Highway Management Systems for Pavements, Bridges, Congestion, and Safety

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The legislative proposal of the Bush administration for a post-1991 highway program would require state transportation departments to develop and implement comprehensive management systems for pavements, bridges, congestion, and safety.

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In addition, traffic monitoring systems would be required to provide basic usage information needed for effective management systems. The administration believes that these systems would aid in the stewardship of federal-aid highway program funds and other resources in the maintenance, expansion, preservation, and operation of the nation's major highway facilities. The systems are based on the management tenets of the U.S. Department of Transportation National Transportation Policy discussed in an article in *TR News* (July–August 1990).

The National Transportation Policy includes recognition that the transportation infrastructure is now at risk because of declining investment in aging networks of highways, mass transit, railroads, airports, waterways, ports, and other fixed facilities. Renewed efforts to reinvest in the maintenance and expansion of these facilities and

to support their efficiency, capacity, and performance are recommended. The reinvestment in transportation infrastructure is necessary to ensure the growth and strength of the national economy. The National Transportation Policy draws from recent studies of the nation's declining infrastructure and scores of outreach meetings held throughout the country. Study results showing deterioration of the condition of highways and bridges and the extent of congestion in many areas were echoed in town meetings in both rural and urban areas.

Recommendations of the National Transportation Policy include (a) giving priority to maintenance and preservation of transportation facilities; (b) stronger requirements for pavement and bridge management systems and better designs for long-range durability; (c) improving the management of transportation systems in order to accommodate more traffic and to handle it more safely and efficiently, particularly in areas in which congestion already exists. The management systems concept will foster investment strategies that achieve the highest payoff and are consistent with and supportive of other national objectives in such areas as clean air, economic growth, and energy conservation.

Legislative Development

The National Transportation Policy was developed at a critical time—the federal transportation assistance programs of the Federal Highway Administration, the Urban Mass Transportation Administration, and the National Highway Traffic Safety Administration are up for reauthorization. The federal-aid Interstate program, begun in the 1950s, has reached the final stages of construction. New initiatives are needed to protect the huge investment in the Interstate system and to provide new and enhanced service to a growing and geographically shifting U.S. economy.

The Bush administration's post-1991 highway program reauthorization proposal incorporates the National Transportation Policy recommendations by requiring states to develop and implement management systems for pavements, bridges, congestion, and safety. These systems, coupled with another policy recommendation, a national highway system (NHS) (basically a subset of today's primary system, which includes the Interstate system), are key features of the administration's legislative proposal. In addition, operational and rehabilitation improvements of the Interstate system, which will result from the management systems, are proposed to be funded at a higher federal match, 90 percent versus 75 percent for other NHS expenditures.

These four management systems will be required in order to monitor the condition and performance of the NHS in each state. Annual federal-aid highway project activity of the states will be based to a large degree on the information flowing from these management systems. The federal-aid program will be the primary incentive for these management systems, and the federal match requirement could be waived for the use of planning funds in the development costs.

These systems are in various stages of development. Pavement management systems are currently required by regulation to be in place in each state by January 1993. Bridge management systems are in the early stages of development in a few states. Safety and congestion management systems require further advancement and have been initiated in various ways by some states. Development is expected to occur in stages with final implementation to be completed by 1995. Early development is necessary because of the close alignment with federal-aid participation in both the development of the systems and the products, one of which will be funding priorities for federal-aid projects.

A congestion management system should provide an integrated framework for making transportation programming and other areawide decisions intended to ease traffic congestion.

Common Elements

The intent of implementing management systems is to provide decision makers with quantifiable data and impact information on which they can base decisions to manage highways effectively and efficiently. The major elements common to these systems are an inventory, including condition and impact factors; data analysis, including forecasting; assessment of strategies and alternatives; priority evaluations; project selection; and performance monitoring.

These elements are in place to some extent in most transportation agencies, but are frequently not coordinated in a comprehensive and systematic fashion. Some of the elements will be developed by, and others will have to be coordinated with, metropolitan planning organizations because they will be closely aligned with the planning activities in urbanized areas. Some elements may require further refinement to evaluate design procedures, materials, construction practices, and maintenance techniques, or to develop more sophisticated electronic control systems. The elements all work together within each of the systems, and there are obvious interrelations among systems.

The management systems will be used to establish formal procedures for recommending candidate projects and evaluating different strategies for solving problems, correcting deficiencies, and assessing trends to evaluate future needs and prevent serious budget shortfalls. They will incorporate forecasting tools to develop trends of conditions, assess needs, and analyze future funding or budget scenarios, and will result in development of both short- and long-term solutions.

Pavement Management

A pavement management system can best be described as a systematic computer-assisted method of providing quantifiable engineering and financial information to help highway decision makers manage pavements.

