The pilot program was developed in one district. It has been installed statewide. The MMS coordinator is able to build the county annual work plans within the limits of the county's personnel and equipment resources. Only after these plans are fully developed is the plan input to the files on the mainframe.

CONCLUSION

Productivity and efficiency appear to be tied to the availability of data to substantiate daily decision making and daily plans and in giving proper direction to the work force. The telecommunications network in Pennsylvania is being systematically upgraded to provide managers with the information required to manage operations in an efficient manner.

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Second-Generation Highway Maintenance Management Systems

MARTIN C. RISSEL

ABSTRACT

Highway maintenance management systems are composed of six interrelated system elements: planning, budgeting, scheduling, performing, reporting, and evaluating. Improvements must be made in all of these elements to develop a second-generation maintenance management system, which is a far more effective and responsive management tool. When highway maintenance management systems were first developed, it was established that they were being designed for managing maintenance to avoid the implication that they were an accounting system or could be used for one. The rigid adherence to this precept, although it eliminated some possible problems, also created deficiencies. The need for this separation was also brought about by the relatively unsophisticated state of computer technology at the time when maintenance management systems were first designed. Advances in computer technology and data management now permit the convenient and efficient transfer of data between systems. The elimination of deficiencies common to early system designs through the use of these advances is the source of opportunities for the development of second-generation maintenance management systems. Some of the advantages that can be attained are a reduction in the number of forms completed in the field and the amount of information on them, greatly simplified means of collecting accurate costs when required for invoicing, labor costs that may be reconciled exactly with those obtained from a payroll system, equipment costs that exactly reflect rental rates from the equipment management system, the elimination of the necessity of recording management information on equipment reports and salary vouchers, improved accuracy of material costs, and improved costs and procedures for the development of performance budgets.

Highway maintenance management systems (MMSs) were first developed in an attempt to provide the same advantages to those responsible for maintaining highways as had been available for many years to those managing highway construction programs. The basic concepts and the system elements were identical to those used for managing any complex undertaking regardless of the field of endeavor. These system elements and their relation can conveniently be shown on a simple diagram (Figure 1).

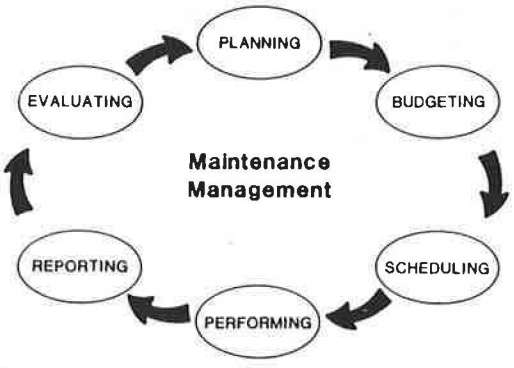

FIGURE 1 Relation of system elements.

Before a means by which an MMS can be upgraded to a second generation is developed, a review of the elements of a typical system and the part each one plays in its successful operation is necessary. Each system element must operate satisfactorily to make a complete system that will offer all the benefits that such a system should provide. The expense and effort of a system's acquisition and operation must also be justified.

SYSTEM ELEMENTS

Planning

Planning, the first of the system elements, involves the selection of objectives and the determination of the policies, programs, and procedures to be used for achievement of the selected objectives. Of all the management functions, planning is the one that facilitates the maximum utilization of available labor, equipment, and materials. Lack of emphasis on planning is often the cause for much of the criticism leveled at maintenance activities as being unresponsive, unproductive, or too costly.

The MMS element of planning is an effort that considers the whole highway system and its maintenance needs over an extended period of time. It must also consider everything that affects or can affect that highway system. The design of this element must therefore include the entire MMS planning process, beginning with the sources that provide basic information on which the system depends, such as inventory, work models, and so on, and continuing through to the development of procedures used to communicate planned work to those who must execute the plans.

