5.0 MAINTENANCE RESEARCH AND DEVELOPMENT

5.1 ADMINISTRATION

Research of interest and benefit to the maintenance engineer and maintenance manager can be conducted through many mechanisms. More important than the mechanism used to administer the research is that the research be proposed and funded. In any case, the role of maintenance must continue to grow in transportation research. Almost all research in structures, materials, design, operations, and communications technology directly affects maintenance if the research produces data that can be implemented. Consequently, there is a self-interest on the part of the maintenance community to be involved in transportation research; there is also a professional and societal responsibility to be involved, to guide research expenditures into avenues of inquiry that will make a lasting life-cycle cost improvement in the transportation system.

The first and most obvious step in advancing maintenance research is for maintenance engineers and maintenance managers to encourage field personnel to communicate their concerns about methods, materials, and processes that do not "work right" to their supervisors and to other people in their own organization, generating ideas that might be appropriate for study.

Maintenance engineers and managers should interact with persons who manage and program the local research fund in your organization to promote maintenance projects that address issues, problems, or ideas from your maintenance personnel. In cases where the research idea might interest agencies in adjacent states, a joint effort can be arranged. This joint effort can be direct or it can be administered through your agency as a "pooled fund" project. One example of such a multistate effort is the advanced concept maintenance vehicle that the Iowa DOT and the Minnesota DOT are jointly designing.

The Minnesota DOT brings maintenance research needs from field personnel into a research program funded with a small fraction of the total maintenance budget and managed by the maintenance division. Ideas are forwarded from field-level personnel, evaluated and refined, and submitted for prioritization with respect to the funds available. Then the projects that can be pursued each year are initiated. (The program is known as the Statewide Maintenance Operations Research Program [1].) Field forces that have participated in the process are kept informed of the progress of their ideas and any projects that arise from the process. This innovative approach to creating a modest in-house research program that focuses on maintenance needs pays dividends in several ways: (1) projects that fulfill a research and development need to improve maintenance but would not ordinarily be competitive for research funds in a large-scale program get initiated; (2) maintenance personnel who have a keen intuitive sense about what needs to be done but ordinarily never get to participate in the research and development process become active participants; (3) field personnel who actually implement the results of research efforts are stimulated to be more observant and more analytical about potential ways to improve methods, materials, and equipment because they see the direct application of research results in which they or their colleagues were active participants.

If the idea, issue, or problem is regional or national in scope, maintenance engineers and managers should inquire within their own agency how an idea gets submitted to the AASHTO review process for consideration as an annual NCHRP effort. Whenever any idea, or even part of one, from your maintenance organization becomes an NCHRP project, this should be communicated to all personnel, and a communication liaison should be established to keep your organization informed about progress on and the results of the research.

Finally, agencies need to encourage and to assist maintenance engineers and maintenance managers to serve on technical and administrative committees of AASHTO and the Transportation Research Board, bringing a maintenance community perspective to research dissemination and evaluation as well as increasing the interest of a broad range of researchers in conducting maintenance research.

5.1.1 Managing Contract Research

Some agencies have sufficient staff and funding resources to permit them to conduct in-house research. The previous section alluded to the Minnesota DOT program in maintenance-directed research. However, most agencies must use periodic "lumps" of money to contract the services of universities or consultants to conduct research directed toward their specific maintenance needs. *NCHRP Synthesis 231* [2] provides guidance for maintenance engineers and managers entering into this process for the first time. Chapters in this document discuss the following topics:

1. Selecting contract programs.
2. Contractor solicitation and selection.
3. Negotiating a contract.
4. Monitoring a contract.
5. Implementation of contract results.

Implementation is often the most neglected of these topics in successfully managing research contracts. People and organizations conducting the actual research are often uninterested in finding ways to actually apply the results of their research. However, if an agency specifies elements covering implementation in the final contract, researchers will be compelled to examine their work for practical applications while research is underway.

