

Perspective on Maintenance and Operations

RONALD B. HAMILTON, *Roy Jorgensen Associates, Inc.*

WILLIAM A. HYMAN, *Booz-Allen & Hamilton*

The importance of maintenance is increasingly recognized as we approach the new millennium. With the Interstate highway system essentially in place, the focus of transportation programs is shifting from capital investment to maintenance and operation. Senior executives, legislators, and the public consider maintenance the key to not only protecting the nation's multibillion-dollar highway investment but also continuing to provide a safe, efficient transportation system. Funding for new highways on the scale of the Interstate program is not likely to be allocated again in the foreseeable future. Thus, the challenge for maintenance managers is to achieve maximum performance from the existing system.

In this article, we identify the major trends that affect maintenance, cite current and emerging innovations in management and technology, and examine the key maintenance challenges of the next century.

TRENDS THAT AFFECT MAINTENANCE

As they approach the new millennium, maintenance professionals face important challenges: to provide efficient transportation with an aging infrastructure, to meet growing public and legislative demands for accountability, and to manage the rapid pace of change. With these challenges come exciting opportunities. Today, maintenance is more visible than ever before, and thinking in maintenance management is moving faster than it has been since the 1960s. In state departments of transportation (DOTs) across the nation, many exciting new developments are under way to improve business practices, transform organizations, and leverage new technologies. The major trends that affect maintenance include the following:

- Infrastructure growth is slowing, so the maintenance and rehabilitation of existing infrastructure is becoming increasingly important. As public funding shifts from construction to maintenance, maintenance organizations become more accountable to administrators, politicians, and the public for a safe, convenient, and accessible transportation system. This shift in emphasis brings new governance and institutional issues.
- The nation's aging infrastructure is challenging maintenance managers, who must respond to the need for more effective business practices. Innovations in management systems, resources, materials, technology, equipment, and work methods improve maintenance effectiveness and efficiency.
- Technology is changing the kinds of infrastructure that must be maintained. Advanced technology is increasingly being incorporated into the transportation

infrastructure; as a result, new maintenance procedures and a very different set of skills for maintenance workers are required.

- Technology is affecting how we perform maintenance. Information technology—especially advances in integrated information systems—removes institutional and organizational barriers throughout the enterprise. Other tremendous advances are taking place in areas such as data collection, diagnostics, analytical techniques, material sciences, and maintenance equipment.
- The political climate that calls for smaller government is making its mark on the institutional and cultural aspects of maintenance organizations. Fewer maintenance staff in state DOTs means increased use of private contractors and alliances with local agencies to provide the resources to enhance overall transportation services to the customer.
- State DOTs are implementing private-sector best practices in customer service and performance management. Public perception and expectations for better service change the way maintenance managers define and respond to customer needs. The debate over government accountability brings about new ways to measure maintenance performance. Emerging trends include outcome-based planning, budgeting, and measuring results.
- Recruiting and retaining a skilled work force is becoming more difficult. The private sector tends to pay higher salaries for technology jobs, thus attracting many potential recruits away from highway maintenance careers.
- Environmental concerns continue to have a significant affect on maintenance. New regulations are anticipated, and the trend is toward stronger enforcement of existing regulations.

Slowdown in Highway Construction, Aging Infrastructure

Throughout most of the 20th century, the federal, state, and local agencies pursued a mission to build a national and interstate highway network that would support burgeoning commerce and development in the United States. The U.S. Congress saw the federal role as financing and supporting construction, and as such made almost no provisions for maintaining the Interstate system. The responsibility for maintenance and operations was left to the state and local agencies.

Without an emphasis on maintenance, highway and bridge infrastructure aged more rapidly than it could be reconstructed, rehabilitated, or restored. Currently, new attitudes toward maintenance prevail as understanding and awareness grow. Preservation of assets and mobility are high-priority challenges for a highway system that is essentially in place.

As the Interstate system construction was essentially completed, federal involvement in maintenance increased. The federal government belatedly instituted a program of reconstruction, rehabilitation, resurfacing, and restoration and slowly expanded its role in funding maintenance.

The Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) placed major emphasis on preservation of the system and the environment. It fostered greater use of nonhighway modes of transportation, intermodal connections, operational improvement, and advanced technology to promote a more efficient surface transportation system. ISTEA established the Interstate Maintenance Program and called on states to implement pavement, bridge, and other management systems to extend the life of the current network and maximize its efficiency.

The 1998 Transportation Equity Act for the 21st Century renewed the emphasis on construction as legislators earmarked numerous high-priority projects for construction. However, formidable funding and environmental barriers to new construction remain.

The emphasis on maintaining and operating our existing system in lieu of new construction will almost surely continue well into the next century. Accountability for meeting the nation's transportation needs will rest with maintenance. The federal role will continue to shift from construction to maintenance, and states will be given more latitude in how their federal maintenance dollars are spent.

Technology-Based Infrastructure

The application of technology to meeting transportation needs has become an integral part of transportation infrastructure. The Intelligent Transportation System consists of some 30 different user services that involve various systems, including the Advanced Traffic Management System and the Advanced Traveler Information System.

These technologies and others, such as Roadway Weather Information Systems (RWIS), are widely used and beneficial to both motorists and maintenance organizations. For motorists, they provide the tools to maximize system efficiency and safety as well as traveler advisories. For maintenance organizations, they provide real-time surveillance of the road network, allowing rapid response to emergencies and traffic incidents.

Although these technologies provide benefits in operating the infrastructure, they also create a maintenance need very different from that of the past. Managing these technology-based assets requires skilled technicians and a proper preventive maintenance program to ensure maximum operability and optimum cost-effectiveness. Maintenance personnel in the 21st century will need technical skills in electronics, robotics, computerized systems, virtual reality, expert diagnostics, and related areas to maintain our technology-based infrastructure.

We are seeing only the tip of the iceberg in the use of advanced technologies in highway infrastructure. Radically new technologies will be used throughout the highway system in the next millennium. Whether the actual maintenance is done with in-house forces, contracted out, or left to technology suppliers, the responsibility for maintenance will rest with the maintenance manager.

Technology for Better Maintenance Management

Technology is changing the business of maintenance management. Tremendous advances in applying technology for better management—physical technologies as well as information technology—are under way. Significant breakthroughs are taking place in many areas, as illustrated by the following examples:

- Technologies such as RWIS provide real-time data about pavement and weather conditions, allowing more timely deployment of winter maintenance crews and deicing equipment.
- Development of the Advanced Maintenance Concept Vehicle, under the sponsorship of Minnesota, Michigan, and Iowa, is expected to enhance productivity through equipment design.

- South Dakota's spray-applied patching machine and California's experimental crack-sealing machine will improve efficiency, minimize lane-closure time, and increase safety for operators and motorists.
- Advances in diagnosing infrastructure performance, such as pavement cracking and sign reflectivity, help track asset conditions and determine maintenance needs.
- Geographic information systems and digital databases of roadway assets allow managers to view asset characteristics, assess field conditions, and deploy resources to solve maintenance problems without time-consuming field trips.
- In the future, maintenance vehicles and equipment will include global positioning system guidance systems, robotics, hydraulics, and advanced electronics such as digital voice and data communication systems.

In the area of information technology, advances in software, hardware, and telecommunications (including the Internet) will increase the feasibility of data-collection systems, enterprise databases, and integrated decision support systems for maintenance management. These trends were evident a few years ago, as reported in National Cooperative Highway Research Program (NCHRP) Report 363 (1). Integrated Maintenance Management Systems (IMMS) that encompass bridge, pavement, equipment, financial, and materials management are within sight. Funding and organizational barriers that previously prohibited IMMS are beginning to be addressed as the technology becomes more affordable and the benefits across the enterprise are recognized.

The Internet is becoming a powerful communication tool between DOTs and their customers. Nearly every state DOT has a home page on the Internet. Through public access of their home page, some states are beginning to make important information on such topics as road conditions, construction work locations, budgets, and program funding available to their customers. Communication with customers will expand significantly in the next century.

The Tennessee DOT, in cooperation with surrounding states, is leading an effort to install information kiosks at the Interstate rest areas. Computer monitors in the kiosks will give road users a real-time visual display of road and weather conditions, including current roadway construction. Motorists will be able to plan their travel along the safest, least-congested routes.