Budgeting

Budgeting follows planning and is the process by which the funds and resources to implement the plans are obtained. Governmental bodies are accustomed to reviewing line-item budgets that aggregate the budget requests into defined object classes such as pay of personnel and equipment purchases. The relationship of a line-item budget to the work to be accomplished is always obscure. No one is ever certain what the impact of a percentage change in the total line-item budget request will be on the highway system. A performance-based budget that relates work to be accomplished with the resources of labor, equipment, and materials and their costs required is far superior because alternative budgets can be associated with needs. This was recognized in older MMSs but implementation tended to be sketchy at best and deceptive at worst.

Scheduling

Scheduling is a process concerned with laying out the work for the future. A good scheduling process develops work schedules on at least three levels--organization, supervisor, and foreman. This provides a uniform maintenance approach and ensures that the plans and budgets are implemented to achieve the objectives. The amount of schedule detail and specificity increases from higher to lower level. In reality, the organization's and supervisor's schedules are the final approved and budgeted work plans. The region schedules include assignments to crews, general time frames, and so on. The foreman's schedules are specific as to location, time, date, and assigned crew members. The work reflects the needs that conform to seasonal requirements, and in addition plans made by higher administrative levels are taken into account. Scheduling accounts for all resources--labor, equipment, and material. It must conform to performance standards so that the schedule is consistent with reasonable and possible levels of effort. Because emergency work is always a possibility for highway agencies, the scheduling process must also be flexible so emergency conditions can be met without undue strain on the organization.

Performing

Performing concerns the actual completion of the work in the field. To satisfy the requirements of the MMS the work must be done in a manner that conforms with prescribed quality and quantity standards. Material, equipment, and labor are used as indicated on performance standards or as nearly as is possible. Obviously, variations occur, but if these are consistently larger or smaller than the standards, either the standards are in error or more or less efficient procedures than those prescribed are being followed.

Reporting

Reporting represents the primary means of communication between those actually performing the work and those who must manage it. Reporting is done on input formats in conformance with prescribed methods. Work performance and the utilization of resources used in that performance are reported as they occur. Obviously, reporting forms that are easy to complete with correct information generate the best data.

Evaluating

Evaluation is the means by which the quantity and quality of work are measured and is the basis on which management can exercise control actions. The most effective MMSs make provisions so that those most involved with the actual work, the foremen, for example, regularly receive information from the system so they can judge their own performance. Reports should be provided to each administrative level appropriate to the needs of that level. Evaluations are based on comparisons between like crews or personnel performing like tasks. Comparisons are also made against standards so the standards may be adjusted to make expectations reasonable and so that planning and budgeting efforts are reasonable. Evaluation is also the system element that serves to measure the effectiveness of all of the other elements and to produce the means by which not only highway maintenance but the personnel performing it can be improved.

CHARACTERISTICS OF CURRENT SYSTEMS

The concepts of maintenance management are straightforward. There are, however, some circumstances surrounding highway maintenance activities that create the need to develop different methods of approach for implementing the various system elements of MMSs. Unlike most functions in industry, the same employees are required to work at a relatively large number of diversified tasks. This not only presents problems of training and efficiency but also causes difficulties in accurate and effective reporting.

Location of Maintenance Operations

Highway maintenance occurs at a great variety of locations over extensive geographical regions. In addition, most of the work is likely to be of short duration performed by a relatively small number of employees. Under these circumstances, most on-site formal processes to monitor work, which are customary in all types of construction, are impossible to implement by any reasonable means.

Supervisory Relationships

Because of the characteristics of highway maintenance and its locations, proper supervisory relationships are difficult to develop. Communication problems are likely to occur between all levels

of supervision--district office to area supervisor and area supervisor to foreman or sectionman. At one time, before the amount of traffic placed so many demands on highway maintenance, much of the work was done by a patrolman and a helper on an assigned section of highway. This less formal approach also necessitated a less formal approach to management, and the quality of the work for the most part was judged solely by the appearance of the highway. In- creasing requirements gradually caused the evolution into the crew system, but some record-keeping practices such as individual time sheets and individual tracking of material use are probably left over from past practices. It is interesting that some vestiges of this individuality are still evident in many systems.