The key features of a pavement management system are the abilities to predict performance, anticipate needs, and identify resources to meet those needs over time. An important part of the system is the ability to evaluate materials, design, mainte-

nance, rehabilitation, and construction procedures.

The output of a pavement management system consists of a variety of reports. Prioritization reports, budget reports, trends, pavement condition summaries, and "what-if" scenarios can be developed. Annual and multiyear work plans are expected products, with priorities of maintenance, reconstruction, and rehabilitation projects arrayed to yield a cost-effective value for the available funds consistent with the goals, objectives, and policies of the state highway agency.

The South Carolina Department of Highways and Public Transportation, with consultant support, recently developed and is implementing a comprehensive pavement management system. The system consists of three major subsystems: the data base, network analysis, and engineering feedback subsystems.

The data base subsystem provides an automated system for the collection, storage, and retrieval of highway inventory and condition data, as well as extensive reporting capability. This subsystem also provides the major inputs to the other two subsystems. A semi-automated data collection system using a South Dakota–type road profiler with keyboards for entry of observations of road distress provides the primary data input. The main performance data are roughness and observed surface distresses. Six types of distress are recorded for flexible pavements and eight for rigid pavements. The distresses are combined into a pavement distress index.

The network analysis subsystem provides the capabilities of predicting pavement performance and performing lifecycle analyses of alternatives, as well as performing optimization for determining work programs. This subsystem is the heart of the management system, with capabilities of performing analyses of alternative funding scenarios. Performance models developed in the research phase are verified and adapted as historical data are accumulated.

An engineering feedback subsystem provides procedures for evaluating various aspects of the highway network, including analysis of historical rehabilitation treatments, update of performance models, and analysis of historical network trends. This allows modification to design and construction practices.

South Carolina highway officials and the consultant drew heavily on the experience of other states in developing the pavement management system. The goals and objectives of the system are being coordinated by a steering committee composed of high-level management personnel from each major office (preconstruction, maintenance, planning, and construction).

Implementation of the pavement system involves all units of the highway agency. Responsibility for most of the budget planning and system forecasting resides in the planning office. Field testing and pavement design are conducted through the construction office. The network software will be provided to the district offices for their use in developing candidate project lists and developing annual resurfacing programs.

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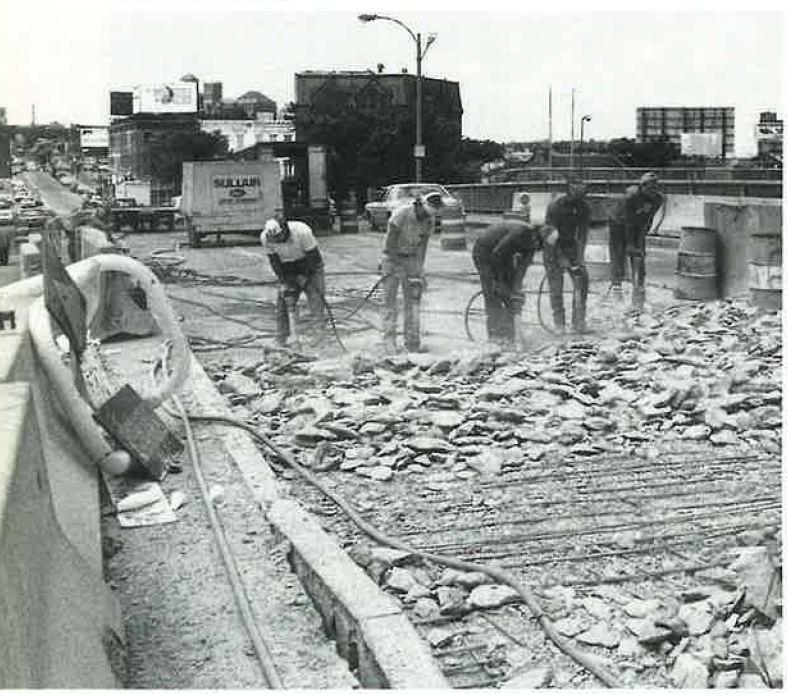

Management systems provide decision makers with quantifiable data and information on which decisons to manage highways and bridges effectively and efficiently can be based.

Bridge Management

Like their pavement counterparts, bridge management systems can be used to establish formal procedures for selecting projects and strategies to meet needs. Projects for maintenance, repair, rehabilitation, and replacement can be developed through a bridge management system. Network needs as well as funding constraints must be considered. The objective is to minimize agency and user costs while keeping public safety and convenience of travel at a high level. A typical system also provides the ability to develop and substantiate funding proposals by providing reliable short- and long-term predictive capabilities.

A bridge management system includes engineering and management functions necessary to effectively and efficiently manage a bridge program. Such a system brings together the following:

- Programs for bridge inspections, maintenance, design, construction, and other essential activities;
- Formal procedures for coordinating these activities and functions; and
- Suitable analytical tools for objectively assessing bridge needs and establishing priorities.

