Makings of an Effective Maintenance Management System

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Maintenance management systems (MMSs) have existed for 20 years. Nearly every highway agency has a system in operation. It is appropriate to examine the experience to determine what is being done right and where improvements are needed. An effective MMS results in improved service and efficiency and reduced costs through preparing work programs that are based on prevailing field conditions and budget constraints, staffing at optimum levels, scheduling and directing maintenance crews for maximum productivity, and assuring that work programs are followed. The introduction of microcomputers has profoundly affected maintenance operations. Use of the computer often falls at two extremes. Some believe that the computer is a nuisance and a generator of paper. They would rather not have to apply it. At the other end of the scale, there is a tendency to equate management systems with the software. Some are mesmerized by the technology and lose sight of the objective of the computer systems. Use of computers in highway maintenance operations is examined. Issues discussed include determination of management functions that are most effectively automated and some pitfalls to avoid in system design.

The first maintenance management systems (MMSs) were implemented in the 1960s and 1970s. Although the basic concepts have changed little, recent technological changes have affected the way MMSs are used and viewed. With 20 years of experience, it is appropriate to assess the level of success that has been achieved.

The current state of MMSs in state highway agencies is addressed. The observations were developed from a survey of state highway agencies and personal experience in highway maintenance. The survey was conducted by submitting to all 50 states a questionnaire to identify the current technology and computer applications used in MMSs as well as the degree to which MMSs have provided an effective management approach to maintenance operations. The results of the survey are tabulated in a separate document and are available on request from the authors.

The following topics are discussed:

- A basis for measuring maintenance effectiveness,
- The MMS elements common to most state systems and how effectively they are used, and
- The current state of automation and technology.

BASIS FOR MEASURING PERFORMANCE

A number of indicators measure maintenance effectiveness. All lead to answering two basic questions:

- Is the work being performed in a cost-effective manner?
- Has a higher level of service been achieved?

It is inappropriate to speak of "cost savings" in a maintenance operation. No agency would voluntarily turn back money saved; instead, more work would be performed. Cost-effectiveness, then, should be measured by the unit cost of the work performed, which is normally directly related to crew production.

A higher level of service goes hand in hand with cost-effectiveness. If work is done at a lower unit cost, then more work can be performed, and it would appear that a higher level of service is being achieved. But this is not always the case. One must look at where the efficiency dividends are being spent. There is no greater waste of money than spending it efficiently on the wrong thing. Achieving a higher level of service means doing the right work—developing and executing a maintenance work program geared to the prevailing road conditions within the constraints of available funds.

Five indicators are adequate for measuring maintenance effectiveness: activity unit cost, average daily production, amount of work performed, compliance with the annual plan, and quality of work.

Measures such as personnel or equipment utilization should be reflected in the annual plan. It could be argued that there are other measures of effectiveness, such as safety and aesthetics. However, if the maintenance program is the right one, then those activities that promote motorist safety, comfort, aesthetics, and preservation of infrastructure are balanced within the available funds. Obviously, higher service levels should be possible with more money; however, this is more a measure of funding availability than a measure of how effectively maintenance operations are performed.

It might also be argued that the only true measure of effectiveness is the condition and performance (e.g., safety record) of the highway system over time. Although this might be true overall, funding availability probably plays the largest role here as well.

The effectiveness measures addressed in this paper deal with the operations over which maintenance managers have control. That is, given a budget, how can maintenance managers, at all levels, effectively plan and execute a maintenance program? Assuming that maintenance effectiveness can be measured by the indicators described above, management decisions and actions should be executed with the primary objective of increasing performance as measured by these indicators. (There are exceptions, such as personnel matters dealing with worker safety and rights and actions dictated by

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external sources such as the Occupational Safety and Health Administration, but these are not addressed in this paper.)

The MMS is no exception. The MMS should be designed and implemented for the primary purpose of improving performance—working more cost-effectively or increasing service levels, or both.

ELEMENTS OF AN EFFECTIVE MMS

Of the 42 state highway agencies that responded to the survey questionnaire, 37, or 88 percent, indicated that they have implemented an MMS. Whereas the basic elements of the systems are similar, no two states have precisely the same type of MMS. Given that numerous states report that the MMS has aided in improving services and reducing costs, there is no set definition of how a system should be structured. The structure and application of the MMS vary with organizational structure, management style, data processing capabilities, and general operating environment.

Certain elements are present in most systems. The most common elements are described below. An assessment of how effectively the elements have been implemented is provided on the basis of the measures outlined above.

