283

National Cooperative Highway Research Program

NCHRP Synthesis 283

Fleet Management and Selection Systems for Highway Maintenance Equipment

A Synthesis of Highway Practice

Transportation Research Board
National Research Council

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DAVID H. FLUHARTY

Durham, New Hampshire

Topic Panel

JOHN M. BURNS, JR., *North Carolina Department of Transportation*
GLENN HAGLER, *Texas Department of Transportation*
RICHARD HUNTER, *Illinois Department of Transportation*
FRANK N. LISLE, *Transportation Research Board*
DOUG NIELSEN, *Arkansas State Highway and Transportation Department*
JAMES B. SORENSON, *Federal Highway Administration*
WALTER J. TENNANT, JR., *Cortland, New York, County Highway Department*
CLAY WILCOX, *Washington State Department of Transportation*

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PREFACE

A vast storehouse of information exists on nearly every subject of concern to highway administrators and engineers. Much of this information has resulted from both research and the successful application of solutions to the problems faced by practitioners in their daily work. Because previously there has been no systematic means for compiling such useful information and making it available to the entire community, the American Association of State Highway and Transportation Officials has, through the mechanism of the National Cooperative Highway Research Program, authorized the Transportation Research Board to undertake a continuing project to search out and synthesize useful knowledge from all available sources and to prepare documented reports on current practices in the subject areas of concern.

This synthesis series reports on various practices, making specific recommendations where appropriate but without the detailed directions usually found in handbooks or design manuals. Nonetheless, these documents can serve similar purposes, for each is a compendium of the best knowledge available on those measures found to be the most successful in resolving specific problems. The extent to which these reports are useful will be tempered by the user's knowledge and experience in the particular problem area.

FOREWORD

By Staff
Transportation Research Board

This synthesis report will be of interest to Department of Transportation (DOT) administrators, supervisors, equipment, and Management Information Systems (MIS)/Information Technology (IT) managers and staff, as well as to engineering and MIS/IT consultants that work for them. It reviews the state of the practice, updating an earlier effort. This synthesis addresses highway fleet maintenance issues in management, equipment, staffing, and technology. It identifies the trend toward more sophisticated and complex Management Information Systems and reports on DOT efforts to develop more systematic approaches to measure equipment effectiveness and to incorporate this quantitative technology, successfully, into daily operations.

Administrators, engineers, and researchers are continually faced with highway problems on which much information exists, either in the form of reports or in terms of undocumented experience and practice. Unfortunately, this information often is scattered and unevaluated and, as a consequence, in seeking solutions, full information on what has been learned about a problem frequently is not assembled. Costly research findings may go unused, valuable experience may be overlooked, and full consideration may not be given to available practices for solving or alleviating the problem. In an effort to correct this situation, a continuing NCHRP project has the objective of reporting on common highway problems and synthesizing available information. The synthesis reports from this endeavor constitute an NCHRP publication series in which various forms of relevant information are assembled into single, concise documents pertaining to specific highway problems or sets of closely related problems.

This report of the Transportation Research Board profiles specific state agency experience in hiring and retaining mechanics, staffing levels, management system complexity, and technologies. Sample shop work load and productivity reports from the Montana Department of Transportation are reproduced in this synthesis.

To develop this synthesis in a comprehensive manner and to ensure inclusion of significant knowledge, the available information was assembled from numerous sources, including a large number of state highway and transportation departments. A topic panel of experts in the subject area was established to guide the author's research in organizing and evaluating the collected data, and to review the final synthesis report.

This synthesis is an immediately useful document that records the practices that were acceptable within the limitations of the knowledge available at the time of its preparation. As the processes of advancement continue, new knowledge can be expected to be added to that now at hand.

CONTENTS

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This study was managed by Donna L. Vlasak, Senior Program Officer, who worked with the consultant, the Topic Panel, and the Project 20-5 Committee in the development and review of the report. Assistance in project scope development was provided by Stephen F. Maher, P.E., Manager, Synthesis Studies. Don Tippman was responsible for editing and production. Cheryl Keith assisted in meeting logistics and distribution of the questionnaire and draft reports.

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Information on current practice was provided by many highway and transportation agencies. Their cooperation and assistance are appreciated.

FLEET MANAGEMENT AND SELECTION SYSTEMS FOR HIGHWAY MAINTENANCE EQUIPMENT

SUMMARY

Fleet management of highway maintenance equipment combines essential and unique functions within state and commonwealth Departments of Transportation (DOTs). Its effectiveness depends on the accomplishment of a unique set of management practices.

The Transportation Research Board previously studied these processes, producing in 1978, *NCHRP Synthesis of Highway Practice 52: Maintenance and Selection Systems for Highway Maintenance Equipment*. The scope of this study updates the items and issues covered in NCHRP Synthesis 52, adding contemporary management, equipment, staffing, and technology concerns. This report draws on information from a literature review, a survey of state transportation equipment managers, and interviews with selected managers.

The results of this report represent practices in effect in May and June 1998. In nearly every management and selection area examined, more transportation agencies apply management practices than reported doing so 2 decades ago.

Many equipment managers face a shortage of skilled staff. There are fewer skilled mechanics than needed in both the construction and transportation industries. Agencies also face government-mandated limits on the number of mechanic positions funded and/or adequate wages and benefits to attract the mechanics they need. Equipment managers have increasingly focused on contracting out more of their repairs.

Where the number of mechanics is adequate, or nearly so, cost considerations dictate staffing level management. Management systems used to determine staffing levels range from simple to very complex. The trend in management systems is toward the increasingly complex, especially in those DOTs with a wide assortment of equipment types.

In general, agencies have improved their preventive maintenance programs over the past 2 decades. All but one respondent reported having a preventive maintenance program. Inclusion of three elements necessary for an effective preventive maintenance program—frequencies, levels, and tasks—has increased significantly over the past 20 years.

The study results show that DOTs have become more efficient in parts management. They have reduced by one-third parts chasing, that is, finding a vendor with a needed part. Fewer than 10 percent report regularly experiencing stock outages. Equipment managers who still have significant levels of stock outages tend to remain constrained by minimum usage rates and often by cost accounting/record-keeping rules.

DOTs are, in general, more successful in replacing equipment than they were 20 years ago. This is probably due to highway maintenance management participation, because nearly three-fourths of the respondents reported determining equipment needs by roundtable discussion. Fewer respondents apply quantitative analysis to determine equipment needs than did so in 1978.

Similarly, for equipment selection, more than three-fifths of the responding DOTs rely on discussions with their "customers"; that is, managers of other DOT divisions. They continue to be restricted by one or more of the following barriers to using formal approaches; reliable cost/performance data invariably not being available, a shortage of staff, and no acceptable evaluation formula.

Currently, far fewer agencies modify equipment to perform an added or different function than did so in 1978. These agencies rent or lease specialty high-cost equipment and regular equipment to meet seasonal work-load peaks. About three times as many agencies lease regular equipment full-time.

Nearly three-fourths of the respondents indicated that their Management Information Systems (MISs) promoted effective operating decisions. Only about 1 in 14 indicated that it inhibited decisions. Much of the satisfaction is due to many agencies having developed and/or purchased systems geared to equipment management needs. Moreover, equipment divisions have assumed responsibility for MIS operations in more than one-half of the agencies. This probably accounts for the greatly increased use of two common measures of equipment maintenance effectiveness: road call travel and downtime.

Fewer than one-half of the survey respondents use time standards. DOTs, however, are increasingly applying the concept, including using average repair times for types of repairs and equipment types as management indicators. This is occurring as part of a trend toward more sophisticated and complex MISs. Increasingly, agencies are developing a systematic approach to measuring equipment maintenance effectiveness and incorporating it into their respective MISs.

Equipment managers are increasing the use of workstation computers (WSCs) within their divisions. Almost two-thirds of the responding agencies have WSCs as the primary computers for their equipment management systems. Many divisions have networked WSCs and involved shop personnel. At the time of this study, fewer than one-half of the equipment managers had access to the Internet. This is certain to increase as access and use become easier, enabling equipment managers to communicate with each other on the Internet and to access information on web sites. The implementation of WSCs has also facilitated the use of bar code technology for parts management for about one-fourth of the respondents.

Reducing government-mandated constraints is usually beyond DOT management control. It is noteworthy that where equipment managers have authority over certain functions those functions have shown the greatest improvement over the past 2 decades. Some of that improvement has also been due to reduced constraints.

The trend toward more quantitative management, with more sophisticated MISs, is an area worthy of increased management attention. Not only is the equipment managers' involvement necessary in MIS development and operation, but MIS support staff must consist of skilled analysts with an appreciation of the unique elements of equipment maintenance management and selection.

The resultant conclusions of this report identify the need for improved fleet management within a significant number of DOT fleets.

Constraints have been reduced since the previous equipment management synthesis, but inefficient practices remain. Such practices might be countered with solid documentation by means of the use of MISs that are designed for operational decision support rather than to follow a strict fiscal model.

It appears that there is a lack of computer skills and/or appreciation for the MIS asset among many of these fleets. Such a scarcity may promote business decisions for nonbusiness reasons and bring about a failure to utilize key indicators of the health of associated fleet management

This may provide a challenge and present a worthwhile theme for future study—the documented need for fleet maintenance equipment advocacy.

CHAPTER ONE

INTRODUCTION

BACKGROUND

Fleet maintenance and selection are essential and unique operations within state and commonwealth Departments of Transportation (DOTs). The effectiveness of their management directly impacts an agency's mission. Equipment managers' customers, that is, managers in other agency divisions, need equipment at a specific place during a specific period to perform specific functions. Equipment in the shop or that breaks down on the job not only effects project cost, but also inconveniences, and at time endangers, motorists and their passengers.

In the mid-1970s, the Transportation Research Board (TRB) Committee on Maintenance Equipment (A3C08) recommended that a synthesis be prepared to collect the most successful equipment management practices from around the country. The results were published in 1978 as *NCHRP Synthesis of Highway Practice 52: Management and Selection Systems for Highway Maintenance Equipment* (*1*). That report proved to be a valuable resource as agencies increasingly formalized equipment management and operations and automated information processing. Because the information had become dated due to changes in practice and advancements in information technology (IT), an update was requested.

