of local government use of the local option gas tax in 1987 (*5*). The survey reported widespread acceptance of optional gas taxes. All areas of the state have adopted the tax with the exception of four counties in the panhandle. The survey noted that almost one-half of the counties had the full 6-cent gas tax.

Types and choices of local highway financing were covered in the survey report. Before the optional gas tax, 39 counties used general revenues—primarily property taxes—to fund highways, and 21 counties reported use of impact fees. Eleven of these counties stated that they were able to reduce their dependence on nonuser sources with the adoption of the gas tax. The saved general revenues were applied to other pressing needs.

TABLE 5 FLORIDA LOCAL GOVERNMENT HIGHWAY RECEIPTS (IN $ MILLIONS)

	1987				1985				1983			
	COUNTY	%	MUNICIPALITY	%	COUNTY	%	MUNICIPALITY	%	COUNTY	%	MUNICIPALITY	%
USER 1]	183	47	102	31	112	52	42	15	9	5	2	1
NONUSER 2]	209	53	232	69	105	48	239	85	158	95	218	99
TOTAL	392	100	334	100	217	100	281	100	167	100	220	100

1] Includes local option gas tax and voted gas tax.
2] Includes property taxes (ad valorem, road and special assessments), franchise fees, occupation licenses, interest income, utility tax, general funds and miscellaneous receipts.

Source: FHWA Form 536, various years, supplied by FLDOT. Data reported in Tables LF-1 and UF-1, Highway Statistics, various years.

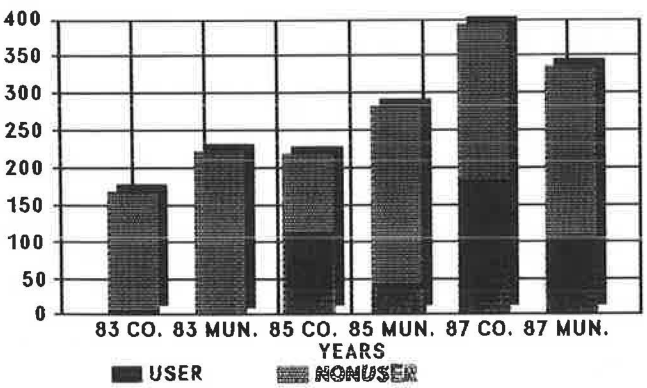


FIGURE 1 Bar chart of Florida local government highway receipts showing growth in spending since 1983 (in $ millions).

All urbanized counties (27) had adopted the local option gas tax, and all but six elected to impose the maximum 6 cents per gallon (the others selected 4 cents). Five of the urbanized counties reported reductions in nonuser revenues devoted to highways. Municipalities also shared in the proceeds of the local gas tax under a variety of distribution formulas. Seven of these noted reductions in the use of nonuser tax revenues. Further, one urban area—Dade County/Miami—reported using significant portions of its receipts for transit operating assistance.

The yield of the local option gas tax caused some early problems for some jurisdictions. Several counties expressed an inability to meet contracting schedules and others had staffing problems, but these problems were shortly overcome. Although some stated that they had insufficient projects on the shelf to use the added funds, 20 of the 67 counties have requested their legislative delegations' support for additional transportation taxes. In fact, all 27 urbanized counties and all 23 municipalities reported a need for more transportation revenues, and some suggested that a "maintenance of effort" clause be included in any new local government taxing authority in order to avoid future reductions in revenues from other sources.

TABLE 6 DISTRIBUTION OF MOTOR FUEL RATES AMONG LEVELS OF GOVERNMENT

	Receipts ($ millions)	Gallons	Calculated Cents per Gallon
Federal	11,643[a]	125,183[b]	9.3
State	14,742[c]	"	11.8
Local	495[d]	"	0.4
Total	26,880	"	21.5

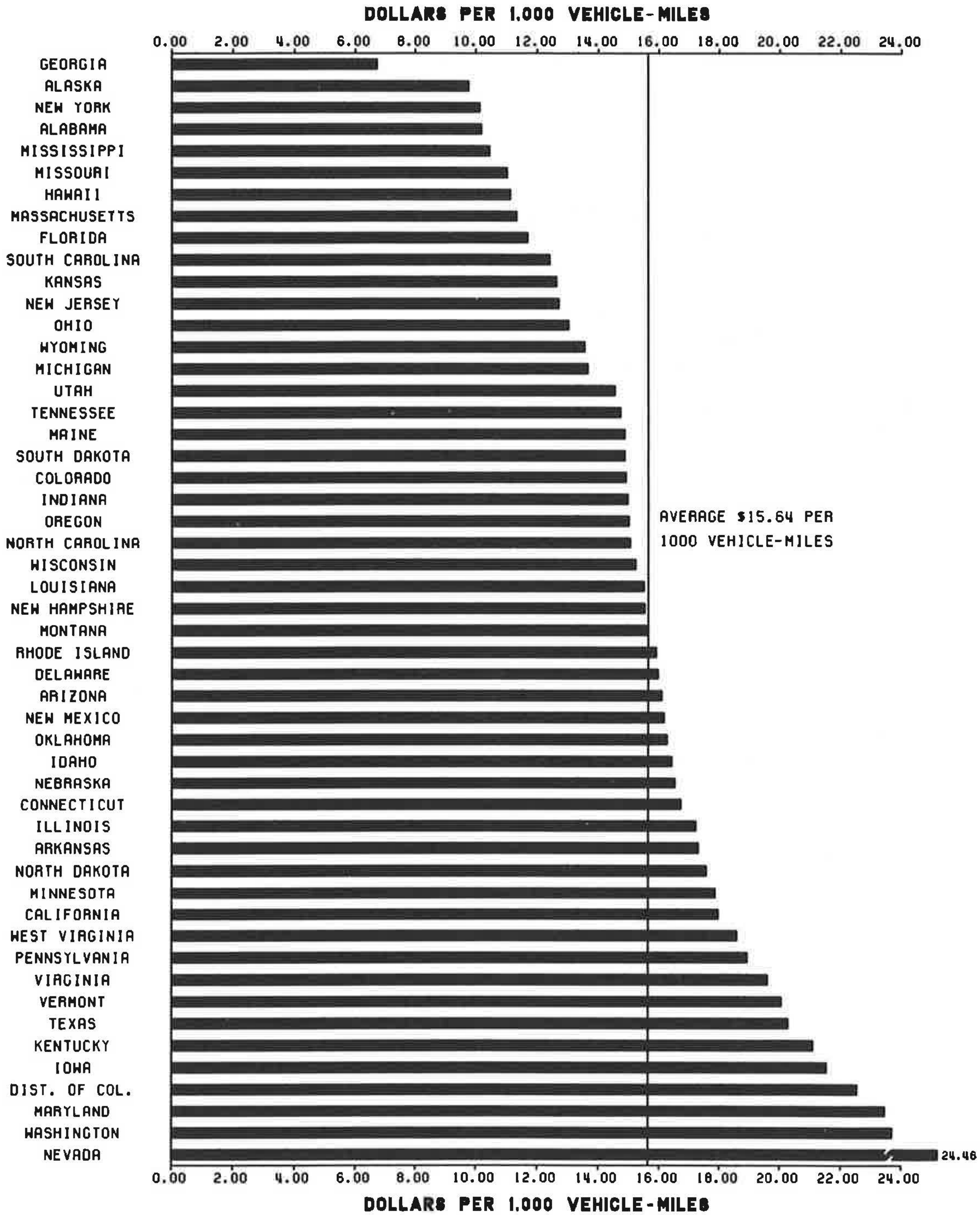
[a](6, Table FE-10).
[b](6, Table MF-2).
[c](6, Table MF-1).
[d]Data from Table 3 of this paper.