Performance Standards

Performance standards are the most basic of the system elements. They are used to establish standard crew sizes, equipment, work methods, and production rates, and they provide the basis for planning work and assessing results. All but two of the states (92 percent) indicated that they use performance standards. The two that did not use standards use the MMS as a reporting system.

To be effective, the standards must be established as basic policy and as procedural guides for executing specific activities. Managers at all levels must be persuaded that the standards represent the best approach to performing work and that, if they are followed, they will lead to increased production, lower unit costs, and higher-quality work. Some pitfalls in the use of performance standards include the following:

- Field organizations are not provided with standard equipment. The performance standards should be based on the most efficient method of achieving quality results and should specify the most efficient equipment. However, equipment-purchasing practices do not always allow for providing the right equipment. Too often the maintenance work plan, developed on the basis of the standards, is not used as the primary input to determining fleet size and makeup. Only 15 percent of the survey respondents indicated that the MMS had a "very significant" impact on fleet size. Thirty-one percent said that the MMS had no impact at all on fleet makeup.

When the MMS is not used to determine fleet makeup, it is difficult to implement standard work methods and crew makeup. One highway district might use a backhoe on an activity while another district uses an excavator, or one might use single-axle trucks while another uses tandems. Variances in quality and unit costs will result. When unit costs are different, it is sometimes believed that the standards are wrong and are therefore useless. To correct this, management must use the standards and the annual work plan as the basis for determining fleet requirements. If this has not been standard practice, a transition period will be required during which it should be recognized that unit cost will naturally vary.

- Field managers are not convinced that standards are applicable in a maintenance operation. In a highway agency, the daily maintenance operations are the responsibility of dozens of field managers around the state. The managers often have their own opinions of how best to perform work. The opinions might be based on the availability of equipment assigned to the organization, the availability of a highly qualified operator, or comfort with the way work has always been performed. Although good management practice dictates that individual initiative not be inhibited, it is incumbent upon middle management to motivate field managers to use good work methods in line with established standards. This can be achieved by comparing results of field organizations. Managers with low production rates will soon be motivated to achieve higher productivity. However, if the field manager is correct and has a better method for improving productivity and achieving higher-quality work, consideration should be given to redefining the standard. The MMS should include a continuous process of reviewing and updating performance standards.
- Standards may be used for short-term ratings of performance. Compliance with plans and standards can and should be used to measure performance on a long-term basis; however, the performance ratings should be done constructively. The survey indicated that one of the most unpopular effects of the MMS is an aversion by field managers to "being controlled or monitored."

This aversion is natural but should not be a deterrent to work monitoring and evaluation. Because field conditions vary significantly with location, season, and general operating environment, compliance with the standards should be measured over a long period of time, perhaps monthly or quarterly. Crews will naturally do better than the standard on some days and not achieve it on others, so day-to-day comparisons are not very helpful.

- Too many standards may be used. In trying to develop a standard to cover most prevailing conditions, it is easy to fall into the trap of overspecifying standards. As a result, too many standards are developed, and it becomes difficult to measure results. Reporting becomes inaccurate and the information from the MMS is not useful. The best way to correct this is to view the MMS as a tool for managing the significant few activities that consume the bulk of manpower and dollars. A rule of thumb has not been established, and the number of performance standards that should be used varies from state to state; however, in nearly all cases 30 or 40 activities are more than adequate for an effective MMS. Agencies with scores of performance standards should take a critical look at the usefulness of having so many activities.

Annual Work Planning

Annual work planning in a state highway maintenance operation consists of defining the types of activities that should be performed to balance preservation, safety, aesthetics, and

comfort within the available funding. All but two of the states responding to the survey indicated that they have an annual planning process.

Planning is most effective when it is done in the context of establishing program objectives. In field maintenance operations, the program is represented by the annual plan of activities to be performed by the field organizations. In planning the amount of work, objectives are established for each activity, for example, the amount of mowing or chip seals. The annual plan should establish the most effective maintenance program, given funding limits and the physical needs of the roadway system.

For each activity, a quantity standard or level of service should be established on the basis of engineering judgment or analysis, agency policy, or historical performance. Recognition should be given to varying topographical and climatic conditions in the state. For example, one corner of a state might experience significantly more rainfall than another, and as a result, mowing might have to be performed more often to achieve the same level of service.

A primary objective in the planning process should be to achieve a consistent maintenance program from district to district. This does not mean that the program will look the same, but it does mean that the infrastructure will be maintained at approximately the same level and that the citizens will receive the same basic services. If this is achieved, a higher level of service will result.