Growth in Maintenance Contracting and Public and Private Partnerships

Contracting and maintenance privatization are growing trends worldwide. Although the rate of growth is slower in the United States than abroad, the use of private contracting is expected to increase well into the next millennium.

Nearly all states contract out a portion of their maintenance program. Activity-based contracting is the most prevalent form of maintenance contracting and probably will be for many years. Florida, Massachusetts, and Virginia have taken some of the most innovative approaches to contracting. Florida has implemented several geography-based contracts in which the contractor is responsible for almost all maintenance activities on designated road segments. On three different sections of its Interstate system, Virginia has implemented a performance-contracting approach, whereby the contractor is responsible for achieving specified system performance and outcomes instead of carrying out traditional work specifications.

As a means of maximizing the use of resources, state DOTs also are reevaluating their relationships with other government agencies. Pennsylvania is implementing a new program called AGILITY to form temporary maintenance enterprises with local governments and other state agencies. This program will bring together state and local agencies to combine their strengths toward a goal of providing motorists with a seamless transportation system.

Although maintenance contracting will increase, states probably will not contract out entire maintenance programs. They will retain at least a core staff that could respond rapidly to snowstorms, floods, hurricanes, and other disasters.

Increased emphasis will be placed on performance specifications rather than method or material specifications. New contracting models will emerge to fit each agency's local culture, labor practices, and political climate.

New Business Practices in Performance Management and Customer Service

The public debate over government accountability provides an impetus for maintenance organizations to implement better business practices. New management approaches for maintenance planning, budgeting, and performance measurement are tied to customer needs and expectations. Similarly, maintenance organizations are beginning to define outcomes and performance in terms that are easily understood by the general public, thus improving communication among customers, legislatures, and stakeholders.

Performance measurement is becoming a key element in the overall performance management approach. The Florida DOT has been measuring maintenance performance by using the Maintenance Rating Program (MRP) for nearly 10 years. The Florida DOT is required by law to maintain its highway systems at a specified level of performance. The MRP is increasing both understanding and confidence at the level of the Florida legislature.

Minnesota is improving customer service in all aspects of its highway management, including maintenance. The state-set maintenance goals and programs require regular assessments of customer satisfaction and desires. Washington state's Maintenance Accountability Process (MAP) is very successful. The MAP allows the Washington DOT to communicate maintenance outcomes in clear, nontechnical terms to the public, legislators, and budget analysts. When they understand what their maintenance dollars are buying, legislators are more likely to fund maintenance needs.

Agencies seek to measure not only outputs and outcomes but also value-added in terms of avoidable user costs (e.g., travel time, accidents, vehicle operation), avoidable taxpayer costs (expressed in terms of savings over a life cycle), and reductions in externalities such as air, noise, and water pollution.

Other private-sector business practices that are being implemented by transportation agencies include continuous quality improvement, business process reengineering, and technology business planning. Perhaps the real success story as we approach the 21st century is that maintenance managers are taking a more formal business approach to maintenance. The maintenance manager of the future probably will be less technical and more business-oriented than today's equivalent.

Environmentally Sound Maintenance Work Practices

Maintenance must consider environmental regulations and impacts that are quite different from those associated with new construction. Examples of some maintenance practices that require special handling include

- Containing structures when removing lead paint,
- Implementing National Pollutant Discharge Elimination System regulations,
- Discarding cut vegetation and road debris,
- Avoiding contamination of wells from road salt and street sweeping, and
- Disposing of Vector waste.

These environmental regulations affect efficiency, work methods, and budgets.

Because maintenance is growing in complexity and importance, the need to adopt best management practices for environmental issues related to infrastructure maintenance will increase. Together, the creation of the Transportation Research Board (TRB) Environmental Maintenance Task Force, the subsequent establishment of the TRB Subcommittee on Environmental Maintenance, and the publication of the NCHRP Synthesis 272 (2) are explicit acknowledgment of this trend and its increasing importance.

We do not expect significant growth in new environmental laws. However, more stringent enforcement of current regulations probably will affect future maintenance programs significantly.