CONCLUDING REMARKS

Local Motor Fuel Taxes

Combined state and local motor fuel taxes are moving Florida into the mainstream. Total motor fuel taxes averaged 21.5 cents per gallon in 1986. Nationally, motor fuel rates are distributed among levels of government as shown in Table 6. The weighted average state motor fuel tax, that is, 11.8 cents, is used in the tabulation in Table 6. The choice gives weight to the high-motor-fuel-consuming states, such as California, that have a below average state tax (9 cents). The arithmetic average is over 14 cents per gallon. In fact, several states' total tax is close to 30 cents per gallon, including those with and without a local tax. Examples of the latter include Montana and Minnesota, which levy a state tax of 20 or more cents (plus the federal 9.3 cents). On the opposite end of the spectrum, low-motor-fuel-tax states, such as Florida (9.7 cents), by permitting local option motor fuel taxes, can move toward or exceed the national average. Adding the average local option tax places Florida above the national average as shown here (note that state datum includes 4 cents dedicated to local governments; local datum is from Table 4 of this paper):

Level	*Cents per Gallon*
Federal	9.3
State	9.7
Local	5.2
Total	24.2



Source: Selected Highway Statistics and Charts 1987,
Federal Highway Administration

FIGURE 2 1987 state highway-user revenue per vehicle-mile of travel (*6*).

The preceding discussion focuses on motor fuel taxation exclusively. However, certain other fees on motor vehicles and motor carriers are imposed and these must be considered in the composition of total highway taxation. When the sum of all state level user taxes and fees are considered, Florida ranks below the national average for state road user revenues per 1,000 vehicle-miles of travel (VMT) (see Figure 2). Total state user tax receipts, including motor fuel taxes and motor vehicle fees, averaged $15.64 per 1,000 VMT for the nation in 1987; Florida was below this level at $11.69 per 1,000 VMT. This evaluation considered the state motor fuel tax of 9.7 cents per gallon and omitted any local option tax. If the local option tax had been included, that is, state tax of 9.7 cents plus local tax of 5.2 cents per gallon, the revised revenue per 1,000 VMT would be $15.36, or approximately the U.S. average.

Local Option Gas Tax

A shift in state and local priorities has occurred as a result of the local option gas tax. Based on the experience in Florida, aggressive adoption of local motor fuel taxation can shift the focus of motor fuel tax revenues from state to local programs. Total state motor fuel gallonage taxes generated $14.7 billion in 1986, and local governments received grants-in-aid of $3.86 billion of this, or about 3.1 cents per gallon. Local option motor fuel taxes equaled 0.4 cents per gallon nationally and, when added to the local share of state motor fuel taxes, equals 3.5 cents per gallon (out of 12.19 cents). The remaining 8.7 cents is the state share. In the case of Florida, locals get 4 cents of the 9.7-cent state tax plus all of the newly enacted local tax of 5.2 cents. The local share of combined state and local motor fuel taxes is now 9.2 cents of 14.9 cents a gallon, or 62 percent of combined gas tax revenue. Nationally, the local share is 29 percent.

Highway User Charges

Congestion occurs on highways, particularly freeways, when demand for a scarce resource (roadway space) exceeds its supply. Congestion does not occur at all times, rather only at the busier times of the day; other times do not experience a supply problem. The imbalance between demand and supply is caused, in part, by pricing the use of highways. If user charges are not imposed, people have no economic incentive to economize on the use of a scarce resource. Hence, it is appropriate to charge users for highways as opposed to charging the community-at-large for the provision of roads and streets (*7*).

Summary

For the most part, local governments look to nonuser revenues for highways, but the local option gas tax in Florida may change this. The tax has been nearly universally adopted and most locals elect to impose the maximum allowable tax of 6 cents per gallon—and the yield is substantial. Florida recognized that local option taxes (and maybe any tax) are not popular with the electorate, thus placement of the decision making responsibility with the governing body rather than the voters is credited for its success. Road user charges meet the test of appropriateness and are overwhelmingly used by federal and state governments (road user charges average 85 percent of combined receipts in 1987) but are used sparingly by counties and municipalities.

Florida local governments now receive up to one-half of their local support for road programs from road users since the adoption of the local option gas tax. This revenue device may have appeal in other states, particularly in those that have user taxes below the national average.

REFERENCES

1. *America's Challenge for Highway Transportation in the 21st Century*. FHWA, Nov. 1988.
2. *State Tax Guide*. Commerce Clearing House, Chicago, Ill., 1988.
3. *Orlando Sentinel*, Orlando, Fla., Jan. 16, 1987.
4. *Pensacola News Journal*, Pensacola, Fla., May 27, 1987.
5. *Capability of Local Governments to Commit Additional Transportation Revenues*. Florida Department of Transportation, Tallahassee, March 1987.
6. *Highway Statistics*, FHWA, Washington, D.C., 1988.
7. R. W. Poole, Jr. *Private Tollways: Resolving Gridlock in Southern California*. Local Government Center, Reason Foundation, Santa Monica, Calif., May 1988.

Publication of this paper sponsored by Committee on Local Transportation Finance.

Adapting HDM3 User-Cost Model to Saskatchewan Pavement Management Information System

PETER BEIN

The World Bank's HDM3 submodel of user costs was applied in the Saskatchewan Pavement Management Information System, which integrates agency and user costs into a life-cycle analysis of construction and maintenance strategies for the provincial highway network. Fleet use and cost data were gathered from public sources and from a pilot survey of highway users. User-cost–roadroughness equations were developed for nine types of vehicles, for the financial and economic cost cases with and without user delay cost. The cost components of cargo delay and damage need further work. Depreciation, interest, and maintenance costs interplay in vehicle owner decisions and should be reinvestigated. Depreciation and maintenance costs overlap because the costs of repair on factory warranties are included in the purchase price. Available vehicle use data are not clear because of mixed urban/highway travel and distinct use staging of lives of all vehicle types. In speed predictions for trucks, more data are required on payload and used engine power. The road surface texture affects speed prediction and fuel and tire consumption, but its effect on user costs remains to be clarified. Tire consumption relationships are inappropriate for the radial tire technology. Maintenance parts and labor cost equations can be calibrated with some difficulty. Further research will depend on large-scale surveys, in order to cover a wide range of paved road roughness and texture and to quantify the experimental errors.