Common pitfalls in maintenance planning are as follows:

- The program is not established as an objective. Too often the planning process becomes an exercise in budgeting—justifying current or increased funding levels and personnel quotas. Once the plan is developed, the commitment to achieving it no longer exists. To complete the management cycle, the work plan must be viewed as an objective at all levels, especially in the field. Natural catastrophes such as floods or exceptional snowfall will alter the plan but should not be a deterrent. Obtaining commitment to the annual work plan requires (*a*) that upper management be committed to planning the maintenance program and executing the plan, (*b*) that this commitment and the plan be communicated to field managers, and (*c*) that field managers be involved in the planning process using the MMS quantity standards and performance standards.
- Resources are not organized in line with the annual plan. Fifty-six percent of the state highway agencies responding to the survey indicated that personnel levels are established by agencies external to the maintenance program, such as through legislative or executive mandate. Though this may be inevitable, management should recognize that it damages maintenance operations. Establishing fixed personnel quotas normally means that staffing will be constant throughout the year. When staffing is not adjusted for peaks and valleys in the work load, compliance with the annual plan is nearly impossible and service levels decrease.

To be most effective, personnel quotas should be established on the basis of the annual work calendar. Once the annual plan is established, a work calendar should be developed to depict the work to be accomplished each month. The work calendar will dictate the resource requirements for labor, equipment, and materials. In nearly all cases, there will be significant peaks and valleys in the work load. Staffing levels should be established on the basis of needs generated from the work calendar, making use of temporary help or private contracting during periods of peak work load.

In the same fashion, leasing equipment during such periods will avoid keeping the unit in the fleet beyond the short periods of need. If rental units are commercially available, equipment ownership costs can be reduced significantly through an effective leasing program.

Correcting the problem of staffing quotas set by external agencies might be difficult. In states where labor quotas are established by legislative mandate, considerable effort is required to make changes. Use of the MMS annual work plan and work calendar can be a valuable tool for managers to convince authorities of the need for change.

Crew Scheduling

Crew scheduling deals with the short-term scheduling and assignment of crews to specific routes and activities. Seventy-five percent of the responding states use some form of short-term scheduling. To be most effective, scheduling should consider three primary inputs: the annual work plan, performance standards, and the prevailing physical condition of the road infrastructure.

If the annual work plan is established as an objective, crew scheduling should follow the work calendar developed from the annual plan. The work calendar specifies the general amount of work for each activity to be accomplished each month. If it is followed closely, the work plan will be accomplished and the maximum level of service will be achieved. Performing the work in accordance with established standards will ensure that the work is accomplished within the available budget and at the least unit cost.

Routine maintenance activities cannot effectively be planned on an annual basis for each route. The work calendar specifies only the total number of units to schedule each month. The routes and locations of the work will depend on where short-term needs arise. Scheduling pothole patching, for example, will depend on where the potholes occur and the routes with the highest priority for patching.

An effective scheduling program requires the field manager to be constantly aware of prevailing conditions through a systematic road inspection process. Some common pitfalls in the scheduling element of the MMS are discussed:

- Not following the annual work plan: Sixty-six percent of the states use the annual work plan "none" or "some" as part of developing short-term work schedules. Thirty-four percent indicated that the annual plan has a "very significant impact" in the scheduling process.

The work plan is achieved by using it as a primary input to the scheduling process. Too often the annual work plan is not followed, and the work performed is left to the discretion of the field supervisor. When the annual plan is not followed, the wrong work is done, and service levels decrease.

- Not following performance standards: When standard crew sizes or equipment complements are not followed, the unit cost of the activity will probably be higher than planned,

affecting compliance with budgets. Following performance standards requires that the field manager be committed to the standards and that the proper equipment be available. Good scheduling consumes time, and it is easier for a manager to assign personnel and equipment on the basis of their ready availability than to develop and execute a schedule.

Achieving compliance with standards normally requires (*a*) that the MMS annual plan be used to determine equipment needs and that the agency supply those needs to field organizations and (*b*) that the field manager view the performance standards as policy to be followed unless extenuating circumstances arise. Where the standards are not followed, field managers must be motivated to understand how they can help achieve quality work at a lower unit cost.

- Not using a systematic process of field inspections: Because the annual plan cannot specify the timing of work on particular routes, the field manager must ensure that crew schedules are aimed at the most critical needs. This requires routine inspection of roads by the field manager or foreman. Without a clear definition of needs, work is normally scheduled on routes where the most external pressure is applied. This results in inefficiencies and high unit costs because crews jump from one location to another and experience a high proportion of mobilization time. This in turn results in a self-perpetuating "brush fire" approach to maintenance work.

To correct this, the manager must be convinced that a systematic approach to crew scheduling will be beneficial. Good scheduling requires a great deal of management time to inspect roads, develop schedules, communicate the schedules to crew foremen, and coordinate the logistics of equipment and materials. The time spent in these management actions, however, is repaid many times over in improved crew efficiency and reduced unit costs.