FUTURE CHALLENGES AND GETTING PREPARED

Clearly, the importance of maintenance is growing. The character of maintenance also is changing. Major factors influencing these changes include

- Increased accountability of maintenance professionals for stewardship of the nation's multi-billion-dollar transportation investment;
- Deployment of new technologies;
- Implementation of customer-oriented management systems and business practices;
- Realignment of institutional relationships between local, state, and federal governments; and
- Increasing dependence on public and private partnerships to implement maintenance programs.

Tremendous change is already afoot throughout the entire highway industry. Without question, maintenance professionals will have to respond to changing needs. Agencies of the future that will stand out as high-performance maintenance organizations will be the ones that recognize the changing role of maintenance, embrace it, and take proactive measures to ensure that they are ready to meet the future challenges.

Smart Implementation of Emerging Technologies

It is impractical to think that states can or even should implement every new technology. Many new technologies have been tried, without success. Experience can point to valiant efforts to implement new technology that, in reality, did not fit the agency's operating environment. Although attempted with the best intentions, the initiatives did not achieve the intended objectives.

As rapidly as technologies are advancing, agencies can easily be lured into believing that technology offers ultimate solutions to maintenance problems. Likewise, a one-size-fits-all mentality is not prudent with respect to emerging technologies. What works well in one state might not be appropriate in another.

Notwithstanding the risks associated with its implementation, technology is vital to the future of maintaining and operating the transportation system efficiently. Many new technologies will increase productivity, improve worker safety, prolong the life of maintenance assets, allow better management of the infrastructure, and enable top-quality customer service.

Meeting the challenge will require strategic and tactical assaults at both national and state levels. On the national level, research is the key to identifying, designing, developing, and testing new technologies. The American Association of State Highway and Transportation Officials is taking a leadership role with its Task Force on Maintenance Management. In cooperation with the Federal Highway Administration, this task force sponsored the Maintenance Management for the 21st Century Forum in Arlington, Texas, in March 1999. In a similar effort, TRB sponsored its second Maintenance Quality Workshop in May 1999. The continuation of these kinds of initiatives is critical to long-term continuous improvement in maintenance management.

At the state level, each state must implement technologies prudently, recognizing that not all technologies work equally well in all states. Each state should implement strategic planning procedures that will provide the necessary guidance for its maintenance programs. With well-defined strategic goals and objectives, each state can effectively assess how it will use technology to meet its maintenance and operations needs.

Developing a Skilled Work Force of Maintenance Managers and Technicians

The U.S. military is one of the most technologically advanced organizations in the world, yet military leaders recognize and regularly proclaim that the technology would be useless without the skilled personnel to support it. That same premise applies to highway maintenance. Because of the rapid advances in technology—both built into the infrastructure and used to maintain it—a skilled work force will be vital.

The maintenance work force is becoming more professional already. South Carolina has graduate engineers managing most of its county maintenance organizations. Recognizing the importance of having a skilled organization, Utah has implemented a maintenance training program for personnel at all levels of maintenance.

Most other states offer training programs of varying scope and focus. As new technologies are introduced in the next century, training of maintenance personnel will take on added importance. The highway industry already has a model for technical training with its National Institute for Certification in Engineering Technologies program for construction personnel. A similar industry-wide approach to certifying maintenance technicians would ensure that highway system maintenance is entrusted to skilled workers.

State DOTs will be challenged to recruit and retain a highly competent staff. Young people entering the work force are attracted to high-technology jobs that offer exciting opportunities and better pay. Maintenance organizations will need to develop innovative programs for training, advancement, and reward.

Implementing Performance-Based Management Systems for Customer Service

Soon, maintenance organizations will no longer be allowed to measure performance solely in terms of budget compliance or units of work performed. The public demands accountability for results and wants assurance that their highway tax dollars are being invested wisely. Work is already under way in Arizona, Colorado, Florida, Minnesota, and

Washington to develop performance measures for maintenance. In the next millennium, the new paradigm for maintenance management must incorporate performance management and customer service at all organizational levels. Performance management elements should include

- Obtaining customer input on maintenance program objectives, levels of service, and investment options;
- Incorporating life-cycle cost analysis into maintenance investment strategies;
- Developing performance-based budgets and programs that are geared toward achieving specific levels of services and outcomes;
- Infusing customer-oriented decision making in the day-to-day assignment of maintenance resources;
- Measuring maintenance program outcomes in nontechnical terms, so results can be clearly communicated to the public, budget analysts, and legislators; and
- Integrating information systems to achieve consistent, nonduplicated stewardship of asset data across the enterprise.