The practice for effective equipment management has been well established for many years. The basic practice that was effective when current senior transportation managers began their careers remains effective today. The equipment, however, has changed. Its technical sophistication has increased greatly over the past several decades, and continues to increase. These technical changes are among several that effect a managers' ability to apply the time-tested equipment management process.

Impacts on the Equipment Management Process

Over the past several decades, private companies and public agencies have come to view equipment as a replacement for labor. Operations managers have increasingly relied on equipment to accomplish construction and maintenance projects of all types and sizes. This has not only increased the need for dependable equipment, it has also resulted in ever more technically sophisticated equipment.

Equipment managers must devote more and more time to keeping abreast of emerging equipment technologies. Determining causes of equipment failure, and repairing them, requires highly skilled craftspeople, effective supervisors, and specialized diagnostic and mechanics' tools. Talented mechanics and supervisors are often hard to find and retain. Government wages are frequently less than those offered by private construction and industrial companies. In some locations, the benefit packages of private firms have become as good, if not better, than those offered by transportation departments. Also, supervisors and mechanics need more training than in the past.

In addition, parts inventories have expanded. As equipment becomes increasingly sophisticated, so do the tools necessary to maintain and repair them. Equipment is increasingly more expensive to purchase as well as to maintain. Although equipment costs can amount to from one-fourth to one-third of the total operating budget, its funding is often perceived to be of secondary importance.

This pattern also applies to equipment management in local governments and in private construction and industrial companies. Public and private equipment managers support divisions responsible for their agency's or company's primary functions. They too are responsible for maintaining increasingly sophisticated equipment, and often with inadequate funding, personnel, and tools to fulfill that responsibility.

Both public and private sector equipment managers are subject to restrictions imposed by government regulations. Safety and environmental regulations, for example, have proliferated over the past 2 decades. Public sector equipment managers, as part of a governmental body, are more affected by these fund allocations, mandates, and policies. Legislatures authorize funds for equipment purchases and operating expenses, usually in amounts inadequate for complete mission fulfillment. Many legislatures impose personnel ceilings and/or reductions. Executive branches tend to establish personnel wages and benefits, often below the levels available to maintenance staff in the private sector.

Management Systems

Modern management systems, using increasingly powerful computers, can store and process huge amounts of data. These systems are effective to the degree that they provide information for effective management decisions. As noted previously, equipment management has a well-established decision-making process. The factors that equipment managers need to consider are also well known within their profession.

Financial management factors dominated early management systems. Equipment management factors were seldom emphasized. That situation continues in some contemporary DOTs. A few have developed specific systems for equipment management. Others have incorporated equipment management factors in their existing interdepartmental management systems. More development is underway.

In general, equipment management systems share a characteristic common among DOT management systems. In *NCHRP Synthesis 238,* this characteristic is described as follows:

> State transportation departments have traditionally been data rich agencies, with huge data files updating inventories of facilities, equipment, and materials, and other databases recording work accomplished in far-flung highway maintenance programs and large volumes of transactions in other programs. In addition, other files contain data on existing travel patterns, volumes of usage, and accident statistics as well as information on projects pending and completed. But, all this does not necessarily mean that DOTs were using data to measure the performance of their programs, and actual transportation system, beyond project level evaluations *(2,* p. 10).

Nor do such data rich systems ensure effective and efficient equipment management. Some agency equipment managers are developing new systems or modify existing ones that better support their decision-making needs.

These systems and other management decision-making tools and processes are the subject of this synthesis. The research provides a picture at one point in time of fleet maintenance management and selection practices. Its purpose is to help equipment managers and their superiors, through assessment of this picture, to evaluate their own practices.

SYNTHESIS SCOPE AND OBJECTIVES

The scope of this synthesis includes management, equipment, staffing, and technology issues, and highlights the following concerns:

- Constraints of organizational structure,
- Purchasing policy and practice,
- The importance of an effective program,
- Obtaining management support,
- Communications,
- Outsourcing operations and privatization,
- Downsizing,
- Use of rented and leased equipment,
- Equipment purchasing,
- Parts procurement and inventory,
- Preventive maintenance,
- Level of maintenance standards,
- Performance indicators,
- Recruiting, training, and keeping qualified personnel,
- Staffing levels,
- Use of personal computers (PCs), and
- Systems integration.

The issues and findings are reported in two ways. The first is a description of the prevailing patterns of equipment management and selection practices across DOTs. The second describes practices particular to individual transportation agencies. Some illustrate or clarify a pattern, whereas others describe a practice that merits consideration.

APPROACH AND METHODOLOGY

This synthesis draws on information derived from a literature review, in addition to a survey of transportation equipment managers and interviews with selected managers. Much of the literature review, developed from a search of library databases, preceded preparation of the survey questionnaire. This review provided the references cited in the text and items for the survey.

Through the survey questionnaire (reproduced in Appendix A) information was gathered about equipment management and selection practices in various transportation agencies. In April 1998, the TRB distributed the survey to all 50 states, Puerto Rico, and the District of Columbia. Responses were received from 45 of the 52 agencies surveyed (44 states and Puerto Rico; see Appendix B).

Data analysis identified current patterns of equipment maintenance and selection practices. Interviews provided case studies to illustrate specific examples of successful practices and of the concerns of equipment managers.

SYNTHESIS ORGANIZATION

Chapter 2 describes equipment management, with emphasis on mechanic hiring and retention, staffing level determination, preventive maintenance, and parts purchasing and inventory. Chapter 3 describes the ways transportation agencies determine equipment replacement needs, their equipment selection systems, and equipment replacement alternatives. Chapter 4 describes the use of Management Information Systems (MISs), PCs, and related technologies. Chapter 5 presents conclusions based on synthesis study findings.

CHAPTER TWO

EQUIPMENT MAINTENANCE MANAGEMENT

INTRODUCTION

A mechanics' skill and productivity are the primary determinants of maintenance system effectiveness and efficiency. Hiring and retaining skilled and productive mechanics is, therefore, essential for all agencies and companies engaged in equipment management.

Hiring and retention become more difficult during periods of low unemployment. Nearly all states have had low unemployment since the mid-1990s. Both public and private equipment managers have had difficulty finding and retaining skilled mechanics. Private sector organizations can increase pay and benefits to attract and keep skilled craftspeople, but transportation agencies seldom have these options. Even though legislatures and executive branches expect their transportation agencies to operate like private sector businesses, they place restrictions on management in setting wages and benefits. The effects on staffing levels and some innovative solutions are described in this chapter.

A shortage of skilled mechanics makes effective management even more important than at those times when mechanics can be easily hired and retained. The central components of effective equipment management are preventive maintenance and parts availability. Patterns of transportation agency practices are described here using separate sections for each component.

MECHANIC STAFFING

Hiring Mechanics

In 1996, the Associated Equipment Distributors (AED) commissioned a survey of its members in order to examine the availability of equipment service technicians. Reviewing responses from 256 heavy equipment firms, they found a shortfall of between 700 and 1,000 specialists and technicians. The researchers forecast that the industry-wide shortfall would rise to nearly 6,000 by the year 2000. According to AED Foundation Executive Director Patricia A. Jordan, "The need is so great that mechanics can virtually determine what area of the U.S. they would like to live in and find good employment opportunities that provide high pay and security" (*3*).

In 1997, the FMI Corporation conducted a national survey of construction companies. It found that 36 percent of all respondents ranked the shortage of skilled personnel as their most pressing concern. FMI concluded that finding adequate skilled labor was the greatest challenge facing the construction industry.

This shortage is a recent development. FMI found little concern in a 1992 survey when a recession had produced downsizing, layoffs, and a surplus of skilled labor. FMI attributed the more recent shortage of workers to the surging economy and low unemployment. They also anticipated that the shortage would only intensify as skilled craftspeople retired and fewer qualified individuals entered the job market (*4*).

These shortages can have an even greater impact on DOTs. Private employers have greater flexibility to increase pay and benefits to attract skilled people. Government-established wage rates and benefits therefore can limit an agency's ability to compete for mechanics. Almost 75 percent of the respondents reported that they are less successful than they would like to be in finding and hiring qualified mechanics. In contrast, the Ohio and Washington State DOTs are very successful in finding mechanics and also very successful in keeping them.

Ohio

- The Ohio DOT (ODOT) has hired fewer mechanics during the 1990s because of state government-mandated personnel cuts. Nearly all reductions in the staffing level of mechanics have been by attrition.
- ODOT has replaced many mechanics by promoting mechanic assistants from within the agency.
- When ODOT hires from outside the department, they find that state pay and benefits packages are very attractive relative to the private sector.
- Ohio is a rural state and has a large labor pool of skilled and productive workers.

Washington

- The Washington State DOT (WSDOT) has experience a low turnover in mechanics due, in part, to competitive pay and benefits packages.
- WSDOT has many applicants who are retired military or trade school-trained mechanics.
- In addition, many mechanics begin employment in the equipment division as mechanic assistants. In an informal but apprentice-like program, many assistants,

as they become more skilled, are promoted to mechanic, and then on up through the levels of their craft. By the time they become mechanics, they have invested in the retirement system and have the benefit of several weeks of annual vacation time.

Both ODOT and WSDOT hire mechanic helpers as entry-level positions. After on-the-job training, many of these individuals fill vacant mechanic positions. This hiring from within the organization reduces the need to compete with private companies. In addition, when they hire from outside their organization, each can offer attractive pay and benefits to a pool of skilled mechanics.

DOT equipment managers without such a pool of potential mechanics are in the same situation as many of their private sector counterparts. The AED, in response to this shortage of skilled technicians, has begun working with schools to encourage students to enter the construction equipment industry (*3*).

Retaining Mechanics

Hiring difficulties make retaining employees very important. Retention, however, is problematic for many DOTs; almost two-thirds of whom report difficulty in retaining qualified mechanics.

Attractive benefits become more important than wages to individuals once they are employed. The importance of benefits is significant for both the Alabama and Hawaii DOTs, who report usually being successful at retaining employees.

Alabama

- In general, private companies offer better pay, but the state has a better retirement system.
- The Alabama DOT reports hiring more applicants in their late 30s and early 40s, an age group more concerned with retirement than are younger mechanics.

Hawaii

- State benefits are better than those offered in the private sector.
- Hawaii DOT mechanics can retire after 10 years, at which time they have earned lifetime medical benefits.
- Upon retiring, spouses also receive lifetime medical benefits.
- The Hawaii DOT contributes to a retirement fund, which encourages mechanics to stay beyond the time they are eligible to retire.
- The sick leave and vacation time are rarely matched in the private sector. The union contract enables employees to use this benefit with few restrictions.