A number of state highway agencies—40 percent—have implemented a work order system as part of the scheduling process. With a work order system, the field manager can maintain a backlog of maintenance needs by location. The backlog can be generated from routine road inspections, citizens' requests for assistance, and directives from superiors. The work in the backlog can be ordered by priority and becomes a good input to the scheduling process and an aid in carrying out the annual work plan. Maintaining a perpetual backlog of maintenance needs through the work order system can also be helpful in developing the annual work plan.

Work Reporting and Monitoring

Work reporting and monitoring are essential in an MMS. They complete the management cycle and provide the information needed to monitor work progress and assess work performance. All of the states indicated that they have a reporting process for maintenance work. Eighty-three percent have some form of performance monitoring through the MMS.

Work reporting procedures vary significantly from state to state. The variance generally depends on the level of automation. Some states continue to use a batch process, submitting reports to the central office through field computer terminals. Some states have on-line reporting and report generation capabilities. And some have recently implemented microcomputers in field operations with selected uploading of data to central office mainframes.

The types of management reports produced by the MMS are generally a function of the data processing environment and management style. States with on-line systems have information readily available, whereas batch systems normally result in less timely management reports. States with data base management systems are able to produce reports better suited to the needs of each manager.

More important than the data processing aspect, however, is management's commitment to the principle of work monitoring and evaluation. Surprisingly, a number of high-level managers do not use the MMS. The proportions of state highway engineers, state maintenance engineers, and district engineers who "never" or "seldom" use the MMS are 84, 45, and 71 percent, respectively.

Although managers in these positions are not involved in the daily maintenance operations, the MMS can be extremely valuable for them in planning and monitoring the maintenance program. Obviously, the varying responsibilities of each position require that information from the MMS be presented in formats that meet individual needs.

Some of the pitfalls in the reporting and monitoring element of the MMS are discussed below. All can be corrected by getting the necessary information to the right manager in a timely fashion and in the proper format.

- Lateness of management information was cited in the survey as the most unpopular element of the MMS. Management information is not fed back to the manager in a timely enough fashion for effective decision making.
- Reports are filled with too much data, and managers do not have enough time to pore over all the information.
- If too much time is required for work reporting, it is likely that the reporting will not be done with a great deal of enthusiasm, and accuracy will suffer.
- Most systems have a standard set of management reports. The format and content of the reports are fixed, and all managers who receive the reports get the same information in the same format. However, because responsibilities vary, managers at different levels might need different information.

Correcting these pitfalls requires a practical, management-oriented approach. It must be recognized that most individuals do not like the paperwork associated with reporting work, no matter how little time it might take, and that most managers do not enjoy studying reports to find answers and do not have the time.

This has not changed in the 20 or more years that MMSs have existed and in all likelihood will not change in the future. This must be recognized in the design of management reports. An effective MMS reporting and monitoring element requires that reporting be as simple as possible and that management reports be designed to be used.

Making reporting simple starts with performance standards. There is a direct correlation between reporting accuracy and the number of activities that must be reported. If only two activities (for example, work and leave) had to be reported, accuracy would probably be high. On the other hand, setting program objectives with just these two activities would not be possible. The number of activities must be balanced so

that there are enough to achieve good planning and monitoring but not so many that reporting becomes unwieldy and the information useless.

To be useful, management information must be timely, accurate, and presented in the right format.

Timeliness generally requires that management reports be automated. But automation does not guarantee timely information, and it should not be considered a substitute for manual methods of monitoring. For example, a field manager who reviews daily work reports before they are entered into the computer has instant information. The manager does not have to wait for feedback reports to point out problems. Likewise, a district maintenance engineer does not have to rely solely on automated reports to determine whether a particular field crew is following standards. The engineer who is in the field often will form an opinion of how well the crews follow standards from personal observations.

Management information that is late will not be used. How late will depend on the individual style of the manager.

Although some states have ad hoc reporting capability, a common shortcoming of MMSs is that managers at different levels receive standard reports. For instance, a monthly progress report is likely to contain the same information and be formatted in the same way for the state highway engineer, the state maintenance engineer, the district engineer, and anyone else who receives it. In practice, these individuals have different levels of maintenance responsibility. The management reports they receive should help them make decisions with respect to their specific responsibilities—and no more. This might mean that a special report is prepared just for the state highway engineer or that the district engineer gets a report different from the one received by the maintenance engineer. Management reports must be designed in this manner if they are going to be used. Most important, each manager should be given only the information that manager needs and nothing more.