A large-scale study was carried out in Brazil in 1975 to 1981 to develop user-cost models for evaluations of the total transportation costs and benefits of alternative highway investment strategies (*1*). State-of-the-art user-cost relationships were developed by the World Bank from the study data and were incorporated into a life-cycle investment model called the Highway Design and Maintenance Standards Model (*2,3*), whose current version is HDM3. User-cost models are required for the economic analysis of the total life-cycle costs in the Pavement Management Information System (PMIS) developed for the Saskatchewan Highways and Transportation (SHT) (*4*). The province of Saskatchewan has one of the world's most extensive highway networks per capita, the most intensive vehicle use in Canada, annual operating costs of the fleet in the order of some $3 billion, and a provincial highway budget of $200 to $300 million. In the PMIS, calibrated user costs derived from HDM3 help establish optimum intervention levels for rehabilitation, overlay, and maintenance treatments. Alternative strategies composed with these treatments are evaluated with total agency and user-costs criteria, in the budgeting and programming modules of the PMIS. In this paper, the author summarizes the data assembled and the adaptation of the HDM3 user-cost model to Saskatchewan conditions. Details can be found in a report prepared for SHT (*5*).

N.D. Lea International Ltd., 1455 West Georgia Street, Vancouver, British Columbia, Canada. Current address: Transportation System Consultant, 3955 West 14th Avenue, Vancouver, British Columbia, Canada V6R2X2.

COLLECTION OF SASKATCHEWAN DATA

Vehicle operating costs (VOCs) depend on a region's economy as well as vehicle technology, operation, and management. Present Saskatchewan vehicles, trucks in particular, are larger and more energy-efficient than vehicles surveyed in Brazil (Table 1). Brazilian labor was much cheaper, relative to prices of fuel, tires, and vehicles. To account for change in conditions when HDM3 is being transferred to a new environment, the model's relationships have been structured on generic, mechanistic principles. Adaptation of the model to Saskatchewan requires representative local vehicle characteristics and unit costs.

Vehicle Fleet Characteristics and Cost Data

Provincial registration records of cars, ranch wagons, vans, buses, trucks, and power units were compared with SHT vehicle travel statistics to obtain average annual travel per vehicle (Table 2). Representative car characteristics have been derived using relative frequency of makes/models in the provincial registrations as a weighting factor. Car automotive data have been obtained from dealers and catalogues. Registration reports were not available for pickups, vans, and trucks, and data were sought through a survey of fleet operators.

Most of the trips and tonnage on arterial highways are hauled by the common carriers. On collectors and local roads, the private carriers tend to dominate, but common carriers still haul the highest average payloads. Over the last 12 years, the number of combination units has been increasing at the expense of two- and three-axle straight trucks. The most common truck body type is a general merchandise van followed by a flat deck. Bulk cargo hauls are heavier, but less frequent than general merchandise trips. Empties constitute 20 to 40 percent of all trips. Lightly loaded trucks are most frequent on collectors and local roads. The fully laden truck was the most frequent among nonempty hauls.

Economic costs reflect the use of resources. Economic costs plus taxes, subsidies, and duties are required for financial

TABLE 1 COMPARISON OF TYPICAL VEHICLE CHARACTERISTICS, SASKATCHEWAN VERSUS HDM3 DATA BASE

Vehicle Type	Curb Weight tonnes	GVW tonnes	Maximum Rated Engine Power hp	Maximum Rated Engine Speed rpm	Annual Utilization, 10^3 km	Annual Utilization, 10^3 hours	Service (f)
Small Car							
Chevrolet Chevette/VW1300	1.0/1.0	-	65/48	5200/4600	16/20	-	I,U/I
Medium Car							
Ford Granada/Chevrolet Opala	1.4/1.2	-	120/146	4000/4400	16/20	-	I,U/I
Large Car							
Pontiac Parisienne/Dodge Dart	1.6/1.7	-	155/198	4000/4400	16/20	-	I,U/I
Utility							
Ford F-Series/VW Kombi	1.7/1.3	2.5/2.1	225/60	4000/4600	16/89	-	I,U/I
Two-axle Truck							
International(a)/Mercedes 1113	5.7/5.4	14.6/15.0	166/147	2400/2800	40(b)/101	1.2/2.0	U/I
Three-axle Truck							
International/Mercedes 1113	11.0/6.6	21.5/18.5	180/147	2700/2800	32/101	1.0/2.0	U/I
Five-axle Truck							
Kenworth W900(a)/Scania 110-39	14.5/14.7	37.5/22.0	350/285	2150/2200	160(c)/?	1.6(c)/?	I/I
Seven-axle Truck							
Western Star(d)/(e)	16.0/(e)	53.5/(e)	400/(e)	2000/(e)	160/(e)	1.6/(e)	I/(e)
Three-axle Bus							
MCI/Mercedes 0362	12.9/8.1	17.2/11.5	300/149	2100/2800	100/?	1.6/2.4	I/I

Notes:
/ Separation symbol between Saskatchewan data and HDM3 Brazilian database.
\- Not applicable data.
? Not known.
(a) Trimac (1986) data for Saskatchewan province, general merchandise cargo.
(b) Estimate using 32 km/h average running speed in urban service. Utilization in farm service is 5,000 km and 1,200 hours annually (Lea Associates 1986).
(c) Lea Associates 1987 survey of Saskatchewan truckers and "1985 Travel on Saskatchewan Highways" by Saskatchewan Highways and Transportation.
(d) Trimac (1986) data for Saskatchewan province, bulk cargo.
(e) Equivalents to seven-axle trucks did not exist in the Brazil study.
(f) I = inter-city, U = urban, F = farm

costs analysis. Multipliers were developed separately for fuels, materials and equipment, wages, and administration and were applied to the financial unit costs to obtain the economic costs. The financial costs of new and used vehicles and of tires have been surveyed from the press, dealers, and fleet owners. Average fuel costs were assumed. Maintenance shop labor rates were surveyed from repair and maintenance shops. One driver and one passenger in cars, vans, and pickups and 20 passengers in buses were assumed. The value of time was adopted from current SHT planning practice. For all trucks and buses, one driver at average industry rates per hour was assumed.