Benefits are also more important than wages in Nevada and Vermont. Both of these states reported being only moderately successful finding mechanics, but very successful in keeping them.

Nevada

- Because private companies, especially construction companies, offer mechanics equal or higher wages, the Nevada DOT (NVDOT) has experienced some difficulty in initial hiring.
- When compared with private companies, NVDOT offers comparable pay and better benefits once mechanics are hired.
- In addition to medical and retirement benefits, NVDOT provides high tool and clothing allowances.
- NVDOT has upgraded its facilities. It provides a well-lighted workplace that is cool in the summer and warm in the winter. It has also improved repair tools. Although NVDOT had a low turnover before the new facilities were built, the workplace improvements have probably contributed to increased retention during the recent period of low unemployment.

Vermont

- Mechanics' wages at the Vermont Agency of Transportation (VAOT) are comparable to those of private companies. Benefits packages, however, are better for state employees.
- Medical benefits attract mechanics in their late 20s and early 30s, and retirement benefits attract older workers.

These examples illustrate the importance of wages and benefits in hiring and keeping mechanics. Few DOT equipment managers, however, can increase either. Private garages, on the other hand, can offer more attractive pay and benefits. They must control compensation to compete for work, but competition for skilled craftspeople often requires increasing wages and improving benefits.

Few DOTs are able to control compensation. Local governments usually establish pay scales, retirement and medical plans, retirement eligibility, and sick leave and vacation days. However, equipment managers usually have control over work-related and environmental actions that can improve retention. They can, following the NVDOT example, upgrade facilities and tools, thereby making the DOT a more desirable place to work. In addition, they can ensure that supervisors act toward employees in ways that improve morale and productivity. They can also maximize advancement opportunities.

Related to the hiring and retention of skilled mechanics is determining the number needed, an important issue for many of the respondents. As described here, approaches to determining staffing level vary throughout the DOTs.

Staffing Levels

Mechanic staffing levels depend on maintenance needs. Determining these needs usually involves forecasting future maintenance based on historical information. Agencies vary in the degree of quantitative information used in making their forecasts.

Previously, it was reported that fewer than one-third of the responding agencies had quantitative formulas to determine equipment mechanic needs (*1*, p. 10). Twenty years later more than one-half of the respondents reported determining staffing levels using a formula. Interviews with managers revealed a variation in approaches and factors that influence application success.

The simplest methods occur in agencies with little variation in types of equipment. The North Dakota DOT (NDDOT), for example, has nearly the same types and numbers of equipment throughout its districts. Each district has had three mechanics for many years. The NDDOT headquarters in Bismarck has pool vehicles and five mechanics. Because these levels have proven effective for many years, including during winter months, NDDOT stays with them.

Decentralized Staffing Level Decisions

Decentralized decision making also contributes to relatively simple staffing level determination. The Florida and Mississippi DOTs are among several states that delegate management responsibility to district managers. They also delegate the authority to determine staffing levels. The methods to determine staffing levels, therefore, vary from district to district and do not apply a formal, department-wide system.

Centralized Staffing Level Decisions

Most transportation agencies centralize staffing level determination. The usual approaches are either of two types:

1. Average repair times for equipment types, and
2. Integrated with contract versus in-house repair decisions.

Average Repair Times for Equipment Types The Montana DOT (MDOT) uses ratios based on average repair times for various equipment types. Its management information system connects productivity with workload forecasts. Appendix C contains several report formats that show the data items considered and the analytical elements calculated. Because determining ratios takes considerable effort, they revise the ratios every couple of years.

Several states incorporate history and industry guidelines in their ratios for staffing level determinations. The Maine DOT (MEDOT) derived its current mechanic staffing levels from a large study completed about 5 years ago. The study was based on industry guidelines, which were modified for MEDOT staffing level history, equipment age, nonproductive time, and work for other agencies. They calculated "manpower equivalents," mechanic-hours for various equipment types. Where manpower equivalents were fractions less than half above a whole number, MEDOT shifted maintenance responsibility to a garage with a fraction less than half below.

WSDOT fleet management analysts calculate averages from historical data to determine a simple ratio, and then compare that ratio to industry averages. From that analysis, fleet managers determine staffing levels. WSDOT has not included equipment type because nearly all mechanics work on all sizes of vehicles.

MDOT, MEDOT, and WSDOT have relatively uniform equipment types across their districts. The Missouri DOT (MODOT), on the other hand, purchases heavier equipment for its northern districts because they receive much more snow than do the southern districts. MODOT initially gathered data over several years and developed ratios of average mechanic-hours per equipment type.

Tied to Contract Versus In-House Decisions Another approach is to integrate staffing level determination with contract versus in-house repair decisions. The Colorado DOT (CDOT) contracts nearly all of certain repair types; for example, glass replacement, upholstery, body work, and light vehicle maintenance and repair. For other repairs, CDOT ties staffing to decisions for contract versus in-house repair. It periodically assesses current work backlog, backlog history, repair types, and the capabilities of local garages. It also considers the distance from contractors, many of which are competitive only close to their garages. Analyzing these assessments over time, including seasonal requirements, it then determines optimum staffing levels.

The Virginia DOT (VDOT) workload planning system calculates averages for the past 3 years for planning contract and in-house workloads. Developed within VDOT, the system also produces mechanic staffing levels by analysis of labor hours by repair and equipment types. It also considers nonequipment repairs and nonproductive time, such as training and meetings.

Factors Influencing Application Success

A number of factors influence the degree of success in applying formal methods to staffing level determination. These are as follows:

- Management authority
- Mandated reductions in DOT staffing
- Changes in formula basis
- Management system complexity.

Management Authority A DOT's management authority and structure influence an array of management approaches, including staffing level determinations. Internal authority delegation, such as those noted above for Florida and Mississippi DOTs, lead to district-level determinations of mechanic needs. This system is especially effective in DOTs with variation across districts, where local managers can develop approaches appropriate for specific highway maintenance operations. Such approaches are often simpler than is possible in statewide approaches.

The authority for revolving funds, such as in the North Carolina and Washington State DOTs, provides management stability. They purchase and maintain the fleet and rent equipment to users within the department. The annual rental revenue must equal the annual expenses. With the authority to purchase equipment, these agencies are able to replace vehicles and other equipment when necessary. Equipment age is seldom a factor, because the average age for a given equipment type is usually the same across the historical period.

A North Carolina DOT study established overall staffing levels at about 1 mechanic for each 25 pieces of equipment. Management modified the ratio for the eastern and western regions, which tend to have smaller garages.

The WSDOT is developing a system that will incorporate repair type and productivity. They are currently collecting data and, in time, will use the productivity-oriented system to determine staffing levels.

Mandated Reductions in DOT Staffing Mandated staffing levels, on the other hand, reduce management authority. Formal staffing level models assume that management can hire the number of mechanics needed. Government-mandated staffing reductions invalidate this assumption. DOTs are then forced to abandon the use of formal methods.

The Oklahoma DOT (OKDOT) is one example. OKDOT used an established table of organization until about 5 years ago, when the state government began mandating staffing cuts by attrition. Because they have recently filled only a few vacancies, the table has been of little use. Because staffing levels have become political rather than objective decisions, OKDOT no longer updates the table.

The New Mexico DOT and the VAOT have had similar experiences. Both had established staffing levels based on formulas, but can no longer apply them because of government-mandated hiring restrictions. Each had previously used the private sector for equipment maintenance, but now contract more work.

Changes in Formula Basis Whatever the approach, staffing level formulas are based on specific information. When this information changes significantly, the formulas become inaccurate or must be revised. The Florida DOT (FLDOT), for example, had Florida State University researchers develop ratios for staffing levels. These are applied infrequently, because recent developments changed the bases for the ratios. The purchase of vehicles with extended warranties reduces maintenance early in the equipment life cycle. Modern equipment, in general, requires less maintenance over its lifetime than does older model equipment.

MODOT found that their ratios needed revision because equipment type varied, and because equipment age and warranty periods changed from year to year. As the fleet aged, equipment needed more maintenance, and MODOT needed more mechanics. Longer warranty periods, on the other hand, reduced maintenance. However, because maintenance is relatively infrequent early in the equipment life cycle, this reduction did not compensate for the increasing fleet age. MODOT also found that replacement equipment had different features and characteristics and was often more complex and difficult to maintain.

Management System Complexity

As seen in the FLDOT and MODOT examples, equipment replacement generates a number of factors that affect mechanic staffing needs. Variation in overall equipment age and/or across regions requires more complex staffing level calculations. Fluctuating warranty periods affect staffing level needs and add complexity to the methods used to determine them. Complexity itself can limit a manager's ability to clearly establish mechanic needs.

Returning to the MODOT experience, this agency has determined the relationships between these and other variables. One goal was to determine the true cost of owning, operating, and maintaining equipment. Assisted by a consultant, MODOT developed a model that incorporates all pertinent variables and their behavior over time. This model calculates cost per repair type, in addition to hours required or cost per equipment unit type.

Because the program has been in place for only a short time, MODOT has not yet accumulated the historical data needed to determine optimum staffing levels, optimum replacement times, or warranty periods. MODOT also faces shortages of personnel skilled in data analysis and with the background necessary to convey results in practical terms. MODOT staff has sought to compare results from other DOTs using models obtained from the same consultant. However, other DOTs have modified the model and collect and analyze data in ways that interfere with such interstate comparisons.

Staffing Level Summary

DOTs varied in the ways they determined maintenance needs and thereby mechanic staffing levels. The approaches ranged from simple to very complex. The degree of complexity largely depends on the variation of highway maintenance operations across the DOT jurisdiction. For example, where equipment type varies within a jurisdiction, the DOT includes equipment type and repair type as prominent factors.

Where relative repair efficiency varies across equipment management districts, staffing level models incorporate productivity. In some instances, the management system emphasizes productivity, with staffing level assessment a by-product.

The number of factors is usually large in DOTs with recently developed or planned staffing level models. It will take some time before these DOTs can evaluate their effectiveness. Such models tend to require the collection of considerable information over several years in order to have sufficient data for pattern identification. These systems necessitate large data collection efforts, which usually takes significant time to yield sufficiently accurate and timely information. They also require special staff dedicated to data interpretation and application. This staff must include highly skilled technical analysts trained to make sense of the data and individuals oriented to equipment management practice to ensure effective implementation.