Control Sections

Because highway maintenance is so diversified and dispersed, all original record keeping was financial in nature because cost was the one universal measure. Accounting systems were provided with devices or modifications to supply additional controls on expenditures. One of these was the control-section system in which sections of highways having similar physical characteristics were identified. Control-section numbers were also changed at county lines because the practice was to incorporate digits identifying the county into the number. Numbering in this format was provided only for federal-aid highways. If the highway agency maintained off-system highways, a separate parallel system had to be devised, which introduced other complications. The control-section system proved to be ineffective for establishing costs of maintaining identified sections of highways because of intermittent construction projects and erratic development, which caused radical irregularities in traffic density and patterns.

Control sections, however, partly satisfy cost-accounting needs, because expenditures can be associated with a source of expenditure, but unfortunately this process creates inefficient practices. For example, it was, and undoubtedly still is, a practice in some states to distribute costs to control sections as material, such as salt, is delivered to storage buildings from which it will be used. As striping crews stripe highways, sheets full of control-section numbers can uselessly clutter up records. To compound the problem, two or more crews can be responsible for a control section, which eliminates any accuracy in the evaluation of crew performance.

Coding Systems

In an attempt to overcome the deficiencies in the control-section system or similar systems that preceded it and to increase financial control, a proliferation of hierarchical coding systems have been introduced in almost all jurisdictions. These include a variety of appropriations, accounts, functions, activities, classes, commodity codes, and so on, which have to be entered and reentered on a multiplicity of forms and that have been expanded rapidly in an attempt to capture and narrowly define all costs associated with highway maintenance. By this means, an indirect measurement can be made of work that has been performed. The natural desire and need for orderliness in accounting divisions can be satisfied by this complex system because expenditures can be associated with specific items. There is no indication, however, of the results attained by making the expenditures. In addition, there is nothing contained in this information that can be used to measure the effectiveness of personnel. In short, accounting-based systems track the amount of expenditures and where they are made but provide only the slightest hint of any value received from them.

Payroll Records

In addition to records of expenditures, there are other systems that are used to contribute information about costs associated with maintenance. Attempts have been made to expand this information to the point where it can provide some information about performance, but this is awkward at best. Payroll systems, for example, are often cluttered up with all sorts of elaborate codings used for a variety of purposes other than ensuring that an employee is paid properly. Because in many jurisdictions individuals fill out their own time sheets, the possibility of error increases rapidly as the coding becomes more complex.

Equipment and Stores Use Reporting

Equipment reporting systems also often include coding requirements beyond that necessary to track the amount of use, performance, and cost of operating a unit of equipment. Codes indicating what use is made of the equipment and its location of use cause the same kind of complexity on equipment reporting forms as can be found on payroll forms. In much the same way, stores issue forms often contain a great deal of information that may satisfy elaborate coding regulations and requirements but also produce uncounted errors by their very complexity.

Maintenance Costs

Attempts to determine the cost of performing maintenance by using accounting systems normally consists of taking information from the sources described previously and combining them. This obviously requires duplicate record keeping because, at the least, the work location and descriptions of work, usually in the form of codes, must be duplicated on each of the various forms. Multiple sources of information not only cause compilation problems but are by their very nature prone to a high error rate. When it is necessary to collect exact cost, in the case of accounts receivable, for example, the collection of data sufficiently detailed and accurate to develop an auditable invoice can be time consuming and delay the sending of the invoice and the receiving of payment by weeks because of the work required to correlate the data.

Line-Item Budgeting

The use of accounting-based data to collect costs also led naturally to its use in the budgeting process. Because no worthwhile records of the work done are kept, the only means to develop a budget is directly in terms of cost. Past history of expenditures categorized by various objects of expenditure such as personal services, employee benefits, equipment rentals, and so on, is used as a basis on which to project future costs. Inflation factors, changes in the number of permitted personnel, changes in policy emphasis, and other similar factors are used with the historical record to develop proposed budgets in a so-called line-item format. The assumption is usually made in this budgeting process that maintenance will be at the same level as in the previous budget period in spite of changes in funding levels that might not permit it. Because there is no indication in this budgeting method of the

results that will be provided as a result of the expenditures, the foregoing assumption, although not particularly logical, is the best one available under the circumstances.