Survey of Saskatchewan Vehicle Operators

A pilot survey was carried out among Saskatchewan fleet operators in the summer of 1987. The survey asked for 1986

TABLE 2 VEHICLE TYPES AND USE IN SASKATCHEWAN

Vehicle Type	10^3 Registrations(e)		Highway Travel (f) 10^6 km/yr		Vehicle km/yr Hwy.	Vehicle km/yr Total(g)	Vehicle km/yr Assume
Car(a)	380		3,424		9,010	16,200	
Small		57			–	–	16,000
Medium		95			–	–	16,000
Large		228			–	–	16,000
1/2-ton(b)	171		1,541		9,010	16,200	–
Van(c)		46			–	–	16,000
Pickup		125			–	–	16,000
Truck(d)	87		742		–	–	–
2-Axle		71		230	3,200	5,800	40,000
3-Axle		10		60	6,000	10,800	40,000
≥5-Axle		6		452	75,000	135,600	160,000
Total	638		5,707				

Notes:
(a) Curb mass: small <1,000 kg; medium 1,000-1,400 kg; large >1,400 kg.
(b) Including farm registration plates.
(c) Including ranch wagons.
(d) Excluding farm trucks, including buses.
(e) Saskatchewan Government Insurance, registration reports, 1986.
(f) "1985 Travel on Saskatchewan Highways," Saskatchewan Highways and Transporation.
(g) Travel on all roads = 1.8 * travel on provincial highways.

TABLE 3 SURVEY RESULTS: CARS AND LIGHT VEHICLES, GOVERNMENT AGENCY

Class	Typical Use	Annual Distance (km)	Average Service Life Time (yr)	Average Service Life Distance (km)	GVW (tonnes)	Average Tire Life (km)	Fuel, Oil and Grease Cost (¢/km)	Tire Cost (¢/km)	Maintenance, Parts, and Labor (¢/km)	Depreciation (¢/km)
Subcompact	Urban	18,000	6	100,000	–	40,000	3.6	0.3	3.5	5.0
Compact	Urban, highway	20,000	5	100,000	–	50,000	3.4	0.2	2.1	4.7
Mid-sized sedan	Highway	24,000	5	100,000	–	80,000	4.7	0.4	2.2	3.9
Mid-sized wagon	Highway	24,000	5	100,000	–	80,000	4.3	0.3	2.1	4.6
Standard sedan	Highway	27,000	4	100,000	–	95,000	4.7	0.3	2.9	5.2
Standard wagon	Highway	25,000	4	100,000	–	95,000	5.3	0.4	2.6	5.0
Compact pickup	Urban	18,000	5	100,000	–	45,000	4.5	0.3	1.5	5.6
Cargo van	Urban, highway	15,000	6	100,000	3–4.5	50,000	7.5	0.3	3.6	4.8
Passenger van	Highway	18,000	5	100,000	3–4.5	60,000	8.0	0.7	3.5	6.5
Four-wheel-drive pickup	Poor road, off-road	20,000	5	80,000	3–4.5	40,000	8.5	0.8	4.9	5.8
Two-wheel-drive pickup	Highway, off-road	26,000	5	100,000	3–4.5	80,000	7.6	0.6	3.2	4.0
1-ton truck	Mixed	15,000	7	100,000	5	40,000	12.3	1.2	6.7	8.0
2-ton truck	Mixed	15,000	8	150,000	10	50,000	16.7	2.0	9.0	13.0

TABLE 4 SURVEY RESULTS FOR BULK COMMODITY CARRIERS

	Carrier No.				
	1	2	3	4	5
Carrier Type	Common	Common	Common	Common	Private
Number of Tractors	22	42	81	15	12
Tractor Axles/hp (SAE)	3/400	3/400	3/400	3/335 & 400	3/400
Tractor Service, years	5	5	9	10	5
Typical Combination	7-axle tank	7-axle tank	7-axle open box	7-axle tank	5 & 7-axle tank
Annual 10^3km (a)	155	110-185	137	67(e), 173(f)	230
Annual hours (a)	4000	3000(b)	1850	?	2600
GVW, t	53.5	47.6(c)	49.0-53.5	49.0-53.5	34.5-49.9
Tare weight, t	18.5	18.0	15.9	18.5	?
Roundtrip payload, t	17.5	16.5	29.0(g)	13.5-16.5	?
New Tractor Cost	83000	83000	104000(d)	65000	120000(d)
Trailer & Pup Cost	110000	?	50000	100000	?
New Tire Cost	?	350	425	300-450	350
Number/Cost of Recap	?	2/120	2/250	?/150	?/117
New Driving Tire Life, km	?	225000	225000	200000	210000
New Steering Tire Life, km	?	160000	?	?	?
Recap Life, km	?	225000	177000	200000	160000
Fuel, ¢/km	16.5	14.2	17.4	20.0	17.4
Oil and Grease, ¢/km	In maint. cost	In maint. cost	?	?	?
Tires Tractor/Trailer, ¢/km	2.3/?	2.2/2.3	1.4/2.2	3.4	2.4
Maint. Parts " , ¢/km	10.2/?	6.1/6.0	4.2/0.9	19.3	2.4/?
Maint. Labour " , ¢/km	12.1/?	?	?	?	4.0/?
Driver Wage, ¢/km	40.1	33.7	19.9	21.2	26.8

Notes: (a) Tractor only
(b) Including loading/unloading
(c) GVW limited by usage in the U.S.A.
(d) Including sleeper
(e) One driver
(f) Two drivers
(g) 15% haul distance empty, 85% fully loaded
? No data available
All costs in 1986 dollars

data, and 13 trucking companies operating about 700 tractors in Saskatchewan responded to the survey. Response from operators of two- and three-axle straight trucks, vans, and pickups was limited. Car rental and courier companies could not provide compatible data. The only usable data on cars and light vehicles were provided by a government agency (Table 3), but the tire and depreciation costs reflect confidential purchase prices.

The truckers' responses are summarized in Table 4 for bulk and in Table 5 for general merchandise carriers. The number of tractors refers to units used in Saskatchewan, although most of the carriers also operate other units in other provinces. Some scatter is present in the data because of differences in equipment and operating conditions, but trends in the operating costs can be linked to vehicle characteristics and use. Some companies do not manage trailers and could not provide cost data for them. Truckers secure different discount prices on fuel and equipment. Management policies also vary regarding driver selection and speed limits to minimize fuel costs and on-the-road maintenance. Each company controls tire wear uniquely. Maintenance and resale practice to optimize life-cycle cost of tractors also varies, as does the ratio of own