In contrast with a trend toward more complex models, some DOTs with formal staffing level models no longer apply the results due to government mandates and policies. These agencies tend to give priority to contract versus in-house decisions, treating staffing levels as fixed or with little variation.

Where staffing level models exist, preventive maintenance is usually a distinct repair type. DOTs, in general, recognize its importance to equipment management effectiveness by developing specific systems to manage preventive maintenance frequencies and accomplishment.

PREVENTIVE MAINTENANCE

An effective preventive maintenance program increases the ultimate service life of a piece of equipment, while minimizing the costs incurred. Staff find and fix problems before they cause equipment breakdowns. Effective programs not only save equipment maintenance expenses, but also decrease highway maintenance or other work interruptions and their resultant costs.

The goal of a preventive maintenance program is to prevent equipment breakdowns through routine, predictive, or planned maintenance. Routine maintenance includes inspection, lubrication, and oil and filter changes to reduce wear and prevent equipment failure. For predictive maintenance, the agency uses manufacturers' guidelines and vehicle history records to determine when component parts will most likely fail. The agency then schedules replacement in relation to shop and operator availability (*5*, p. 89).

In 1978, five elements defined a formal preventive maintenance program:

1. When to administer preventive maintenance (the *frequencies* at which it should be undertaken).
2. What *level* of preventive maintenance to apply at each frequency.
3. How to administer preventive maintenance (definitions of specific *tasks* to be performed at each level of preventive maintenance).
4. *Who should perform* the preventive maintenance (equipment operators, field mechanics, or central shop mechanics).
5. How long should the preventive maintenance take (*time standards* for each specific task) (*1*, p. 8; emphasis added).

The frequencies, levels, and tasks elements contribute to the <u>effectiveness</u> of a preventive maintenance program. That is, the greater the number of these elements incorporated in a program, the more potential problems will be found and the more breakdowns prevented. In 1978, more than 70 percent of responding DOTs reported having preventive maintenance programs that incorporated one or more of these elements. By 1998, DOTs had increased their effectiveness, most significantly with all but one agency reporting the frequencies element in its preventive maintenance program. More than 80 percent of all respondents cited increased application.

The remaining two elements, who should perform the task and time standards, contribute to efficiency of a preventive maintenance program. DOTs only slightly increased inclusion of these elements over the percentages reported in NCHRP Synthesis 52.

Fluids analysis is a recently developed technique used in refining preventive maintenance frequencies and tasks. Much as an annual blood test allows a physician to evaluate a patient's condition, oil analysis allows a mechanic to evaluate the condition of engines, transmissions, and hydraulic systems (*6*). Fewer than 20 percent of the reporting DOTs use fluid analysis as a regular feature of their preventive maintenance programs. Informal discussions with DOT equipment managers indicate a much greater use for particular types of equipment. Because of the cost of testing and evaluation, fluid analysis is most frequently used when there are many pieces of similar equipment.

PARTS PURCHASING AND INVENTORY

There is a direct relationship between the time needed to acquire parts and equipment downtime. Efficient parts acquisition reduces downtime; inefficient parts acquisition almost always increases downtime. Parts inventory and purchase efficiencies, therefore, can positively or negatively affect equipment availability for highway maintenance operations.

Several states (e.g., Virginia) have initiated pilot programs to contract large portions of their parts management. At the time of this study, results were not yet clear.

Despite the regulation of inventory and purchasing procedures by governing bodies, transportation agencies have improved their parts management practices over the past 20 years. In 1978 NCHRP Synthesis 52, more than 75 percent of the respondents experienced frequent occurrences of parts chasing (*1*, p. 11). In 1998, fewer than 25 percent reported frequent or regular problems "finding a vendor who has a needed part." Only about one-third reported problems often, frequently, or regularly.

In 1978, more than one-half of the respondents reported frequent stock outages. Twenty years later, fewer than 10 percent reported regular stock outages. Six of seven responding agencies often apply minimizing downtime as a factor in purchasing decisions. They similarly apply other factors that contribute to purchase decision efficiency: price discounts, best sources for quality products, and best sources for available products.

Certain imposed restrictions appear to contribute to stock outages and parts chasing. The most significant restrictions came from applying minimum usage rates in parts purchasing decisions and cost accounting/record-keeping rules. A ceiling on inventory by dollar volume was also an important factor. It appears that many agencies have improved their parts management despite these restrictions; however, they continue to negatively effect others.

Constraining factors also effect the frequency of emergency purchases. A ceiling on inventory by dollar volume appears to be the greatest influence on emergency purchases.

The respondents' largest problem in parts inventory administration inventory was low-bid syndrome. However, many transportation agencies appear to have overcome its impact on parts outages. Staffing was problematic for about one-third of the respondents, but had similar benign affects on parts inventory effectiveness. It is likely, however, that these elements of part inventory administration are expensive and that agencies seldom documented their costs.

SUMMARY

Many agency equipment managers face the same problem as their civilian counterparts: a shortage of skilled staff. For many, government-established wages and benefits exacerbate the problem, limiting their ability to hire and/or retain this scarce resource. A minority is able to offer adequate wages and benefits in order to compete; however, in only a few instances are wages and benefits sufficient to attract needed mechanics.

A greater problem is government-mandated limits on the number of mechanic positions. In these DOTs, equipment managers contract out more of their repairs. They also have little need for management systems geared toward staffing level determination.

Where the number of mechanics is not limited by such mandates, cost considerations dictate staffing level management. Management systems to determine staffing levels range from simple to very complex. The trend is toward becoming increasingly complex, especially in those agencies with an assortment of equipment types.

In general, state agencies have improved preventive maintenance programs over the past 2 decades. All but one state reported having such a program. The inclusion of the frequencies, levels, and tasks elements in these preventive maintenance programs has increased significantly over the past 20 years.

The study results show that DOTs have become more efficient in parts management than was reported 20 years ago. They have reduced parts chasing by one-third. Fewer than 10 percent regularly experience stock outages. Equipment managers still experiencing significant levels of stock outages remain constrained by minimum usage rates, and many are limited by cost accounting/record-keeping rules.

A management pattern is less clear for how DOTs have achieved improvements in parts purchasing and inventory. The application of purchasing decision factors was mixed when comparing the DOTs, with varying degrees of success reported.

CHAPTER THREE

EQUIPMENT REPLACEMENT AND SELECTION

BACKGROUND

John Dolce has succinctly described a dilemma facing both private and public transportation fleet managers: "Younger, newer equipment requires more capital, less space and less personnel than older equipment." Conversely, private companies' capital costs or public agencies' tax revenue needs decrease as fleet age increases, but maintenance needs and costs increase (*7*, p. 337). Also, older equipment breaks down more often, at times interrupting or even stopping a highway construction or maintenance project.

Although recent economic prosperity has made more capital available in the private sector, legislatures have increased pressure on the public sector to reduce expenditures. In 1985, Frank E. Aldrich, then the VAOT Director of Maintenance, wrote, "The combination of declining tax and escalating equipment replacement costs has created an unhealthy financial condition for equipment purchase programs" (*8*). Thirteen years later, tax generated funds for vehicle replacement are even tighter, and equipment costs have continued to increase.

Despite these factors, many transportation agencies have replaced equipment more often than documented 20 years ago. At that time, 38 states reported having been prevented, to a significant degree, from replacing equipment, on average, in 6 of the previous 10 years. In 1998, the median time was one-half of what agencies had reported 20 years earlier. Twenty-nine of the respondents reported being prevented, to a significant degree, from replacing equipment within the previous 3 years.

As reported in 1978, replacement-related practices were infrequently applied in DOTs. These practices cover determination of equipment replacement needs, equipment selection systems, and equipment replacement approaches and alternatives. Today, increased success in equipment replacement has occurred without the increased use of many of these practices. This chapter discusses each practice.

EQUIPMENT REPLACEMENT NEEDS

Quantitative Analysis

For an article published in 1987, Michael Vorster and Glenn Sears searched the literature since the 1920s covering "models aimed at quantifying the various decisions that must be made by managers of construction equipment" (*9*, p. 125). They concluded that "new thinking must be introduced to include the many factors which influence equipment decisions, but which do not appear as hard data in any cost-accounting system" (*9*, p. 126). Their proposed model also required considerable data and analysis, as have the new and revised models developed over the past decade.

The effect of model complexity on equipment replacement decisions was identified in 1978 as follows:

> The reason given (for being prevented from replacing equipment) may be lack of funds, but the cause lies in a widespread inability to articulate, in an objective manner, the impact of the failure to replace equipment that has exhausted its useful economic life. A barrier that plagues most agencies in this regard is represented by the inadequate data presently produced by their equipment management system (*1*, p. 9).

Twenty years later, many more transportation agencies collect data. However, these agencies tend to rely on equipment users' judgments rather than data analysis. Almost three-fourths of the 1998 respondents reported determining equipment needs largely by "round-table discussion with district managers." This is many more than reported doing so in 1978.

Based on informal discussions with equipment managers, this increase is attributed to the recent emphasis on "customer" orientation. The customer emphasis also exists in replacement requests. From these discussions, equipment managers can better articulate replacement needs. This has resulted in transportation agencies, in general, being more successful replacing equipment in 1998 than in 1978.

Downtime

The customer orientation and associated reliance on informal discussion is also seen in the use of downtime data. In 1998, only 3 of 44 respondents reported that they apply projected downtime when establishing equipment needs; in 1978, more than one-third did so. The decreased application of downtime projections is also inconsistent with how agencies use downtime for parts purchases, as noted in chapter 2. Many DOTs have the necessary data to include downtime in their analyses. Thirty agencies reported regularly recording equipment use in terms of downtime. More than three-fourths can access downtime information at least monthly. With several years of data, downtime projection is not a difficult calculation. Instead, equipment managers apply what they have found successful in equipment replacement need determinations: emphasis on customer input.

Life-Cycle Costing

One-fourth of the responding transportation agencies apply a particular quantitative model: life-cycle costing. It was addressed in 1978, when it was emerging as a decision-making tool. During the past several decades many scholars and practitioners have advocated its use for a broad range of management decisions.