Historically, maintenance engineers and managers have been reluctant to participate in research programs, believing that their maintenance problems were not sufficient to warrant such "high-level" attention. *NCHRP Synthesis 280* [3] offers some worthwhile advice for anyone pondering whether the maintenance operation of an agency should pursue a research agenda. This document lists seven keys to building and sustaining a robust research program.

1. ***Found It on Trust:*** Determine who in the organization handles the administration of research, and then open lines of communication about maintenance research needs that encourage trust and honesty regarding the flow of information.
2. ***Market Boldly:*** Marketing is encouraged along a broad front. Maintenance organizations must use every available means of communication to solicit interest in their problems from private industry, university faculties, and professional associations.
3. ***Root It in Economics:*** Track research project results after they are applied to promote awareness of every cost-saving measure, productivity increase, and safety enhancement, etc.. that can be attributed to maintenance research projects. Let people know when research pays off in positive outcomes, especially those with economic upsides.
4. ***Make Deals Unabashedly:*** Actively seek ways to share costs with interested parties and leverage your own agency's contribution of maintenance funds. Although it is always possible that enlisting financial partners in a research project will diminish your own

organization's control over the project, additional funds may more than compensate by giving the project a wider or deeper scope in addressing the research problem.

5. ***Insist on Accountability:*** Funded research programs and activities must be consistent with an agency's needs and objectives. Funds must also be conscientiously accounted for in ways that assure all parties that monies are spent on activities in accordance with proposal and contract requirements.

A continuing concern of research programs in an era of heightened expectations for asset management is the need to define and measure changes in program performance. *NCHRP Synthesis 300* [4] found that organizations conducting performance assessment in 2001 were, for the most part, the same organizations doing so in 1996, suggesting little change in adoption of the practice to measure performance. For the most part, the conclusions of the NCHRP Synthesis provide only general guidance for the management of research programs, or maintenance research programs in particular. Still, these conclusions are worth noting here, namely that:

1. Performance measures should be tied to the organization's strategic goals.
2. Performance measures should be expressed in terms that are easily understood by upper-level management of the organization.
3. Measures should be relatively simple.
4. Any data collected for performance measures should be obtained in a cost-effective manner (i.e., only as much data as needed to complete the task).
5. Peer assessment can be useful, especially for qualitative measures.
6. The human resource development aspect of a program is an important measure.
7. Performance measures should assess the program-level benefits of research.
8. For tracking purposes, and in order to determine performance values, program-level benefits should be quantitatively measurable over time.
9. Some measure of post-project performance is needed to document implementation of the research, if any.
10. Peer reviews and exchanges have historically offered useful assessment of performance for professional activities.
11. Library activities (i.e., archival and dissemination functions) need to be measured for performance, as these are typically considered important by customers of the research unit.

5.2 METHODS

Maintenance engineers are always looking for better ways of doing things; it is just the nature of their personality and the work of their people. In Minnesota, the Office of the Legislative Auditor published a report on their administrative examination of snow and ice control across all levels of agencies in the state. This report compiles the best practices from a public administration view [5]. This approach is not normally the type of review associated with research, but it does present a fresh viewpoint that can stimulate thinking about what is good and what might be studied to make maintenance methods better.

The fundamental questions to be asked when examining any maintenance method with respect to assessing the need to conduct research into a particular maintenance method include the following:

- Can it be done with less equipment?
- Can it be done with fewer workers?
- Can it be done with less materials?
- Can it be done with less interference to traffic through the work zone?
- Can it contribute to increased productivity?
- Can it increase the quality of the result of the maintenance activity?
- Can it make the work operation safer for workers, the traveling public, or both?
- Can it reduce the cost of conducting the maintenance activity?

Some selected maintenance management issues appropriate for study to improve the context within which maintenance engineers and managers operate include the following:

- Methods of planning and scheduling maintenance
- Strategic planning for maintenance
- The maintenance role in asset management
- The maintenance role in pavement preservation
- The maintenance role in bridge preservation
- Effective use of contracts to supplement state forces
- How contract maintenance is being used around the world

Obviously, no single research effort to improve a maintenance method can be expected to generate improvements in all areas. Maintenance engineering judgment has to determine the suitability of any method change that has been studied and analyzed. NCHRP Report 422 (*Maintenance QA Program Implementation Manual*) [6] is the result of a maintenance research project whose implementation resulted in many agencies modifying the way they do business. This may not be what is commonly thought of as a "method," in which the usual expectation is to find a new test procedure, but it nonetheless creates a new method for maintenance operations.