TABLE 5 SURVEY RESULTS FOR GENERAL MERCHANDISE CARRIERS

	Carrier No.						
Carrier No.	1	2	3	4	5	6	7
Carrier Type	Common	Common	Private	Common	Common	Private	Private
Number of Tractors	200	40	119	50	28	8	29
Tractor Axles/hp (SAE)	2-3/350	3/300-400	3/300	3/350	3/240-400	3/210	2-3/300-350
Tractor Service, years	8	4	10	3	6.5	12	10
Combination Axles	5-8	5-7	5	5-8	5-6	5	4-8
Annual km (a)	190,000	160,000	73,000[b]	160,000	170,000	322,000	144,000
Annual Hours (a)	?	2,100	?	?	?	?	?
GVW, t	36.3-53.5	37.2-53.5	36.3	36.3-49.9	36.3-47.7	?	16.0-36.0
Tare Weight, t	?	11.4-18.2	?	?	?	?	10.7-20.7
Roundtrip Payload, t	?	20.4[b]	?	14.5	12.3	?	3.4
New Tractor Cost	?	82,000-100,000	71,000	80,000	70,000	55,000	70,000
Trailer & Pup Cost	110,000	20,000-25,000 van		30,000 reefer	33,000	?	?
New Driving Tire Cost	450[c]	400[c]	280[d]	325	408[c]	350	325
Number/Cost of Recap	1/107	2/240-300	?/230	2/100	?	?/135	?/130
New Tire Life, km	250,000	160,000-240,000	?	180,000	?	55,000	160,000
Recap Life, km	0-100,000	100,000-180,000	?	64,000	?	?	100,000
Fuel/Oil, ¢/km	15.3/1.6	?	?	16.1/?	8.1/0.3	14.0/?	10.8/0.6
Tires Tractor/Trailer, ¢/km	1.3/?	?	2.9 total	1.9/?	0.7/?	1.9/?	0.9/0.7
Maint. Parts " , ¢/km	7.1 total	?	?	1.6/?	3.5/?	8.0/?	6.1/2.1
Maint. Labour " , ¢/km	?	?	?	0.6/?	?	?	?
Driver Wage, ¢/km	31.7[e], 20.2[f]	?	69.0	17.7(g)	25.5	?	42.8

Notes: (a) Tractor only
(b) Peddle lines
(c) Radial tire
(d) Bias ply tire
(e) Less Than Truckload (LTL) operation
(f) Truck load (TL) operation
(g) Excluding burden
? No data available
All costs in 1986 dollars

equipment to lease-operators for capacity and productivity reasons. These practices are often confidential, and the reported costs may not fully reflect the extra savings achievable.

ADAPTATION OF HDM3 BRAZIL VOC MODEL TO SASKATCHEWAN PMIS

PMIS Requirements

The survey data and operating costs of Canadian cars (*6*) and Saskatchewan trucks (*7*) were input into the HDM3 micro-computer program for calculation of user costs as a function of road roughness. Administration cost has been added as shown in Equation 1. The program was also modified to improve the fitting of Equation 1 to the computed total costs by restricting the rougher limit of road roughness to 5 m/km international roughness index (IRI). The VOC function for vehicle type i in the traffic mix is given by

$$VOC_i = a_i e^{(A_i + B_i \cdot IRI)} \quad (1)$$

where

A_i and B_i = calibrated constants for Saskatchewan vehicle type i,
a_i = administration cost factor for vehicle type i, $a_i \geq 1.0$,
IRI = international roughness index,
$IRI = 1.44 + 29.8\,(10^{-0.2278\,\mathrm{RCI}})$, where $R^2 = 0.89$, $n = 22$, and
RCI = Saskatchewan riding comfort index scale.

Financial and economic costs are required by the PMIS, both with user delay and excluding the delay costs. The calibrated cost equations are used in the PMIS analysis with weights reflecting the traffic mix on each highway section.

Calibration of the HDM3 user-cost model must reflect the differences between typical vehicle technology, operation, management, and price relativities in Saskatchewan and in the HDM3 database. HDM3 relationships based on concepts inadequate for the province need revision, but limited resources only permitted calibrations of designated default values of the HDM3 model. Sensitivity of PMIS results to the uncertain HDM3 relationships will determine the need for further adaptation work. Large-scale interprovincial surveys may prove necessary to validate HDM3, owing to the experimental error normally found in this type of research. Of immediate consequence would be a check of the user-cost–roughness slope, which in PMIS could only be adapted from the Brazil study. Another survey should clarify the effect, if any, of pavement surface texture on rolling resistance, operating speed, fuel, and tire consumption. HDM3 ignores this variable, although other studies indicate significant effects (*8–10*). More work is also required to include cargo delay and damage, because in developed economies large quantities of high-valued cargo are transported. Damage and delay involve direct losses, as well as the disruption of materials and goods flow for manufacturers and distributors who rely on road transportation (*11–14*).

Calibration of Speed

It was first determined what the desirable speed (VDESIR) might be on Saskatchewan highways, and then iteration with the HDM3 model found the travel speed that matches observed average travel speeds. The assumed VDESIR was the 85th percentile, whereas the running speed was the average speed from the SHT 1986 speed survey. The corresponding value of β, the shape parameter of the Weibull distribution, was substituted into the speed equation. VDESIR so computed agreed to 2 percent for cars and 5 percent for trucks with the assumed VDESIR values. The β was calibrated for cars and articulated trucks. It was assumed that buses and half-tons have the same speed characteristics as cars and that all the truck types travel with the speed of five-axle combination units. The trucks were analyzed separately for the empty, fully laden, and average payload conditions to check the effect of averaging vehicle weight over round-trip distance.

The calibrated VDESIR is higher than in Brazil for both cars and trucks (Table 6) because of higher speed limit and possibly a perception of a better traffic safety in Saskatchewan. All values of β are well below unity and lower than HDM3 defaults, which agrees with the theory underlying the speed equation and with the observation of smaller variance of speeds on Saskatchewan highways compared to Brazilian data. For the heavier trucks carrying average network payloads, β needs to be forced to a limiting value of 0.04. This value of β increases the running speeds of empty trucks and decreases the speeds of fully laden units. Also, increasing VDESIR to car levels increases the calculated running speeds of empty trucks substantially, but not for fully laden trucks because β for this load condition is at the limiting value. Further investigation of the speed equation for trucks would be in order.

TABLE 6 SPEED CALIBRATION

Vehicle Type	Payload tonnes	VDESIR, km/h Assumed	VDESIR, km/h HDM3 Default	β Iterated	β HDM3 Default	Calculated Running Speed, km/h
Car	0.1-0.2	111	98.3	0.23	0.274	103.3 [b]
1/2-Ton	0.5	108	98.3	0.24	0.274	97.3 [b]
2-axle Truck	4.0	105	88.8	0.10	0.310	97.2 [b]
3-axle Truck	8.4	105	88.8	0.04	0.310	95.5
Bus	2.0	111	93.4	0.13	0.273	103.2 [b]
5-axle Truck	0.0	105	84.1	0.16	0.244	97.1 [b]
	10.3 [a]	105	84.1	0.04	0.244	96.5
	23.0	105	84.1	0.04	0.244	81.4
7-axle Truck	0.0	105	84.1	0.22	0.244	97.0 [b]
	22.0 [a]	105	84.1	0.04	0.244	97.3 [b]
	37.5	105	84.1	0.04	0.244	81.9

Notes: (a) Average network payload, including empties.

(b) Approximately equal to average speed observed in 1986 survey.