The low use of life-cycle costing is likely due to its inconsistent impact on replacement decision effectiveness. Data analysis reveals that transportation agencies that never apply the tool are more successful in equipment replacement than those who regularly apply it. Those who rarely apply it are nearly as successful as those who frequently do so.

In addition to determining equipment replacement needs, equipment managers must select which equipment to purchase. The following section describes transportation agency practices regarding equipment selection.

EQUIPMENT SELECTION SYSTEMS

A systematic approach involves formal, quantitative evaluation of current and potential equipment. The questionnaire for this study contained the following definition of formal evaluation: " . . . analysis and documented cost/performance comparisons related to alternative maintenance methods employing different equipment types, capacities, or features" (*1*, p. 6).

In 1978, researchers found that only 2 of 49 states applied formal evaluation methods for equipment selection decisions. By 1998, 17 of 44 agencies applied formal evaluation methods, although more than 60 percent do not, preferring informal methods.

In 1978, three primary reasons why 12 states seldom used a formal approach and why 35 never did were reported:

- Reliable cost/performance data invariably were not available,
- There was a shortage of staff, and
- No acceptable evaluation formula for equipment selection decisions exists.

These barriers still remain. For the 17 respondents that apply formal methods, 7 confront at least one of these barriers. Examination in terms of their having the necessary components—reliable cost/performance data, adequate staff, and an acceptable formula—reveals that only 4 of the 17 states regularly have all three components. Three more had them frequently or regularly. Because these agencies vary in applying all elements, other agencies have these components available even less frequently.

More than two-thirds of the respondents reported sometimes exchanging detailed performance/cost data. Only eight reported doing so regularly, and another six often. Lack of communication about such important information indicates a need to improve interagency communications about other aspects of equipment management as well.

Equipment managers have several alternatives to purchasing replacement equipment with appropriated funds. The most important for transportation agencies are major equipment modification, rental and leasing, and revolving funds. The factors considered in deciding on these alternatives are discussed in the next section.

EQUIPMENT REPLACEMENT ALTERNATIVES

Major Modification of Equipment

As defined in this study, a major modification enables equipment to perform an added or different function. Effective selection procedures and the improved replacement procedures described previously should result in fewer major modifications. That appears to have occurred. In 1978, nearly 60 percent of the respondents had undertaken major modifications in the previous 5 years (*1*, p. 7). In 1998, only 20 percent had done so in the previous 3 years.

The decreasing availability of mechanics, described in chapter 2, is also a likely reason for fewer major modifications. Such work requires many hours of work by skilled mechanics, a scarce resource in many agencies. Analysis of a set of questions supports this conclusion. Respondents were asked to indicate the degree to which certain factors influence their agency's major modification decisions. They indicated the degree of influence in the following order:

1. The agency has the necessary facilities and equipment,
2. The agency has the necessary skilled manpower,
3. Unable to purchase new equipment, modification is the only viable option,
4. Modification versus purchase cost justifies modification, and
5. Local vendors have the necessary facilities and equipment.

The first factor, necessary facilities and equipment, and the second, necessary skilled manpower, were rated nearly equal in influence, and factors 3 and 4, financial considerations, were close behind. Local vendor capability is an option for only about 20 percent of the agencies.

Equipment Rental and Leasing

Another alternative to purchasing replacement equipment is to rent or lease it. Comparing the 1978 study with the current one, it was found that the frequency of hiring some regular equipment full-time has more than tripled. (Examples of "regular equipment" in both studies include trucks, loaders, graders, tractors, and mowers.) In 1998, respondents reported owning more than three-fourths of their regular equipment.

There has been little change in the level of renting or leasing specialty high-cost or regular equipment to meet seasonal workload peaks. More than one-third of the DOTs reported regularly renting or leasing specialty high-cost equipment. To meet seasonal needs, more than 10 percent rent regular equipment

Revolving Funds

Revolving funds, in which equipment users "rent" equipment from a DOT division, generate monies for equipment replacement. In 1978, 14 states had such funds for the purchase of equipment. In four of these states, however, the transportation agency had to go to another department for approval. In the past 20 years, little has changed. In 1998, 15 of the 44 responding transportation agencies reported having revolving funds, and 3 needed outside approval to use such funds.

SUMMARY

Transportation agencies are, in general, more successful in replacing equipment than they were 20 years ago. This is probably due to highway maintenance management participation, because nearly three-fourths of the respondents reported determining equipment needs by round-table discussion. Relying on their "customers" judgments and justifications, fewer contemporary equipment managers apply quantitative analysis to determine equipment needs than did so in 1978.

Similarly, more than 60 percent of the respondents apply informal evaluation methods in their equipment selection systems. They continue to be restricted by one or more of the following barriers to using formal approaches:

- Reliable cost/performance data invariably were not available
- Shortage of staff
- No acceptable evaluation formula.

Currently, far fewer DOTs modify equipment to perform an added or different function than did so in 1978. They rent or lease specialty high-cost equipment and regular equipment to meet seasonal workload peaks. About three times as many hire regular equipment full-time.

CHAPTER FOUR

TECHNOLOGIES

MANAGEMENT INFORMATION SYSTEMS

The terms "management system" and "management information system" have specific meanings. A true management system has provisions for planning, organizing, directing, and controlling the work. Providing management information is one aspect of a management system. A management information system (MIS) "provides information that managers can use to determine the status of certain events to assist them in making management decisions" (*10*, p. 3–8).

An MIS depends on data collection and manipulation. The types of data collected and the frameworks for its manipulation govern the information with which managers make decisions. Businesses and government agencies used MISs long before they had computers to quickly process data. The development of increasingly sophisticated MISs has paralleled the development of more powerful computers.

The increased sophistication was initially in the number of data elements, especially financial data. Financial and computer specialists often determined system output. Such specialists, having a greater understanding of computers than equipment and operations managers, also tended to develop the frameworks for equipment management systems. Equipment managers had better tools for financial management, but seldom for operational decision making.

In the 1980s, more powerful mainframe and desktop computers led to more data elements, more complex reports, and more unfulfilled expectations. George Combes described the VAOT experience at the 1996 TRB Equipment Management Workshop:

> In the mid-1980s, portable computers (PCs) arrived making it possible to automate some of the functions at the Garage using Garage staff to do the programming. This helped in a number of areas but also added to the problem in the mainframe development of maintaining and updating multiple files and records. Basically there was very little interfacing within the systems without a lot of manual intervention.
>
> By the late 1980s, the mainframe programming work was getting to be very costly and slow because new work was impacting on the earlier programs. The programmers that had done the earlier work had moved to new positions and very few people were left that knew anything about the system. Essentially at this point emphasis was shifted to fix and maintain the mainframe and not add anything else (*11*).

Other equipment managers had similar difficulties during the 1980s. It will be shown in this chapter that MISs improved for many agencies during the 1990s.

Respondents in this study provided information for the MIS most often used by equipment managers in their agency. Nearly three-fourths of the respondents indicated that their MIS promoted meaningful operating decisions. Yet, as described in the preceding chapters, few of the improved results over those reported in 1978 could be attributed to quantitative data analysis.

Combes (*11*) provides a probable explanation for the widespread satisfaction with MISs and the low use for certain decisions. In evaluating the 25–30 equipment management systems on the market, he and his colleagues talked to users:

> It was difficult to find a user that was not happy with the system that they had purchased. Some wished they had purchased one or two of the optional features available for the system they had, but had no regrets that they purchased the system. One interesting thing we found was that very few users use the total system they purchased. Most purchased the system to eliminate a particular problem and that's how they used it. Each system had its strong points and that was what the user was interested in when they purchased the system.

Findings from this study are consistent with Combes' observations. Description of MIS use begins with the extent to which equipment divisions are responsible for their MIS and their system oriented for equipment management.

Responsibility, Orientation, and Satisfaction

Financial departments developed the initial MISs and emphasized accounting information and financial decision making. Increasingly, equipment management divisions have assumed responsibility for their MISs and have concurrently oriented them for equipment management decision making. The managers with responsibility for an operational-oriented MIS have a high degree of satisfaction with their system.

During the 1990s, many agencies developed and/or purchased MISs geared to equipment management needs. Moreover, DOT operating divisions increasingly assumed responsibility for MIS operation. In 1998, equipment divisions were responsible for their MISs in more than one-half of the responding agencies, and highway maintenance divisions for almost 20 percent more. Of those equipment managers who indicated promotion of meaningful decisions, more than 80 percent have an operations division-responsible MIS. Only one respondent indicated that an equipment division-responsible system inhibited meaningful operational decisions.

In 1978, two-thirds of the responding states reported "that the data made available by their systems were essentially accounting-oriented and thus inhibit meaningful operating decisions" (*1*, p. 12) Twenty years later, fewer than one-fifth are accounting oriented. It is noteworthy that all three respondents whose MISs, in their view, inhibited meaningful operational decisions have an accounting-oriented MIS.

Financial and accounting information remains important, however. More than one-half of those who indicated promotion of meaningful operating decisions have systems balanced between operations and accounting.

Productivity Measurement

DOT equipment managers increasingly rely on accurate productivity measurement for equipment management decisions. In 1978, few agencies reported monitoring mechanic productivity (*1*, p. 8). By 1998, the MISs for one-half of the reporting agencies contained an objective basis for measuring shop productivity. Respondents with an objective basis were asked whether time standards was one basis for productivity measurement.

Time Standards

Time standards, or "flat rate repairs," are based on standards developed by industries to calculate the amount of time a specific repair should take on a specific vehicle model. Commercial guides are published each model year, and manufacturers often provide guides for specialized equipment. In equipment management, time standards have two uses: (1) to schedule equipment servicing and (2) to gauge employee performance.

Preventive maintenance scheduling is an example of the first use. As noted in chapter 2, fewer than one-third of the respondents include time standards in their preventive maintenance program.

A key element to gauge employee performance is the measuring of productivity. Of the agencies that measure productivity with an objective basis, 86 percent apply repair time standards. This represented 43 percent of all agencies, compared with 16.3 percent in 1978 (*1*, p. 12). In 1998, however, about two-thirds of the agencies still did not use time standard for preventive maintenance scheduling, and 57 percent did not for productivity measurement.

This variation reflects the ambivalence surrounding time standard use among equipment managers in public agencies. When the American Public Works Association surveyed its members about flat-rate use, it found that many local agencies considered the standards inaccurate. "Varying opinions of flat rates exist because they are seen as too demanding, too lax, or just right, and are typically representative of repairs under ideal conditions" (*5*, p. 14). Apparently, many transportation agency equipment managers share this view.