DESIGN PRECEPTS OF CURRENT SYSTEMS

When the majority of highway MMSs currently in use were designed and developed, it was with the precept that they were not accounting systems. This was, and is, certainly true, but this approach was extended to the point where the systems were not designed to be competent to develop data of sufficient accuracy to furnish information to an accounting system or any other system. It was, and still is, the general belief that the MMS should not be used to collect official records. The natural extension of this is the conclusion that it is not worthwhile to use data from other systems for the MMS.

The result of these decisions was to establish the MMS as an entirely separate entity. No portion of any other system was replaced, so the MMS was simply superimposed on all the other systems in use in the highway agency. All of the accounting codes, the forms on which they were entered, and the complexities associated with them were left in place. The attempts to reduce the impact of a whole new set of record-keeping requirements on field personnel often produced awkward, inefficient, or inaccurate data-handling or data-entry procedures. Many of these are still in use today. More than one state has had to add personnel in the field as well as in the office to manage the management system. It cannot be denied that the introduction of maintenance management was a step forward, but inefficiencies remain that technology, which is now available, can overcome or at least greatly alleviate.

A series of steps was implemented when the MMS was introduced. The first was to make an inventory of all the facilities that would require maintenance. This was usually a relatively rough inventory as far as location identification was concerned, because the budget that was to be developed from it normally contained approximations not meriting any great accuracy of inventory. The next step was to break the work down into detailed elements called activities. Work units, resources required for each unit of work, and productivity standards were then associated with them. In an attempt to hold down the increase of paper work, the usual practice was to concentrate on only those activities that appeared to be the most significant from a time and cost viewpoint. As a result, not all of the time of the employees was accounted for. In addition, the desire to reduce the impact of introducing an MMS tended to cause the excessive selection of employee hours as a work measurement unit for an excessive number of activities. This work unit, of course, merely demonstrates that one hour of work by an employee equals one employee hour.

The budgeting process normally based on most current MMSs associates either a level of effort or, more commonly, a quantity of material with an inventory item on a relatively rudimentary basis. An example of this is tons of patching premix per lane mile of highway. This procedure does not take into account differences between various highway systems or the condition of segments of highways. It is an improvement over a purely financially based budget because it does give some indication of needs on a general basis as long as the quality of service described can be attained with the resources provided. A budget determined by this process is not a true performance budget, however, because the amount of material used does not indicate the condition or end result provided except by inference. In addition, because there has been a change in quality standards caused by financing problems in many jurisdictions, this budgeting process has either been discarded or at least given less significance because of its lack of flexibility. For these reasons the line-item budget format without appreciable modification is again the only one used in most cases.

CHARACTERISTICS OF SECOND-GENERATION SYSTEMS

Increased availability of computers at reasonable prices has offered opportunities for advancement in many fields. Microcomputers or minicomputers used as intelligent terminals and creative system design work in the development of programs and file management provided the framework on which the first of the second-generation MMSs was constructed for the Montana Department of Highways. Improvements were made in all system elements and components as part of the development process. To do this, two prerequisites had to be satisfied:

1. The level of accuracy had to be increased so other systems could use data from the MSS, and
2. The MMS had to be made compatible with other systems so data could be transferred between computer files in different systems.

Labor Cost

To ensure effectiveness, improvements in accuracy were attained by decreasing, not increasing, the amount of information entered by field personnel. These improvements occurred with respect to all three resources--labor, equipment, and materials. An entirely new concept was required for labor cost, because the average cost per hour of labor that is commonly used is only approximate. Attempting to associate individual labor charges with specific functions or activities, however, was considered too complex and a potential source of excessive errors.