TABLE 7 CALIBRATED ENERGY-EFFICIENCY FACTORS AND MODEL PARAMETERS FOR MAINTENANCE PARTS (CP_o) AND LABOR (CL_o)

Saskatchewan Vehicle	Energy Efficiency Factor	CP_o (10^{-6})	CL_o
Small Car	0.80	20.3	36.2
Medium Car (a)	1.00	20.3	44.5
Large Car	0.66	20.3	53.0
Half-ton Pickup or Van (b)	0.58	26.3	60.5
2-axle Truck	0.80	1.93	136
3-axle Truck	0.65	8.43	179
5-axle Unit	0.75	5.56	232
7-axle Unit	0.65	6.60	296
Bus	1.00	0.445	369

Notes: (a) Analyzed as HDM3 small car.

(b) Analyzed as HDM3 light gasoline truck.

Fuel and Lubricants Consumption

Fuel consumption data exist for the average present road roughness levels in Saskatchewan, but not for rougher conditions. The Brazil study did not find significant increases in fuel consumption in the range of roughness considered in PMIS policy analysis. To calibrate fuel consumption, HDM3 was run for each vehicle with corrected speed parameters, proper vehicle characteristics, and IRI = 2 m/km (RCI 7.5). The model output was compared with typical fuel consumption in Saskatchewan. The energy efficiency factor (Table 7) was calculated as the ratio of data to HDM3 prediction. The HDM3 formula for lubricants consumption is a linear regression with the intercept equal to engine oil volume equivalent of all oils and lubricants. The intercept was adjusted to reflect collected data, whereas the Brazil default coefficient of the roughness variable was assumed to apply to Saskatchewan.

Tire Consumption

The slope coefficient of the roughness variable was assumed to hold for Saskatchewan. The constant term for cars and utilities was calibrated to correspond to tire life of 80,000 km. The regression of rolling resistance on roughness underlies the truck and bus tire consumption formulas in HDM3, and the equations were adopted without any changes. Industry tire consumption data (7) and data from the survey of truckers were input into the model, but the solution was not reasonable, possibly because of high sensitivity to vehicle weight, ratio of recapping to new tire cost, and bias ply versus radial tire properties. An adjustment was made in tire price instead.

Maintenance Parts and Labor

The roughness variable appearing in the parts equation is important, because it also determines maintenance labor in HDM3. The parts cost-roughness slope is a function of the HDM3 default constant CP_o. If CP_o is calibrated, the slope changes relative to the Brazil data. Forcing the slopes before and after calibration to be equal produces negative parts consumption. For this reason the HDM3 expression for the slope of the parts and labor relationships was assumed to apply to Saskatchewan. The truckers indicated that parts account for 45 to 60 percent of the total maintenance cost, but the ratio changes with a vehicle's age. A ratio of 0.5 was assumed, and the resulting calibrated constants CP_o and CL_o for the parts and labor equations, respectively, are shown in Table 7.

Depreciation and Interest

To obtain a correct value for depreciation and interest cost, the vehicle price was reduced by its resale value at the end of its highway use stage. This is particularly important for tractors, which are generally used on highways for about the first 5 years and in urban service afterwards. For this reason, the new price of tractors should be taken net of resale value at approximately 800,000 km. The duration of highway use stage of each vehicle and the ratio of scrap value at the end of the stage to new prices are shown in Table 8, based on local data. A more rigorous method should be developed to take account of vehicle-life staging and, if necessary, the effect of warranty maintenance on the purchase price. This will require changes in the program code, which now is structured to accept the same vehicle price for both the maintenance and the depreciation and interest cost calculations.

CALIBRATED USER-COST EQUATIONS

Aggregated User-Cost–Roughness Relationships

The calibrated model parameters were substituted for default values, and the HDM3 was run for each of the nine typical

TABLE 8 DURATION OF HIGHWAY UTILIZATION STAGE AND SCRAP VALUE

Vehicle Type	Highway Utilization Stage, years	Scrap/ New Value
Small Car	7	0.10
Medium Car	7	0.15
Large Car	7	0.15
Half-ton	10	0.15
2-axle Truck	8	0.18
3-axle Truck	8	0.18
5-axle Truck	5[(a)]	0.40[(b)]
7-axle Truck	5[(a)]	0.40[(b)]
3-axle Bus	13	0.23

Notes: (a) Tractor only, trailer 10 years.

(b) Tractor and trailer combined, based on 0.34 ratio for tractor and 0.50 ratio for trailer.

TABLE 9 CALIBRATED CONSTANTS

	FINANCIAL COSTS					ECONOMIC COSTS				
	Without User Delay			With User Delay		Without User Delay			With User Delay	
Vehicle Type	A_i	B_i	a_i	A_i	B_i	A_i	B_i	a_i	A_i	B_i
Small Car	5.13	0.0256	1.0	5.77	0.0186	4.82	0.0265	1.0	5.45	0.0192
Medium Car	5.34	0.0260	1.0	5.88	0.0206	5.02	0.0272	1.0	5.56	0.0213
Large Car	5.52	0.0249	1.0	5.99	0.0196	5.20	0.0260	1.0	5.67	0.0203
Half-ton	5.42	0.0298	1.0	5.96	0.0216	5.07	0.0320	1.0	5.62	0.0228
2-axle Truck	6.14	0.0564	1.1	-	-	5.79	0.0604	1.1	-	-
3-axle Truck	6.39	0.0394	1.1	-	-	6.04	0.0417	1.1	-	-
5-axle Truck	6.35	0.0343	1.1	-	-	5.98	0.0387	1.1	-	-
7-axle Truck	6.60	0.0421	1.1	-	-	6.24	0.0465	1.1	-	-
3-axle Bus	6.42	0.0236	1.1	7.67	0.0115	6.05	0.0250	1.1	7.33	0.0118

Note: - Not applicable

vehicles to calculate the component user costs and to fit Equation 1 to the aggregate cost. The calculated constants of the exponential equation are assembled in Table 9, which also lists estimated factors a_i for the administration costs of the commercial vehicles.

Calculated financial and economic transportation costs are similar, except for their magnitude. The financial cost-RCI slopes are similar for all light vehicles (Figure 1) and similar for trucks (Figure 2). The breakdown into financial cost components is shown in Figures 3 and 4 for the medium car and seven-axle truck. The largest share of the car operating costs is taken by depreciation plus interest, followed by fuel cost. Crew cost is also significant in the commercial vehicles. The largest cost increase with roughness occurs in the maintenance and depreciation components. Fuel cost drops at lower RCI values because of reduced speeds of large trucks on rough

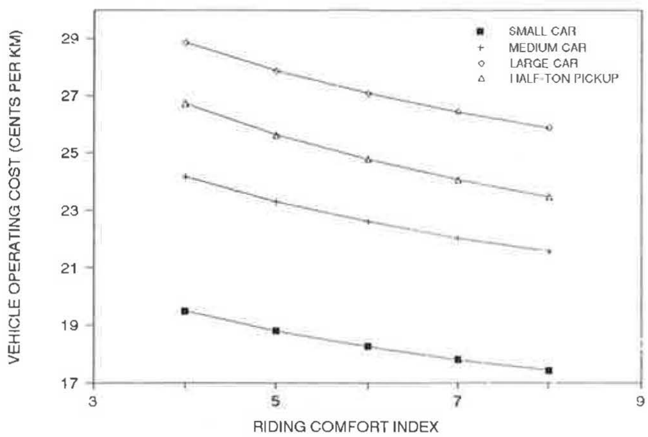


FIGURE 1 Total financial operating cost of light vehicles.