Productivity Measurement Within the MIS

Although time standards per se are in the MISs of fewer than one-half of the responding transportation agencies, others apply the concept in the form of average repair times for repair types and equipment types. The measures are included in sophisticated management systems that some agencies have established and others are developing. Productivity is one of many measures produced by the MIS. The equipment division enters data for mechanic hours coded for repair and equipment type and for many forms of nonproductive time. With data collected over several years, the MIS produces reports that measure productivity.

The framework for productivity and other measures is often DOT specific. Each incorporates factors and/or defines data elements in ways specific to its operation and management philosophy. This is illustrated in the following description of various information types often cited as useful in productivity measurement.

Information Types

In the 1978 report, one conclusion reached was that agencies needed "to upgrade both the quality of data flowing into and the form and content of equipment management systems" (*1*, p. 12). The rationale for the importance of timely access to a range of information applies 20 years later.

> Reliable and timely information is a prerequisite to sound equipment management. It permeates every one of its facets and therefore has a significant bearing on how effectively the highway maintenance manager is able to extract maximum benefit from equipment resources (*1*, p. 12).

An MIS manipulates data and produces information for decision makers. The types and timing of information available to equipment managers in 1998 vary widely across transportation agencies. In this survey, respondents were asked how often managers had access to each of the following information types:

- Road call travel
- Downtime
- Average hours by specific work type
- Costs per job by specific work type
- Cost per equipment unit.

Respondents indicated the shortest period for which each type of information was available. The time of access is described in the following sections.

Road Call Travel and Downtime

Road call travel and downtime are measures of equipment maintenance effectiveness. Road calls are vehicle breakdowns at locations where a mechanic or vendor must travel to the vehicle to repair it or tow it to a garage. Road call breakdowns should be minimized. In addition to equipment repair expense, the impact on highway maintenance operations can range from inconvenience to stopping a major project. One goal of the equipment maintenance manager is "to identify the cause of the road calls, prioritize them, then fact find for causes and initiate actions" (*7*, p. 117).

The number of road calls is itself a useful measure. Tracking road call travel adds the element of equipment division time and effort to correct breakdowns. The previous synthesis reported that only about 12 percent of reporting transportation agencies had road call travel information in 1978. Currently, managers in two-thirds of the reporting agencies have access to such information. Conversely, almost one-third do not, the highest "never" score in the survey.

For many managers, downtime is the primary measure of preventive maintenance program effectiveness (*5*, p. 96). It can also measure equipment operation and one-time repair effectiveness. Agencies can track lost time of service due to downtime and the costs of that lost service time.

In 1978, downtime information was available to managers in 12 percent of the state agencies (*1*, p. 12). By 1998, downtime information was available at least monthly to more than three-fourths of all responding agencies. Perhaps most surprising is that almost 20 percent of equipment managers report that they never have access to downtime information.

Average Hours, Costs Per Job, and Unit Costs

Average hours, costs per job, and unit costs can measure efficiency and contribute to effectiveness. Managers can identify areas of efficiency and inefficiency by comparing values within the agency, across maintenance sections, and over time. They can also compare values with agencies and private firms engaged in similar activities. When measures of downtime and/or road call travel indicate ineffectiveness, managers can use these cost figures to help identify the causes.

In 1978, average hours and costs per job information were available to managers in 12 percent of the responding agencies (*1*, p. 12). About three times as many contemporary equipment managers have access to such information daily, and about six times as many at least monthly.

Cost per equipment unit is the most accessible of all information types. This is probably influenced by many agencies using unit costs for internal and interstate financial transactions. Because accounting considerations were of primary importance in early MIS development and continue to dominate many systems today, unit costs are available in all but one MIS.

Inclusive Management Information Systems

An MIS is inclusive to the extent that it provides management with enough information to make effective decisions. Some agencies have developed inclusive MISs. As noted above, downtime and road call travel are both effectiveness measures. Of the 15 agency managers that have daily access to downtime information, more than one-half have daily access to road call travel data. Of the 32 that monitor downtime at least monthly, three-fourths also monitor road call travel at least as frequently. These agencies have developed a systematic approach to measure equipment management effectiveness and incorporate it into their respective MISs.

The relationship between average hours, costs per job, and unit costs also indicates that many agencies have developed inclusive MISs. Of the 16 agencies that have daily accessible job cost data, three-fourths calculate average hours and three-fourths calculate unit costs. (These are not always the same 12 agencies.) Of the 31 agencies with job cost data available at least monthly, more than 85 percent calculate average hours and 80 percent calculate unit costs in the same period.

Of the 27 agencies that have supervision costs available at least monthly, more than three-fourths calculate training costs as frequently. Furthermore, equipment managers in 12 agencies can access all 7 information types at least monthly, and another 10 can access 6 of the 7. In other words, the MISs in more than one-half of the agencies provide managers with six of the seven information types at least monthly.

Computers are a major factor facilitating the advances described above. Operational managers have become more familiar with computer capabilities and operations. Moreover, they became computer literate during a period when capabilities have soared and operations have become easier. Equipment managers have increasingly assumed responsibility for their MISs, have oriented them toward their operations, and included more and more information types needed for making decisions. WSCs, whether desktops or laptops, are likely to facilitate similar MIS advances in more agencies. Indeed, this will continue a trend already underway in some agencies.

WORKSTATION COMPUTERS

In this synthesis, the term workstation computers (WSCs) refers to desktop and laptop computers that have their own computing capability. DOTs increasingly network WSCs with the computers that process data for MISs. Users can download and process information within their WSC. In some instances, individual workstation or networked computers store and manipulate the data in a MIS.

WSCs also enable agencies to use two computer-related technologies: (1) the Internet and (2) bar codes. The Internet enables communications between equipment managers nationwide and bar codes ease data entry.

DOT practices related to MISs and WSCs are described here in separate sections.

Workstation Computers in Equipment Divisions

Many equipment management divisions have networked WSCs and involved shop personnel. In the 1998 survey, three-fifths of the reporting agencies have shop personnel both enter data and retrieve information using WSCs. Moreover, of the 12 agencies that can access all 7 information types at least monthly, 10 have a WSC network in which shop personnel retrieve information from the equipment management system.

Desktop and laptop computer use has contributed to development of inclusive management information systems. As noted above, 12 agencies can access at least monthly all the information types described above. Eleven of these 12 agencies have WSCs as their primary computers. Of the 18 that track downtime at least weekly, 12 have WSCs as their primary computers.

The increasing use of WSCs within equipment divisions opens a means for communications between them. That means is the Internet.

The Internet

The findings throughout this report show that responding agencies vary in their application of management systems and tools. Even if an equipment manager knows about a system, he or she often must document its benefits to justify usefulness to superiors. Knowledge of systems and documentation of benefits usually require an exchange of information and ideas. Colleges and universities have established the Internet for just that purpose. Faculty and researchers are able to quickly exchange theories and research findings. Private businesses and government agencies soon recognized the potential of the Internet and began exchanging practical ideas and results.

Fewer than one-half of the equipment managers in this survey reported being connected to the Internet. For those managers, and managers who become connected in the future, the Internet enables rapid communication among professionals with similar responsibilities in similar organizations. Internet access also enables users to find information on web sites. For example, manufacturers' web sites contain information on current and future equipment. The Texas DOT has a pilot program for purchasing parts by means of web sites.

Bar Codes

Bar code technology can increase data entry efficiency. Bar codes are a set of 10 different vertical bars, each of which represents a number. When placed in order, to represent a particular number, a scanning instrument can read the series of bars as that number. Bar codes increase where management wants to track the movement of many items of the same type. The most common use is in high volume supermarkets and department stores that want to track inventory and sales information. Each item type has a distinct code that warehouse personnel scan upon receipt and clerks scan when sold.

Today, parts suppliers routinely use bar codes to maintain inventory and to track purchases. Parts purchasers, such as DOTs, can take advantage of the parts already being bar coded. They can incorporate the numbers in their inventory control system and scan the part number at receiving, issue, and use locations. More than one-fourth of the respondents reported using bar codes for parts inventory and issue.

Fewer than one-fourth of the respondents use bar codes for inventory of property. Minimum values range from $100 to $1,000. Agency administrative personnel scan the bar codes annually.

The VAOT uses bar codes for data entry into its equipment maintenance management system. For more than 5 years it has used bar codes to input data into the accounting system, including employee time cards, repair orders, mechanic number, type of repair, mechanical system, and equipment type. Mechanics scan labels on employee identification cards, repair orders, and in notebooks.

The VAOT illustrates the need for supporting software to process the data. In other words, the sophistication of management system software determines bar code application. As management system software sophistication increases, data entry needs increase. Bar codes can often ease data entry, take less time, and increase data accuracy.

SUMMARY

Nearly three-fourths of the respondents indicated that their MISs promoted meaningful operating decisions. Only about 1 in 14 indicated that it inhibited decisions. Much of the satisfaction is due to many agencies having developed and/or purchased systems geared to equipment management needs. Moreover, equipment divisions have assumed responsibility for MIS operations in more than one-half of the agencies. This probably accounts for the greatly increased use of two common measures of equipment management effectiveness, road call travel and downtime.

Fewer than one-half of the DOTs use time standards. The trend is toward this type of use, however, as DOTs increasingly apply the concept in the form of average repair times for repair types and equipment types. This is occurring as a trend toward more sophisticated and complex MISs. Increasingly, agencies are developing a systematic approach to measuring equipment management effectiveness and incorporating it into their respective MISs.

Equipment managers are increasing the use of WSCs within their divisions. Almost two-thirds of responding agencies have WSCs as their primary computers for their equipment management systems. Many divisions have networked WSCs and involved shop personnel. At the time of this study, fewer than one-half of the equipment managers had access to the Internet. This is certain to increase, enabling equipment managers to communicate with each other on the Internet and to access information on web sites. WSC use has also facilitated the use of bar code technology for parts management in about one-fourth of these DOTs.

CHAPTER FIVE

CONCLUSIONS

Technology has become more sophisticated over the past 20 years. Advancement has been so rapid at times that equipment managers have struggled to keep pace in their development of fleet management and selection systems. Transportation agencies continue to be required to respond to ever-increasing demands and still meet public expectations, while operating with constrained resources. More research and researchers are needed in the area, as are skilled technical staff and a full appreciation of the assets of Management Information Systems (MISs).