Using the crew as a basis on which to calculate labor costs for maintenance activities proved to be an effective method that provided the desired accuracy. The true average hourly cost of a crew member during a pay period is simple to attain in principle, because it only requires adding up all the salaries paid to everyone in the crew and dividing by the total number of hours of labor performed by all crew members. To determine labor costs by activity, this amount is then multiplied by the number of labor hours expended by the crew on each of the various activities to which the crew charges time during the pay period. The total labor cost includes all premium time paid as well as regular hours. This produces exact reconciliation for each pay period with results from the accounting system. If viewed from a broad perspective, this method is actually fairer and more accurate than attempting to assign labor costs of individuals to specific tasks with their pay at the time of doing the work, regular or premium. In a crew it is almost always a matter of happenstance whether the highest or lowest-paid member of the crew performs any particular activity. The same thing is true of work done by an employee receiving regular or premium pay. This method is obviously simpler in theory than in practice because many aberrations involving crew assignment occur in any maintenance organization. Formal and informal transfers, borrowing personnel from other divisions, districtwide and statewide crews, and a variey of similar personnel assignments were all accounted for by systems design and computer programming.

Equipment Cost

For equipment costs dual rental or use rates were

provided by the equipment management system. Fixed or ownership costs are based on assignment of the equipment to administrative units and operation costs are based on the amount of use. The maintenance management system records both assignment and use on a class basis, and the equipment management system records use on a unit basis. Computerized edit and reconciliation checks ensure that all hours or miles are reported. With this method the accuracy of equipment reporting matches that attained by labor reporting and similar advantages are gained.

Material Cost

The accuracy attained by the labor and equipment segments of the modern MMS permitted the complete management of bulk material for both quantity and value for the stores system. For other items in the stores system, a computerized method was developed by using weighted average costs to convert the cost of thousands of separate items to the 60 or so meaningful to the MMS. These were identified in the MMS by two-digit codes convenient for field use. With this procedure the cost of bulk stores items used is exact, accounting for the largest percentage of material used by maintenance forces. The cost of other items is far closer than that attained by other management systems and should certainly be considered sufficiently accurate for developing maintenance costs and generally for reconciliation purposes as well.

Highway-Feature Inventory

A review in some detail of the highway-feature inventory system that was devised for Montana's second-generation MMS and the way that it both affects and is used with other elements of the management system will serve two purposes: first to demonstrate the capability, flexibility, and simple operation that the design provided and second to demonstrate the initial time and effort that was required in systems work and computer programming to bring about the operation of the design.

Instead of the obsolete control-section system as described earlier, the crew or section was used as the primary or key unit. In order of priority this was followed by highway system, route number, and pavement type. All inventory items were then identified as being between specific mileposts. Whole miles were used except at section boundaries or route ends. Actual distances between mileposts are maintained in another computerized system to account for changes due to construction and are automatically accessed by the inventory system.

On the surface this seems fairly usual and not particularly new. The way in which it was done, however, provided substantial advantages and the basis for improvement in other segments of the complete system. On a rudimentary level all reports of work performed and productivity are identified with a highway section and a crew and ultimately with with an individual, the section foreman. Information provided allows him to evaluate his own performance compared with standard performance and average performance in his district. Similarly, information provided to his superiors allows the association of performance with an individual and the highways for which he is responsible by system, route, and pavement type. All resources used and other pertinent information are presented so that meaningful management decisions can be made.

On a more sophisticated level, the inventory furnishes much of the basic information on which the performance budget is based. Together with the enumeration of actual inventory amounts of features such as lane miles, linear feet of a specific type of guard rail, and dozens of similar control items, variable inventory items are also identified. These include such items as terrain type, annual rainfall, annual snowfall, date of last major pavement maintenance or reconstruction, and so on. The work model developed to use this information accounts for those types of items for which there is a direct arithmetical relationship and for which the relationship is exponential in nature.

The application of the work model is much different than the past practice of adding up all of a similar inventory item and then multiplying by a factor to obtain an amount of resource used. The desire to account for not only inventory amounts of physical features but those elements that affect their life and maintenance needs created the requirement to separately evaluate each mile on each system with the same pavement type in each section for each inventory item. Obviously a highway system of any magnitude, which is the case in Montana, requires that a performance budget for its maintenance be prepared through the use of a modern high-speed computer, particularly when other features such as variable service levels that are included in the total system are considered.

On still another level, maintenance performed on specific elements of a specific section of highway can be compared on any basis with other sections or elements. The difference in maintenance needs and costs, for example, can be reviewed for two sections of highway constructed the same year under the same specifications but by different contractors or with different aggregate sources.