Through the bridge management system, the yearly funding requirements to attain level-of-service goals at least cost and the backlog that would accrue if sufficient funds are not available can be determined. The system may also be used to identify optimal near-term improvements and predict long-term strategies to accomplish agency goals.

The status of development of comprehensive bridge management systems varies considerably from state to state. Most states

are in the early stages of development; only a few have made significant progress toward sophisticated and comprehensive systems. Many present procedures for selection of projects, though formalized and systematic, rely heavily on engineering judgment and will likely undergo changes as development continues.

A few state agencies have made rapid progress toward development of comprehensive bridge management systems. North Carolina has been working on a management system since 1981 that uses a level-of-service concept for rating its bridges. More recently the state developed an optimization program that uses the annual maintenance cost, the annual user costs, detour costs, and accident costs to project annual costs for continued operation of each bridge. Comparisons can be made with the total cost of replacement or rehabilitation to determine which bridge would offer the greatest benefit in cost reduction. Initial efforts by several states, particularly North Carolina and Pennsylvania, were the basis for the FHWA Demonstration Project 71, a 1½-day workshop in 47 states. It sought, among other things, to establish an analytical foundation for incorporating an evaluation of user costs (accidents, travel time, and vehicle operating costs) into optimization decisions on resource allocation and priority ranking of bridges.

Two years ago, FHWA entered a second phase of Demonstration Project 71 for the development of bridge management system tools. A technical advisory committee was organized, consisting of bridge engineers from FHWA and from the transportation agencies of California, Minnesota, North Carolina, Tennessee, Vermont, and Washington. The committee developed the concept of a core bridge-management-system network-optimization model.

The optimization model, labeled "PONTIS," consists of a number of submodels capable of accepting any agency's decision-making procedure and cost scales, while being flexible enough to adjust to a great variety of environmental differences from state to state and from region to region. The California Department of Transportation (Caltrans) was selected to manage the project because of its significant bridge data base. Caltrans subsequently subcontracted the design and programming portion of the model to two consulting firms: Optima and Cambridge Systematics.

The Caltrans project is expected to result in public domain software consisting of a series of submodels produced as standalone microcomputer programs. The Technical Advisory Committee reviews the submodels as they are produced to ensure transportability and adaptability to the various state programs. When assembled, the submodels make up a multiyear network optimization model that can be used to assess a broad array of corrective strategies and determine an optimal selection of projects (see Figure 1). The demonstration project is scheduled for completion at the end of 1991.

This modeling process and work by other states and the Transportation Research Board's National Cooperative Highway Research Program to develop bridge management systems will bring bridge management closer to the state of the art with pavement management systems.

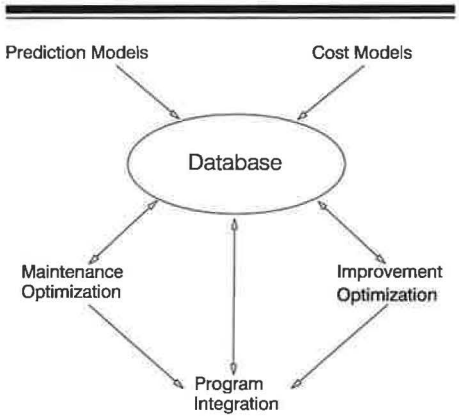

FIGURE 1 Overall structure of PONTIS.

Congestion Management

A congestion management system should provide an integrated framework for making transportation programming and other areawide decisions intended to ease traffic congestion. Because the easing of congestion will improve air quality, a strong link will exist between the congestion management efforts and the process for developing the transportation control measures for state air-quality implementation plans. The congestion management process will

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NCHRP Project on Bridge Management Systems

The Transportation Research Board's National Cooperative Highway Research Program (NCHRP) initiated a project on bridge management systems in 1985. The original objective of NCHRP Project 12-28(2) was to define and develop a model form of effective bridge management at the network level. The first phase of the project resulted in the conceptual development of the modular elements necessary for a model bridge management system, which is documented in NCHRP Report 300, *Bridge Management Systems*. During the second phase, engineering concepts necessary for the operation of such a system were further developed and program development was initiated.

A third phase will soon be under way, with the objective of developing and validating a microcomputer-based bridge management system software package that can be readily used by transportation agencies. The system will be targeted to small to midsize transportation agencies with modest total bridge populations. Unlike the Federal Highway Administration/California Department of Transportation project, the NCHRP bridge management program is intended to incorporate conventional engineering procedures such as deterministic deterioration models, incremental cost-benefit analysis, and life-cycle cost profiles along with the use of level-of-service goals. The project and software should be available for transportation agencies in early 1993.