Although technical applications of management systems have not advanced as rapidly as in most businesses, in nearly every fleet management and selection area examined for this report, DOTs apply management practices in more areas than was reported in 1978. Some practices occur frequently enough to conclude that they are general patterns—established preventive maintenance programs, effective parts management, and MISs that promote meaningful operational decisions. A common feature of these patterns is that equipment managers have sufficient authority over management processes to ensure effective results. Equipment divisions generate nearly all the data for preventive maintenance and parts management systems. Some restrictions on parts management, especially ceilings on inventory by dollar volume, have been significantly reduced over the past 20 years.

One emerging pattern is that equipment managers are assuming responsibility for MISs. More than one-half of the respondents reported that their equipment divisions were responsible for their MISs, and almost two-thirds have workstation computers (WSCs) as the primary computers for equipment management systems. Systems for preventive maintenance and parts management are likely to be within the equipment division.

In addition, centralized MISs appear to increasingly provide essential data and receive reports containing information appropriate for effective decision making. Again, the level of the equipment managers' control of the process is a factor. This study showed that the equipment division is responsible for the MISs of almost two-thirds of the respondents who felt it promoted meaningful operational decisions. This most likely accounts for the greatly increased use of road call travel and downtime measurement.

In another area of notable improvement, equipment replacement, equipment managers provide their expertise in informal processes involving equipment users. Many DOTs apply similar processes for equipment selection, although its effectiveness is less clear in the study.

It is clear, however, that equipment management operates under many constraints. Although equipment managers are expected to employ business-like practices, they often lack the authority to operate like their private sector counterparts.

Certain government mandates and policies create major constraints on equipment management. In some transportation agencies, imposed personnel reductions have been so extensive they make staffing level determination unnecessary. These agencies concentrate instead on whether to use contract maintenance or perform it in-house with a limited workforce. In a few instances, contracting out has been beneficial. Contracting work can also result in increased direct costs and reduced response to highway maintenance and other operations.

Legislated wages and benefits restrict the ability of many agencies to compete for and retain mechanics. This study shows that wages and benefits are by far the most important factors in those DOTs that have successfully hired and retained mechanics.

Government-mandated policies can also constrain equipment management. Although parts management has generally improved over the past 2 decades, about two-thirds of the respondents reported being constrained by minimum usage rates and/or cost accounting/record-keeping rules. Four-fifths of the respondents cited low-bid syndrome as problematic.

Equipment selection is another example of where equipment managers operate under constraints. These managers continue to be restricted by one or more of the following barriers to using formal approaches:

- Reliable cost/performance data invariably are not available,
- There is a shortage of staff, and
- No acceptable evaluation formula for equipment selection decisions exists.

These barriers also exist, in various forms, in many centralized MISs. The barriers can also occur in highly sophisticated internal MISs in equipment divisions. Interviews revealed a trend toward the development of highly sophisticated MISs in some DOTs. To the degree that management overcomes these barriers, these systems will provide reliable, meaningful results enabling equipment managers to make effective decisions.

Staff shortages deserve special attention, because the problem involves staff expertise and perspective as well as numbers of employees. As noted in the MODOT case study (see chapter 2), transportation agencies face shortages of personnel skilled in data analysis and with the background necessary to convey results in practical terms. This problem is common in large MISs.

So also is the propensity to gather huge amounts of data into a system that produces few meaningful results. This most often occurs in accounting-oriented systems. In this study, all three respondents who felt that their MISs significantly inhibited meaningful operational decisions had such systems.

This study also produced evidence that few equipment managers have a continuing dialogue with their counterparts in other DOTs. Although the operations they support vary, their professional responsibilities have more similarities than differences. With increased use of WSCs, the Internet provides a mechanism for expanding this dialogue. Internet access also enables use of web sites for equipment-related information.

Although a reduction in government-mandated constraints is usually beyond DOT management control, agencies can reduce other constraints. It is also noteworthy that, over the past 20 years, where equipment managers have authority over certain functions, those functions have shown the greatest improvement. Some of that improvement has also been due to reduced constraints.

The trend toward more quantitative management, with more sophisticated MISs, is worthy of increased management attention. Not only is the involvement of equipment managers necessary in MIS development and operation, but MIS support staff must consist of skilled analysts with an appreciation of the unique elements of equipment maintenance management and selection.

These conclusions identify the need for improved fleet management among a significant number of DOT fleets.

Constraints have been reduced since the previous synthesis, but inefficient practices remain. Such practices might be countered with solid documentation through the use of MISs that are designed for operational decision support rather than following a strict fiscal model.

It appears that there is a lack of computer skills and/or appreciation for the MIS asset among these fleets. Such a deficiency may promote business decisions for non-business reasons and a failure to utilize key indicators of the health of associated fleet management.

This synthesis identifies a worthwhile challenge for the future; the documented need for fleet maintenance equipment advocacy.

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APPENDIX A

Questionnaire

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

Project 20-5, Topic 29-07

FLEET MANAGEMENT AND SELECTION SYSTEMS FOR HIGHWAY MAINTENANCE EQUIPMENT

SURVEY QUESTIONNAIRE

---

*Name of Primary Respondent:*____________________
*State DOT or Other Affiliation:*____________________
*Title:*____________________
*Phone No.*____________________ *Email:*____________________

In the attached questionnaire, the Transportation Research Board (TRB) seeks information on current management practices related to highway equipment maintenance management and selection.

This questionnaire covers a number of issues and practices. It might be appropriate for individuals other than the primary respondent to fill out particular sections. If so, please have them indicate their name and title in the margin. If the Consultant for this study needs to contact them, he will do so through the primary respondent.

Please return this completed questionnaire to:

Dr. David H. Fluharty
36 Durham Point Road
Durham, NH 03824–3126

If you wish, you may fax your response to 603–862–2364.

We would appreciate your response by

THANK YOU FOR YOUR TIME AND EFFORT!!

If you have any questions, please call Dr. Fluharty at 603–862–2364, or contact via email at dhf@christa.unh.edu.

Preventive Maintenance Program

1. Which of the following five elements are regular features of your agency's preventive maintenance program? (Check all that apply.)

   ☐ When to administer PM (the frequencies at which it should be undertaken).
   ☐ What level of PM to apply at each frequency.
   ☐ How to administer PM (definitions of specific tasks to be performed within each PM level).
   ☐ How long PM should take (time standards for each specific task).
   ☐ Who should perform the PM (equipment operators, field mechanics, central shop mechanics).
   ☐ Fluids analysis to determine PM intervals.

2. In general, how do your agency's PM intervals compare with manufacturers' recommendations for

		Less Frequent	Consistent	More Frequent
a.	Pick-up trucks	1	2	3
b.	Dump trucks	1	2	3
c.	Motor graders	1	2	3

Parts Management Practices and Procedures

3. How much of your parts inventory is stocked within your agency?

   ☐ None ☐ Very little ☐ Some ☐ Most ☐ A lot ☐ Nearly All ☐ All

4. How often are each of the following applied when making parts purchase decisions?

		Never	Rarely	Some	Often	Frequently	Regularly
a.	Minimizing vehicle/equipment downtime	0	1	2	3	4	5
b.	Price discounts	0	1	2	3	4	5
c.	Best sources for quality products	0	1	2	3	4	5
d.	Best sources for available products	0	1	2	3	4	5
e.	Long lead-time, hard-to-get parts	0	1	2	3	4	5
f.	Minimum usage/turnover rates	0	1	2	3	4	5
g.	A ceiling on inventory by dollar volume	0	1	2	3	4	5
h.	Cost accounting/record-keeping rules	0	1	2	3	4	5

5. How often are the following problematic in administering your parts inventory system?

		Never	Rarely	Some	Often	Frequently	Regularly
a.	Staffing	0	1	2	3	4	5
b.	Stockroom security	0	1	2	3	4	5
c.	Low-bid syndrome	0	1	2	3	4	5
d.	Emergency purchases	0	1	2	3	4	5
e.	Audit reviews	0	1	2	3	4	5
f.	Stock outages	0	1	2	3	4	5
g.	Finding a vendor who has a needed part	0	1	2	3	4	5

Equipment Mechanics

6. Does your agency use one or more formulas to determine equipment mechanic staffing levels and makeup?

☐ Yes ☐ No

If **YES**, indicate which type.

☐ Simple ratios of mechanics to units of equipment.
☐ A point system, assigning a relative point value for each equipment type.
☐ Standard hours, assigning relative hours for each equipment type.
☐ A benchmarking approach.
☐ Other ____________________

7. How successful is your agency in finding and hiring qualified mechanics?

☐ Not at all ☐ Somewhat ☐ Moderately ☐ Usually ☐ Very

8. How successful is your agency in retaining qualified mechanics?

☐ Not at all ☐ Somewhat ☐ Moderately ☐ Usually ☐ Very

Equipment Utilization Issues

9. How does your agency establish equipment requirements? (Check all that apply.)

☐ In days at the operating unit level.
☐ Patterns of need projected on a month-to-month basis.
☐ Peak-demand needs levels.
☐ By adding downtime projections.
☐ Largely by round-table discussions with districts.
☐ Other ____________________

10. Does your agency regularly record equipment use in terms of:

a. Routine use?	☐ Yes	☐ No
b. Seasonal/emergency time?	☐ Yes	☐ No
c. Idle time?	☐ Yes	☐ No
d. Downtime?	☐ Yes	☐ No

11. How does your agency rent or lease

	Never	Rarely	Some	Often	Frequently	Regularly
a. Specialty high-cost equipment?	0	1	2	3	4	5
b. Regular equipment (e.g., trucks, loaders, graders, tractors, and mowers) to meet seasonal workload peaks?	0	1	2	3	4	5
c. Some regular equipment full-time?	0	1	2	3	4	5

Equipment Selection and Replacement

12. How often does your agency apply life cycle cost analysis to determine the need for replacement of equipment?

☐ Never ☐ Rarely ☐ Sometimes ☐ Oftentimes ☐ Frequently ☐ Regularly

13. Which of the following best describes the usually applied evaluation techniques to determine purchase of equipment types?