The use of the highway-features inventory as the basis for so much of the total management system carried with it the stipulation that it must be accurate and current. Highway systems are dynamic entities from both a physical and administrative viewpoint in spite of their size and apparent unchanging permanence. Construction, reconstruction, and betterment programs can all change items in a features inventory. Changes can be in terms of types, number, and length of any inventory item and can all be significant. To account for these types of changes the inventory adjustment procedure was directly incorporated into the construction and betterment documentation process. The procedure that is followed appears relatively simple to those employing it and yet the conceptual design, systems development, and programming efforts were substantial.

An even more interesting and difficult challenge was to develop a process to correctly account for administrative changes. Because performance budgets and reports of work done to compare with them are related directly to section, system, route, and pavement type, any change in any one of these must be accounted for and the inventory changed or elements in it redistributed to reflect the change. Federal-aid systems are periodically changed from one route to another to account for changes in traffic patterns and functional needs. Section boundaries are changed on occasion to balance work loads, administrative units are either added or removed for a variety of reasons, sections of highways can be tranferrred to local jurisdictions for maintenance by changes in the law or vice versa, and other sections can be changed from in-house maintenance to contract maintenance. The procedure developed to correctly modify or reallocate inventory items for all of these occurrences and more is straightforward and relatively simple to those inputting the information. The conceptual design and the systems design were complex, however, and the computer program written to operate this relatively small portion of

the system contains more than 3,000 lines. This serves to demonstrate a basic principle on which the entire system was developed. That is, almost any complexity of design and programming is justified if a genuine benefit results and if work for those operating the system is reduced and kept to a minimum. Hundreds of foreman or sectionmen performing additional unnecessary work over an indefinite period of time can only result in an enormous aggregate loss of productivity and a massive increase in consequential cost.

With the use of accurate rather than approximate information, major improvements were made in each of the system elements. The management system then provided opportunities for improvement throughout the maintenance organization.

Planning

For planning, better information from past records will provide the means by which improved plans will be developed for future work. Improved correlation of resources used, cost of resources, and results obtained from the use of the resources will be established. Location of high-cost maintenance regions together with the identification of those activities causing the high cost can provide data so the most worthwhile locations for betterment can be selected.

Budgeting

For budgeting, accurate information will be the basis on which to rapidly increase the accuracy of the work models. With modern computer techniques these work models will be continually improved and updated through curve-fit programs. This procedure corrects a common problem in existing MMSs of difficulty in relating work performed to the budgeting process. Effective performance budgets presented in matrix format with line items are now greatly increasing the understanding of relative costs to those reponsible for analyzing and approving budgets.

Up to five levels of service were provided for each activity with allowance for selection of different ones for each system and pavement type. In this way the Interstate system can be budgeted for level-of-service 1 (the highest) for one activity and one pavement type and secondary highways can be budgeted for level-of-service 3 for the same activity and a different pavement type. The budget output automatically describes the results to be obtained by the decision in narrative format suitable both for being understood by the executive branch and legislature and for modifying the standard of performance as issued to the sectionmen.

Scheduling

For scheduling, improved data will provide information on which more accurate schedules can be developed. Performance standards will be continuously refined and updated in conformance with changing methods and techniques because detailed productivity records showing complete information regarding resource use are readily available.

Performing

For performing, good up-to-date records of resource use and cost will rapidly lead to the selection of the best methods for completing the work. This in turn will lead to improved performance by the entire maintenance organization with the use of the most efficient crew sizes, the most suitable equipment, and the most satisfactory material.

Reporting

For reporting, the total effort required for recording work and resource use was substantially reduced from that which would have been required for older systems because the MMS reporting document has become the sole means by which costs of performing maintenance activities are distributed. The location of work indicated on the MMS reporting form together with the use of resources--labor, equipment, and materials--can provide all the necessary data for any coding needs. If detailed accounting-type coding is required, computer programs have been developed to create the necessary information. If the work is to be paid for by a special fund or is to be reimbursed for any reason, journals with itemized detailed costs can be automatically generated by data-processing systems by providing simple additional coding on the MMS reporting form that indicates such an action is to take place. In this case, the remainder of the coding is precisely the same as it is for all other work, thereby eliminating an all-too-common source of error known to all who have attempted to gain federal reimbursement for special work done by a maintenance organization. Payroll forms, equipment management system forms, and stores issue forms will be substantially simplified; the entries will be exclusively dedicated to their primary purpose--ensuring proper payment, tracking units of equipment, and providing records of stores issue, respectively.