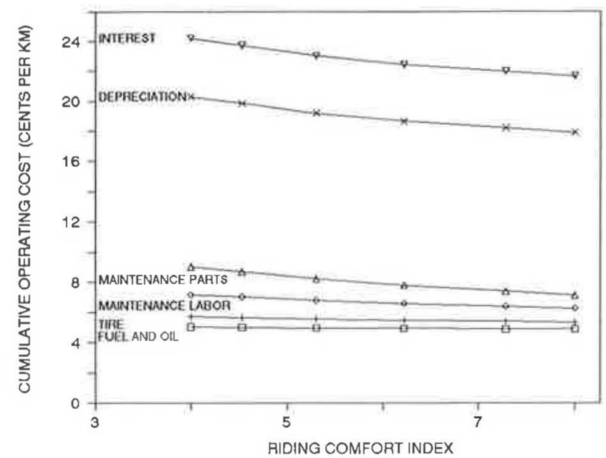


FIGURE 3 Medium-car financial cost components.

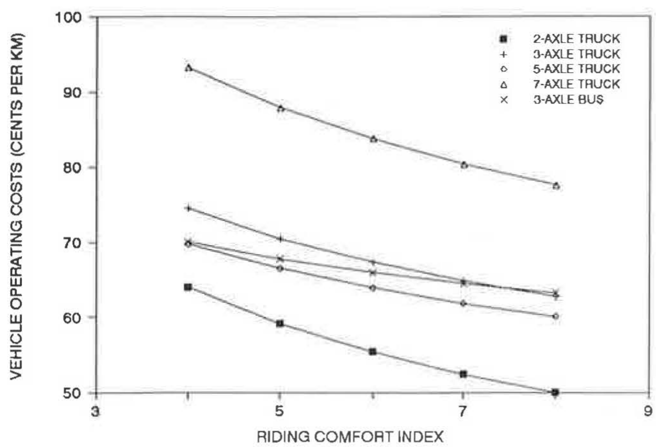


FIGURE 2 Total financial operating cost of heavy vehicles.

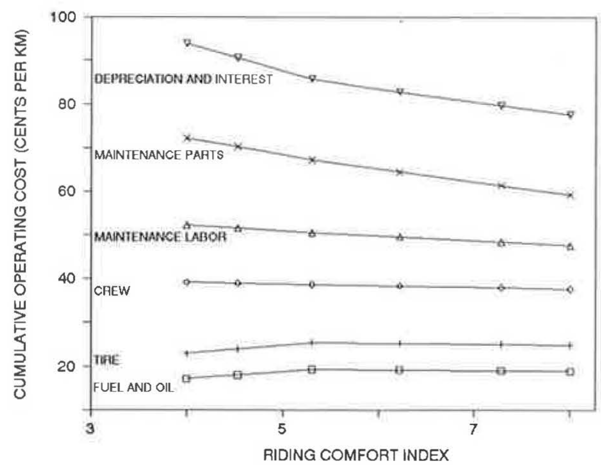


FIGURE 4 Seven-axle truck financial cost components.

roads, but crew time increases. Figure 5 shows the change in total financial costs when roughness decreases from RCI 8 to RCI 4. All cars are represented by the large car. The two-axle truck experiences the highest marginal rates of increase with roughness, whereas the bus has the lowest increase. When user delay is added, the marginal rates drop. The drop is most pronounced for the bus and amounts to halving the marginal rate. One can thus conclude that the bus-cost curve is very sensitive to the number of passengers. Similar conclusions are valid for the economic costs.

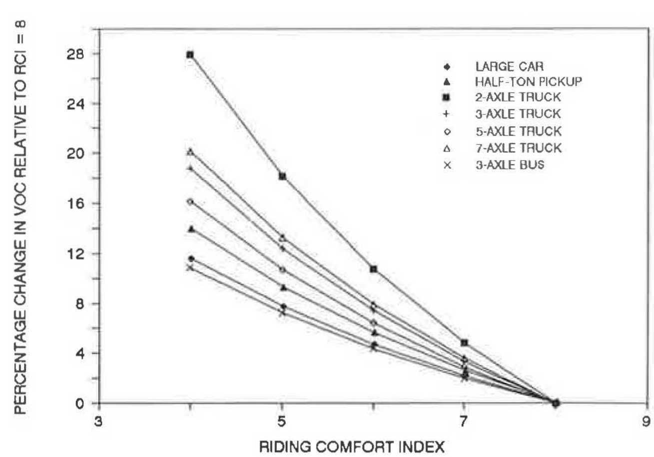


FIGURE 5 Relative change in financial costs.

Sensitivity Analyses

The rolling resistance was varied between 80 and 140 percent of the default value (Figure 6). The operating cost of trucks is about three times more sensitive to rolling resistance at $RCI = 7$ than the cost of cars. On rougher roads the sensitivity drops because trucks then operate at lower speeds. The calibrated engine speed (rpm), the use, and the service life were also changed in 20 percent increments for medium car and seven-axle truck (Figure 7). Increasing engine speed from the levels recommended by HDM3 does not have any effect on the total costs of vehicle operation at either roughness level for the medium car, but decreasing engine speed (rpm) results in a 3 percent drop in the costs. The seven-axle truck experiences a 5 percent drop with increasing rpm and smaller drop with decreasing rpm.

The annual distance driven was varied, but the annual time driven was adjusted to maintain the base case operating speed,

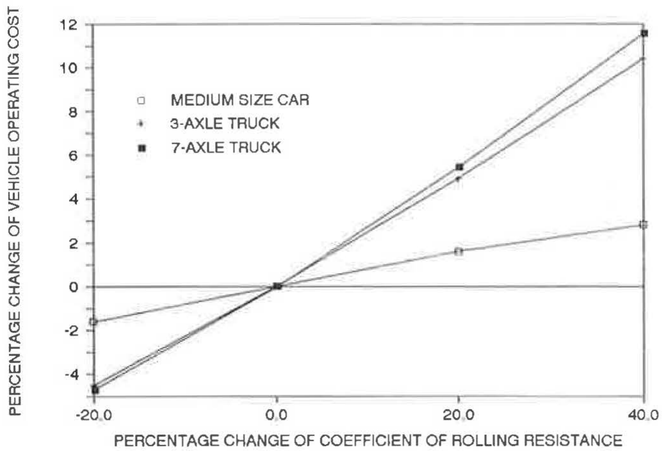


FIGURE 6 Sensitivity of vehicle operating costs to rolling resistance at *RCI* = 7.