	Never	Rarely	Some	Often	Frequently	Regularly
a. Reliable cost/performance data.	0	1	2	3	4	5
b. Skilled staff.	0	1	2	3	4	5
c. An acceptable evaluation formula.	0	1	2	3	4	5

14. How often has your agency undertaken major equipment modifications over the past three years?

☐ Never ☐ Rarely ☐ Sometimes ☐ Oftentimes ☐ Frequently ☐ Regularly

15. Indicate on the scale the degree to which each factor influences whether or not your agency modifies equipment to perform an added or different function.

	Not a Factor	Dominant Factor
a. Unable to purchase new equipment; modification is the only viable option.	0 1 2 3 4	5 6 7
b. Modification versus purchase cost justifies modification.	0 1 2 3 4	5 6 7
c. Agency has the necessary skilled manpower.	0 1 2 3 4	5 6 7
d. Agency has the necessary facilities and equipment.	0 1 2 3 4	5 6 7
e. Local vendors have the necessary facilities and equipment.	0 1 2 3 4	5 6 7

16. How often does your agency provide to others, or receive from others, detailed equipment cost and/or performance data?

☐ Never ☐ Rarely ☐ Sometimes ☐ Oftentimes ☐ Frequently ☐ Regularly

17. In how many of the last ten years has your agency been prevented to a significant degree from replacing equipment?

☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 ☐ 10

18. Does your state have some form of an equipment replacement revolving fund?

☐ Yes ☐ No

If **YES**, does the highway agency need approval from another state department to use it?

☐ Yes ☐ No

Management Information Systems (MIS)

19. The following questions apply to the Management Information System (MIS) that equipment managers use most often to make decisions.

    a. What division in your agency is primarily responsible for operating the MIS?
    - ☐ Equipment division.
    - ☐ Finance/accounting.
    - ☐ Highway maintenance.
    - ☐ Computer services.
    - ☐ Other ____________________

    b. How would you classify the orientation or emphasis of the MIS?
    - ☐ Operational.
    - ☐ Accounting.
    - ☐ A balance between operations and accounting.

    c. To what degree does this MIS, in general, promote or inhibit meaningful operating decisions?

    Promote Inhibit

    5 4 3 2 1 0 -1 -2 -3 -4 -5

20. Does your MIS contain an objective basis for measuring shop productivity? ☐ Yes ☐ No

    If **YES**, is one basis repair time standards? ☐ Yes ☐ No

    If not time standards, what is the base? ____________________________

    ____

21. How often can equipment managers access each of the following information types?

		Never	Annually	Quarterly	Monthly	Weekly	Daily
a.	Cost per equipment unit.	0	1	2	3	4	5
b.	Supervision costs.	0	1	2	3	4	5
c.	Training costs.	0	1	2	3	4	5
d.	Inter-program assistance	0	1	2	3	4	5
e.	Road call travel.	0	1	2	3	4	5
f.	Average hours by specific types of work.	0	1	2	3	4	5
g.	Cost per job by specific types of work.	0	1	2	3	4	5
h.	Downtime	0	1	2	3	4	5

Use of Recently Developed Technologies

22. Are personal computers (PCs) the primary computers for your equipment management system operations? ☐ Yes ☐ No

23. Are the PCs in the equipment maintenance offices?

    a. Adequate in their hardware configuration? ☐ Yes ☐ No

    b. Adequately networked to computers in other divisions that contain needed information? ☐ Yes ☐ No

24. Do shop personnel have PCs?

    a. To enter data into the equipment management system? ☐ Yes ☐ No

    b. To retrieve data from the equipment management system? ☐ Yes ☐ No

25. Does your agency use any of the following technologies in its equipment maintenance management?

    a. Bar code technology for parts. ☐ Yes ☐ No

    b. Bar code technology for other purposes ☐ Yes ☐ No

c. Embedded chips technology. ☐ Yes ☐ No
d. "Smart tires" technology. ☐ Yes ☐ No
e. Geographic Information System (GIS) technology. ☐ Yes ☐ No
f. Intelligent Transportation System (ITS) technology. ☐ Yes ☐ No
g. Global Positioning System (GPS) technology. ☐ Yes ☐ No
h. Automated Vehicle Identification System (AVIS) technology. ☐ Yes ☐ No
i. Internet ☐ Yes ☐ No

APPENDIX B

Transportation Agency Survey Respondents

Alabama	Iowa	New Mexico	South Dakota
Arizona	Louisiana	New York	Tennessee
Arkansas	Maine	Nevada	Texas
Colorado	Maryland	North Carolina	Utah
Connecticut	Massachusetts	North Dakota	Vermont
Delaware	Michigan	Ohio	Virginia
Florida	Mississippi	Oklahoma	Washington
Georgia	Missouri	Oregon	West Virginia
Hawaii	Montana	Pennsylvania	Wyoming
Idaho	Nebraska	Puerto Rico	
Illinois	New Hampshire	Rhode Island	
Indiana	New Jersey	South Carolina	

APPENDIX C

Montana Department of Transportation Shop Work Load and Productivity Reports

EMS-512

SHOP WORK LOAD

EMS-12

This report projects the estimates of shop work load, based on fleet inventory, frequencies of repairs and average hours per repair.

Users:	Equipment Bureau
Frequency:	Annual, or as needed

REPORT DETAILS

A detailed report is sorted for each shop by equipment class, providing repair information for each repair code.

Shop Work Load/Category Detail

Shop:	Appropriate shop area.
Category Description:	Description and number of units in a given category.
Repair Codes:	Listing of repair codes and description of each.
Average Number of Repairs/Unit:	The average number of repairs performed over the past 12 months for each repair code for each class of equipment.
Estimated Number Repairs:	The projected number of repairs based on past performance.
Average Hours/Repair:	Average hours per repair for the past 12 months.
Total Hours/Year:	Estimated number of repairs times average hours per repair equals estimated yearly repair hours.

Shop: Helena

Report #: EMS 12
Run Date: 11/06/97
Page: 6

Montana Department of Highways
Shop Work Load/Staffing Detail

	Average No. Repairs/Unit	Estimated Number Repairs	Average Hours/ Repairs	Total Hrs/Yr
Medium Trucks (8)				
01 Clutch/torque conv	1.9	15	6.1	92
02 Main transmission	1.3	10	8.8	88
03 Aux trans/trans case				
04 Drive shaft/u-joints	0.1	1	2.0	2
05 Power take off				
06 Differentials/axles	1.6	23	3.0	39
07 Final drive/planet				
11 Air intake system				
12 Fuel system	0.6	5	4.6	23
13 Engine repair-minor	1.4	11	9.5	105
14 Engine repair-major	3.1	25	1.3	33
15 Cooling system	2.0	16	3.4	51
16 Exhaust system	1.1	9	2.4	22
21 Hydraulic system	2.0	16	3.4	54
22 Plows				
23 Other				
31 Suspension system	0.8	6	5.5	33
32 Steering system	1.0	8	3.0	24
33 Brake system	3.1	25	4.0	100
34 Wheel/hub/bearings				
35 Instruments/gauges	0.9	7	1.9	13
36 Body repair	2.3	18	3.6	65
41 Ignition system	0.4	3	2.7	8
42 Starting system	1.4	11	1.7	19
43 Changing system	0.6	5	2.4	12
44 Lighting system	1.9	15	2.9	44
51 Air condition/heat	0.4	3	1.7	5
52 Tires	2.1	17	2.8	48
53 Asphalt equipment				
54 Manu/fabricate	1.9	15	12.1	182
55 PM level 1	2.9	23	26.2	603
56 PM level 2	0.6	5	4.6	23
Category total	36.3	282	6.0	1692

EMS-512A

SHOP WORK LOAD

EMS-12A

This report summarizes all area information from the EMS-12

Users: Equipment Bureau
Frequency: Quarterly, or as needed

REPORT DETAILS

This report is organized into two final formats. A detailed report as described and a one-page summary.

Shop Work Load/Category Detail

Shop:	Report area shop.
Categories:	A list of all equipment categories. For a list of categories see EMS-0541.
Actual Inventory:	Current fleet totals by category by area.
Average Number of Repairs/Unit:	Average number of repairs performed by repair code.
Estimated Number Repairs:	Estimated annual number of repairs.
Average Hours/Repair:	Estimated average hours per repair.
Total Hours/Year:	Estimated annual repair hours

Shop Work Load All Area Summary

Same information as described above except the report is by area instead of by category.

EMS-513

MONTHLY MECHANIC PRODUCTION REPORT

EMS-13

This report details where payroll time is charged for the shop superintendent, working shop foreman, and mechanics.

Users:	Equipment Bureau
Frequency:	Monthly

REPORT DETAILS

This report is generated monthly for each area. It formats information from individual time sheets into selected categories. All information is in a percentage of total hours reported.

Employee Number:	Employee personnel number.
Direct:	Time spent in a directly repair activity.
Leave:	Time spent in a leave status.
Non-Reimbursable:	Time spent on accident damage.
AWP	Time spent on Authorized Work in Progress.
AR	Time spent on Accounts Receivable.
Other	All other account I.D. expenditures such as leave without pay, workers comp., etc.
For Maintenance Account 4100	Work performed for Maintenance and charged to the 4030 Account.
General Overhead:	Time spent in any or all of the five general overhead categories. See the detailed explanation at the bottom of the report.

EMS-514

SHOP PERFORMANCE SUMMARY

EMS-14

This report is a one-page summary of the EMS-07 information.

Users: Equipment Bureau
Frequency: Monthly

REPORT DETAILS

A one-page summary of each shop's performance for the last 12 months.

Shop:	Listing of all shops as well as statewide average.
% 4110 Direct:	Percent of shop hours coded to direct repairs. (Includes AWPs and ARs.)
% 4100 Overhead:	Percent of shop hours coded to overhead.
% Leave:	Percent of shop hours coded to leave.
NBR Units:	Current number of units assigned to each area.
Number of repairs:	Number of repairs.
Repairs per unit:	Average number of repairs per unit. (Number of repairs divided by the number of units.)
Average Hrs/Repair:	Average number of hours spent on each repair.
Average Hrs/PM II:	Average hours per Preventive Maintenance Level II performed.
# Repeat Repairs:	Number of repeat repairs.
% Repeat Repairs:	Percent of repairs that are repeats.
# Repairs Scheduled:	Percent of repairs that are scheduled.
% Repairs Road Call:	Percent of repairs that are made away from the shop.

DATE DUE

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