Instilling a new culture that is focused on customer service will be essential. Maintenance professionals will need effective management skills that balance technical, business, and interpersonal relations.

Developing Effective Public and Private Partnerships and Contracting Procedures

As maintenance contracting continues to grow, maintenance managers must find innovative ways of contracting and creating public and private partnerships. The highway industry is moving toward performance specifications for construction. Virginia and Florida are implementing similar performance specifications for maintenance. Understandably, this new business approach will cause uncertainty in the contracting industry. States must work with contractors to develop specifications and contracting methods that will benefit the public. The methods and contracting procedures may differ from state to state. By involving the local contracting industry, each state will find practical, cost-effective approaches to maintenance contracting.

Maintenance contracting does not lend itself to traditional construction contracting methods. Plans and specifications for maintenance functions cannot always be prescribed or developed by using the construction model. Maintenance must be responsive to daily conditions and public needs, which are difficult to express in contractual language. Low-bid maintenance contracting may have long-term detrimental effects on responsiveness, as contractors are forced to bid low and then strictly adhere to broadly worded specifications. Maintenance managers will need to evaluate their objectives for contracting, then carefully structure the programs so that contracting will achieve quality, responsiveness, and cost-effectiveness.

Breaking Down Institutional Barriers

Because maintenance and operations encompass such a diverse set of activities, responsibilities usually are dispersed throughout a highway organization. The responsibility for pavement management systems, for example, may be in any or all of the maintenance, planning, design, or materials units. The organizational structure of a specific highway

department cannot be predetermined or universally prescribed. The most appropriate structure for a given situation will depend on many factors, which include culture, operating and political environment, and staff competency. However, as maintenance more and more becomes the focus of highway agencies, top executives must take steps to ensure that organizational barriers do not negatively impact the agency's ability to deliver a high-performance maintenance program.

SUMMARY

The character of maintenance is changing rapidly as we approach the 21st century, and the pace of change probably will accelerate in the future. Except for incremental progress in equipment and materials, the first 60 years of highway maintenance changed little. Then, in the mid-1970s, technology began to advance, and it continues to do so very quickly. Today, the changes under way involve business attitudes and basic cultural values of the organization. Overall, change has been beneficial. Maintenance organizations are more professional, more productive, and provide higher quality service than ever before. The results are safer highways and more cost-effective maintenance.

We cannot know for sure what maintenance will be like in 20 years. We can only learn from the past and be aware of trends that are developing today. One thing is certain: Maintenance will be very different. To continue to be successful stewards of our customers' tax dollars, the maintenance community must anticipate and prepare for the future. We suggest five strategic initiatives:

- With citizens and legislators, increase awareness about the importance of maintenance in preserving a safe and efficient transportation system.
- Within the maintenance community, promote a culture of continuous improvement with a view that technology, business practices, and management techniques should change continually for the benefit of customers.
- Continue to undertake basic research in maintenance management approaches, such as TRB's current effort under NCHRP Project 20-24(11).
- Accelerate technical research in maintenance methods, equipment, materials, diagnostic procedures, and asset performance to harness technology capacity and implement the most efficient maintenance practices possible.
- Work toward national standards for professionalism and competency to raise the education, training, pay, and recognition of maintenance professionals in an effort to provide the skilled work force that will be needed in the next century.

REFERENCES

1. Markow, M. J., F. D. Harrison, P. D. Thompson, E. A. Harper, W. A. Hyman, R. M. Alfelor, W. G. Mortenson, and T. M. Alexander. *NCHRP Report 363: Role of Highway Maintenance in Integrated Management Systems*. TRB, National Research Council, Washington, D.C., 1994, 147 pp.
2. Hyman, W. A., and D. Vary. *NCHRP Synthesis of Highway Practice 272: Best Management Practices for Environmental Issues Related to Highway and Street Maintenance*. TRB, National Research Council, Washington, D.C., 1999.