Management reports are for determining how things are going. They can be designed to convey this with little time required for deciphering the information presented. A state highway engineer who has to spend more than a few minutes looking at a report before coming to any conclusions will probably not use the report.

AUTOMATION

The first MMSs were manual. With the introduction of computers, the systems became automated. As technology has progressed, the use of automation in MMSs has also progressed. The survey of state highway agencies sought to determine the degree of automation. Some of the major findings are shown in Table 1.

Generally, MMSs lag other systems in state-of-the-art automation. In most cases, new technology will first be implemented in payroll and accounting systems because of their importance to the agency. MMSs in most states use computer technology that is one or two generations old. The greatest impact is on reporting. States using older batch systems are not likely to get information timely enough to satisfy most managers' needs.

TABLE 1 STATE OF MMS AUTOMATION

A. System Implementation

A vast majority of the states have implemented MMS and are currently developing maintenance related management systems as illustrated by the following:

	Number of States			
	Have Implemented	Currently Under Development	Future Plans	No Future Plans
Maintenance Management System	37	1	3	1
Pavement Management System	22	17	1	0
Bridge Management System	11	12	9	3
Equipment Management System	26	7	7	0

B. System Update

Exactly half of the states indicated that their MMS has had a major revision since its initial implementation.

C. Hardware Configuration

The most common automation configuration is "dumb" terminals connected to a central office mainframe.

	Number of States
mainframe with terminals	30
microcomputers	6
mainframe with download to micros	4
other	6

TABLE 1 (*continued on next page*)

TABLE 1 (*continued*)

D. Operating Mode

Most MMS currently operate in a batch mode.

	Number of States
batch system	26
on-line	17

E. Reporting Procedures

Reporting procedures vary significantly.

	Number of States
stand-alone, strictly within MMS	18
done through accounting	18
MMS is source to accounting	16
MMS includes location reporting	22

F. System Interfaces

At present, most maintenance management systems do not interface with other systems. Typical interfaces include:

	Number of States
Pavement Management Systems	6
Bridge Management System	9
Equipment Management System	11

Older technology uses computer languages that are not as user friendly as today's fourth-generation languages. The older languages are harder to maintain, and changes are more time consuming to make.

The trend for MMSs is continued automation, primarily in reporting and interfacing with other systems. New technology will allow reporting with the use of electronic clipboards, hand-held computers, and other state-of-the-art devices. Interfacing with other systems, such as pavement and bridge management systems, is becoming easier as the technology moves toward data base management systems and fourth-generation languages. Better use could be made of computer graphics technology to present management information more effectively.

One strong theme was conveyed by maintenance managers interviewed by telephone after they had completed the survey questionnaire: the computer is only a tool, and the MMS will be effective only if managers are committed to its principles and apply the principles in their daily operations.

The authors' opinion is that too much attention has been given to the data processing aspects of the system. Not enough emphasis is being placed on management concepts. Advancing the technology is important, but technology alone does not achieve greater effectiveness. That is, having an electronic clipboard will not necessarily result in a higher level of service and certainly will not reduce the unit cost of work. States should have a continuous and active management training program, particularly for field supervisors. Top-level managers must have a strong commitment to the management principles of the MMS. The time and effort spent in the management tasks of planning, scheduling, and evaluating will be paid back many times in increased service levels and reduced costs.

Not all elements of the MMS have to be automated. They can be implemented just as effectively in a manual mode. Elements that require a great deal of data manipulation, including planning, work load leveling, projections of resource needs, reporting, and management reports, lend themselves most readily to automation.

Even if these elements are automated, managers still need to become involved in manual calculations. For example, in the equipment requirements area, a manager might want to perform some one-time analyses of the potential for equipment leasing. Although the MMS could provide the manager with information requirements, it would probably not be beneficial to attempt to automate the analysis, because it would be performed infrequently. Another example is assessing performance. It is likely that no management report will answer

all the questions on performance that might arise. For questions on performance that require a unique study, manual calculations and analyses are best.

Scheduling is the most difficult element of the MMS to automate. Because so many variables are involved in scheduling decisions, automation might not be attractive. Some states have automated scheduling; the availability of labor and equipment is kept in files and used as input to the schedules. Mixed success has been reported. Because scheduling is done on a short-term basis, up-to-date information is necessary, which requires much data input and maintenance.

Decisions on the assignment of crews and personnel to routes do not lend themselves to automation. However, maintenance work backlogs can be automated, which is helpful in crew assignment decisions.

In general, elements of the MMS with considerable data input and manipulation can be effectively automated. Elements that require decision making or unique analyses are not effectively automated.