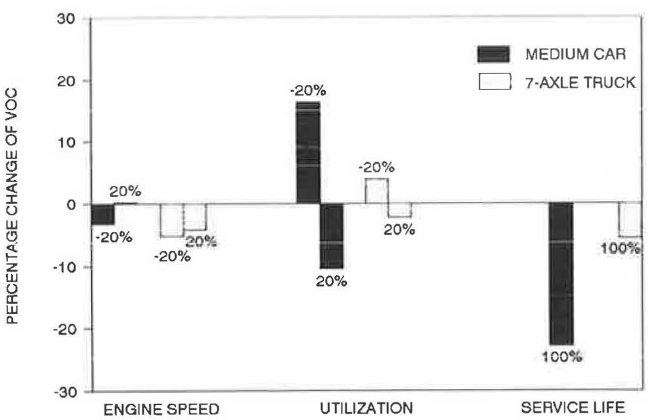


FIGURE 7 Sensitivity of vehicle operating costs to engine speed, utilization, and service life.

and the lifetime distance driven was recalculated using the base case service-life years. A 20 percent change in use of the medium car has a dramatic effect on the total operating costs. For the seven-axle truck, the effects are similar in direction, but smaller in magnitude. Service life was increased by 100 percent because this is the order of magnitude of the ratio of one use stage to the whole life. For example, truck tractors are used in intensive line-haul for about 5 years and then for another 5 to 10 years in less demanding service. Again, the medium car is far more sensitive to this variable than the truck.

CONCLUSIONS

The HDM3 user-cost model proved very useful for the Saskatchewan PMIS and was successfully calibrated to the local conditions, even outside of the inference space covered by the study of user costs in Brazil. The calibration relies on availability of representative vehicle and cost data. It was not possible within the scope of this study to gather vehicle operating cost data from the rougher road surfaces, and the cost-roughness slope found in the Brazilian data will require future verification.

For the needs of Saskatchewan, relationships capturing the costs of delay and damage of cargo in transit should be included into the suite of user-cost models. Depreciation, interest, and maintenance costs also require a closer investigation because of their interplay in vehicle-owner decisions. These decisions depend on the economy, technology, and government regulation, all of which are distinctly different than in the Brazilian study and are also changing quite radically in Canada.

Depreciation and maintenance costs overlap in present-day pricing of vehicles because the costs of repair on factory warranties are included in the purchase price. Available vehicle use data are not clear either, because of mixed urban/highway travel and distinct use staging of lives of all vehicle types. A methodology needs to be developed to address these issues, so that an accurate estimation of user costs can be made for the operation of the PMIS.

More specific observations of truck speeds as a function of payload and engine power are required to calibrate the HDM3 speed relationships for Saskatchewan's heavy trucks. The effect of pavement texture on rolling resistance is significant but remains to be clarified. The texture affects speed prediction, fuel, and tire consumption. Tire consumption relationships are inappropriate for the radial tire technology, but calibration is possible. Maintenance parts and labor cost equations can be calibrated with some difficulty attributable to the mathematical structure of the HDM3 relationships.

Data necessary to clarify these issues should be collected in a national survey to ensure a data base large enough to cover a wide range of paved road roughness and texture and to quantify the experimental error resulting from intercompany differences.

ACKNOWLEDGMENTS

Research reported in this paper has been initiated and sponsored by the Saskatchewan Highways and Transportation. The author wishes to thank Dennis Day, Gary Heiman, Jon Wyatt, and Masood Hassan for valuable inputs into, and constant interest in, the research. Words of gratitude are also due to all the participants of the pilot survey of Saskatchewan vehicle fleets and operating costs.

REFERENCES

1. *Research on the Interrelationships Between Costs of Highway Construction, Maintenance, and Utilization.* Final Report, 12 volumes. Brazilian Ministry of Transport, Texas Research and Development Foundation, and International Bank for Reconstruction and Development, 1982.
2. A. Chesher and R. Harrison. *Vehicle Operating Costs: Evidence from Developing Countries.* Highway Design and Maintenance Standards Series. Johns Hopkins University Press, Baltimore, Md. and London, England, 1987.
3. T. Watanatada, A. M. Dhareshwar and P. R. Lima. *Vehicle Speeds and Operating Costs: Models for Road Planning and Management.* Highway Design and Maintenance Standards Series. Johns Hopkins University Press, Baltimore, Md. and London, England, 1987.
4. J. B Cox, G. H. Heiman, M. U. Hassan and R. A. Deighton. An Integrated Approach to the Development of Pavement Management System for Saskatchewan. *Proc., 2nd North American Conference on Managing Pavements,* Toronto, Ontario, Canada, Vol. 1, 1987.
5. Lea Associates. *Saskatchewan PMIS Engineering Technical Man-*

ual, Appendix 1: Vehicle Operating Costs. Final Report. Saskatchewan Highways and Transportation, Regina, Saskatchewan, Canada, 1988.
6. *1986–87 Car Costs*. Canadian Automobile Association, Ottawa, Ontario, Canada.
7. Trimac Consulting Services Ltd. *Operating Costs of Trucks in Canada, 1986*. Transport Canada Policy and Coordination Branch, Ottawa, Ontario, Canada, 1986.
8. L. W. DeRaad. *The Influence of Road Surface Texture on Rolling Resistance*. Paper 780257. SAE, Warrendale, Pa., 1978.
9. D. C. Biggs. *ARFCOM—Models for Estimating Light to Heavy Vehicle Fuel Consumption*. Research Report ARR152. Australian Road Research Board, Vermont, Victoria, 1988.
10. U. Hammarström and B. Karlsson. *VETO—A Computer Model for Calculation of Transport Costs as a Function of Road Standard*. VTI Meddelande 501. Swedish Road and Traffic Research Institute, Linköping, 1987 (in Swedish with English summary and figure captions).
11. *The Role of Shippers and Transport Operators in the Logistics Chain*. Report of the 76th Round Table on Transport Economics, European Conference of Ministers of Transport, Economic Research Center, Paris, France, 1987.
12. R. K. Whitford. *Aspects of Freight Service Quality for Just-in-Time Transportation Serving the United States Automobile Industry*. VTI Meddelande 537A. Just-in-Time Transport Seminar, Organization for Economic Cooperation and Development and Swedish Road and Traffic Institute, Gothenburg, 1987.
13. J. Lindström. Improved Road Standards and Business Efficiency. *Proc., World Conference on Transport Research*, Vancouver, British Columbia, Canada, Vol. 1, 1986.
14. P. G. Koltnow. User's Perspective of Highway Pavements. *Proc., 2nd North American Conference on Managing Pavements*, Vol. 4, Toronto, Ontario, Canada, 1987.

Publication of this paper sponsored by Committee on Application of Economic Analysis to Transportation Problems.