5.3 MATERIALS

Maintenance costs and the performance of maintenance activities often heavily depend on the character and quality of the materials used in the various processes. There is a growing understanding that if materials were available with improved characteristics, such as durability and flexibility, a lower life-cycle cost to maintenance could be achieved even if these materials were more costly than the traditional materials used. Any agency interested in evaluating improved materials should consider interacting with the materials science and engineering profession to investigate which "designer materials" may meet the specific characteristics needed to increase the quality of materials performance in maintenance activities. A necessary first step in this direction is for maintenance personnel to study and assess what characteristics are necessary for the material to make a major difference in the performance of a maintenance activity.

While some may believe that it is necessary to discover some heretofore unknown material in order to meet the demands of modern maintenance, sometimes all that is needed is to adapt readily available existing materials to a given maintenance application. For example, lignosulfonates, a pulp mill byproduct (essentially "tree sap)," has been used in New York as a binder for shoulder surfacing material [7]. It is reportedly cheaper—not to mention more environmentally friendly—than traditional binders.

Before pursuing its own research study, any maintenance organization interested in evaluating new or "exotic" materials for possible application to maintenance processes is advised to check out the Highway Innovation Technology Evaluation Center on the World Wide Web (www.asce.org, with successive links to CERF and HITEC) to determine if a product has already undergone standard evaluation.

Maintenance engineers and managers need to bring their research problems to the attention of their agency's representatives to the AASHTO Subcommittee on Maintenance (SOM) of the AASHTO Standing Committee on Highways (SCOH) for possible inclusion in the NCHRP project agenda. When any issue of interest to your maintenance organization makes it onto the list of potential NCHRP projects, engineers and managers should request support for that issue from AASHTO's Research Advisory Committee (RAC) and Standing Committee on Research (SCOR), which selects approved NCHRP projects. For example, NCHRP Report 503 is a project on innovative materials that may be of interest to maintenance engineers and managers [8]. This project examined the ways that fiber-reinforced polymer composites can be applied to highways. Their potential long-term durability makes them a family of materials with significant implications for roads and bridge maintenance applications.

5.4 HUMAN RESOURCES AND PERSONNEL

Maintenance management is an activity intended to optimize the allocation of resources (i.e., personnel, equipment, materials) for the total maintenance program to provide the best service within the budgetary constraints in effect at the time. The search for research and innovation that will improve the process requires study of equipment and materials. Too often, innovation and development of new approaches to maintenance human resources and personnel is largely an attempt to borrow private sector profit-oriented organization innovation. While there is much merit to examining what has been done in private industry and evaluating the applicability of private sector concepts to the maintenance agency, public agencies and their constituents might be better served if pilot research projects were a part of all technology transfer initiatives from private sector personnel research to maintenance agencies.

Many issues and problems concerning maintenance agencies that are either insufficiently defined or more in the nature of "what is everyone else doing about this?" call for a "synthesis

of practice" rather than a full-scale research project. *NCHRP Synthesis 323* [9] offers one example of such an issue, in which the problem of retaining a qualified transportation workforce was addressed by an extensive study of the recruitment and retention efforts of individual state DOTs. By reading this document and examining the study team's findings, a maintenance organization can compare its own efforts to build and maintain an appropriate work force to the efforts of other agencies. The document can be mined for approaches already tried by others that may offer potential for improving your own agency—in short, a way to profit from the experience of others.

Conversely, you may pursue a process similar to that for getting a state or NCHRP research project initiated if your maintenance organization has an issue or problem for which you think a synthesis of practice might be an appropriate response. Another path to submitting a synthesis for approval that maintenance engineers and managers might consider is to pursue some form of activity in at least one of the various Transportation Research Board committees dealing with maintenance. If travel funds or time off to attend the annual meeting of a TRB committee is difficult to obtain, contact the committee chair of the maintenance topic of interest to you and ask to be designated a "friend of the committee." Friend-of-the-committee status gives maintenance engineers and managers access to committee communications and actions, which may include proposing topics for NCHRP synthesis studies. (For further information on TRB committees in the maintenance area, consult the Web site, www.trb.org, or contact Mr. Frank N. Lisle, PE, TRB Engineer of Maintenance.)

5.5 EQUIPMENT

As it should be, equipment research is active and ongoing among both manufacturers (and suppliers) and agencies. Innovation in equipment systems is probably the easiest area to evaluate and implement. Seeking innovation in equipment systems is just beginning to include some of the following areas of study, all of which may yield significant improvements in the performance of maintenance:

- Ergonomics or Human Factors: Efforts to improve the person-machine interface in maintenance equipment have the potential to increase safety, productivity, and employee satisfaction in the same ways as has been achieved in the manufacturing industry.
- Robotics: Study of the applicability of robotic methods, machine vision, and computer-controlled processes to maintenance equipment is an intriguing field of research. It is easy to see the potential uses to improve safety by applying robotics to replace drivers of truck-mounted attenuators in work zones and to replace operators of excavation equipment at earth slides and snow avalanche sites. However, much worker skill and judgment is still necessary to use equipment for a maintenance process in such a way as to achieve a high-quality final product. Using robotics for maintenance may depend upon the ability of computer engineers and computer scientists to apply expert systems to maintenance processes. Highway maintenance and support is one area that has been identified for potential application of knowledge-based expert systems [10].

The NCHRP project process is an excellent avenue by which equipment innovations of interest to maintenance engineers and managers can be developed, tested, and evaluated. NCHRP Reports 397A and 397B are examples of this process in action [11,12]. Both documents report efforts to create devices by which the scour under bridge supports can be remotely monitored in order to determine when remedial maintenance is needed to sustain the integrity of a bridge foundation. A related project involving the "soft side" of equipment is documented in NCHRP Report 426 [13], which explains the effort to create an expert system computer program for evaluating scour conditions at bridges.

Maintenance engineers and maintenance managers should always monitor the progress of new NCHRP projects of interest to them. This is easily done by going to the TRB web site (www.trb.org) and clicking on the link to the NCHRP Program, then link to All Projects, then click on a project area that may be of interest (such as Snow and Ice Control, Maintenance of Way and Structures, Equipment, or Safety). As of the time this manual revision is being compiled, three new NCHRP projects may be of interest:

- NCHRP 13-02: Guidelines for Selection and Application of Warning Lights on Roadway-Operations Equipment
- NCHRP 6-15: Testing and Calibration Methods for RWIS Sensors
- NCHRP 6-16: Guidelines for the Selection of Snow and Ice Control Materials to Mitigate Environmental Impacts

5.6 INTERNATIONAL ASPECTS AND TECHNOLOGY TRANSFER

Through multinational corporations, global business and commerce is increasing. Higher education is also increasingly requiring students to be aware of global connections in their field of study. While roadway and bridge systems differ on other continents, while labor and safety regulations in Europe and Asia differ from those in North America, and while the availability of materials on other continents may vary considerably from those available in North America, all nations and continents share a common purpose and intent in terms of roadway and bridge maintenance. Much can be learned from organizations outside of North America, and their practices need to be evaluated for possible technology transfer. Two documented efforts at observing practices outside North America, one in winter maintenance [14] and one in bridges [15], have already stimulated significant research and development activity. The Minnesota DOT has developed a formal personnel and information exchange with Scandinavian countries for winter maintenance.

A large number of scanning tours have been completed under the auspices of the Office of International Programs, Federal Highway Administration, U.S. Department of Transportation. Because they offer an overview of practices in other countries, many of these tours will be of interest to maintenance engineers and managers for their applicability to U.S. maintenance organizations. Although not all are reported as NCHRP documents, any scanning tour report can be accessed at the Web site (www.international.fhwa.dot.gov) for downloading or to order hard copies from the FHWA.

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