Evaluating

For evaluating, accurate data are provided rapidly after the end of a pay period, greatly increasing their effectiveness. This is particularly true for lower management levels because their primary interest lies in short-term effects rather than long-term planning. The best opportunity for improvement throughout an organization is to have meaningful information provided directly to those who can evaluate their own performance and take corrective action. Obviously this cannot be done effectively if excessive time has elapsed between performing the work and receiving reports about it. Little is to be gained from finding out that there is a better way to plow snow when grass is being mowed.

SUMMARY

In summary there is a key difference in the philosophical approach in the development of systems like those currently in use in most jurisdictions and a second-generation MMS as visualized here. The older systems were superimposed on a maintenance organization for the sole purpose of managing narrowly defined maintenance operations. The second-generation MMS as designed for the Montana Department of Highways is an inherent part of the total management of the highway system itself and all of its components. It also makes vital and necessary contributions to other organizations within the department, thereby increasing their efficiency and economy of operation. In this process it is easier to use than other MMSs, provides far more accurate information in a shorter time, and is indispensable to the operation of the department. The advantages and ways that data from such a system can be used and the way it can use data from other systems to the advantage of a highway agency are numerous and limited more by the imagination of the user rather than by limitations of the system. A few examples of features from the Montana design are as follows:

1. The performance-budgeting subsystem automati-

cally estimates the number of personnel required to provide the selected level of service chosen for the various highway systems for use in developing personnel needs.

2. The performance-budgeting subsystem automatically estimates the need for various subclasses of equipment so that equipment needs can be evaluated.

3. The performance-budgeting subsystem automatically estimates the requirement for various stores items and their cost so an evaluation of needs can be easily and efficiently prepared.

4. Construction, betterment, and major contract resurfacing projects are entered in the system by a simple process and are properly accounted for by the performance-budgeting subsystem.

5. Information from the performance-budgeting subsystem is accessed by the management information subsystem and monthly reports show expenditures versus budgeted amounts by both maintenance activity and line item in simple and easily understood matrix format. In addition, information from the payroll, stores, and accounting systems is automatically shown on the same document providing a complete, up-to-date evaluation of the current financial status of a district or maintenance region. This is to become the key document for this purpose because of its completeness and timeliness.

6. Detailed information regarding the use of all resources by activity or group of activities and by location can be automatically obtained for use in the pavement management system or for other purposes such as evaluation of design or construction practices.

7. Detailed itemized invoices can be prepared by the Accounting Division from information obtained directly from the MMS within days of the completion of the work.

8. Equipment utilization by subclass is captured by the MMS, allowing the effectiveness of various types and sizes of equipment for various applications to be evaluated. Current rental rates of equipment as established by the equipment management system are automatically accessed by the MMS (computer file to computer file).

9. Stockpiles of all bulk materials are automatically managed by the MMS for the stores system as to value and quantity for both material used and material added. Only the simplest input is required for this purpose.

10. Contract maintenance is recorded on the same forms as work by in-house forces, and reports permit rapid and full comparison of costs for work done by contract and by maintenance employees.

11. A yearly field evaluation is made of the results of performing key activities to compare work required and work estimated by work models.

12. Detailed up-to-date complete inventory information can be obtained on request for any section of highway of a mile or more in length.

13. A greatly simplified improved audit trail for all materials used in maintenance activities was developed within the MMS for the stores system.

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Contract Maintenance in Ontario

J. HUGH BLAINE

ABSTRACT

The Ontario Ministry of Transportation and Communications has substantially increased the use of private contractors to provide winter maintenance during the last few years. Some summer operations also are now being done by contractors, but total maintenance of sections of the highway has not been carried out by contract. At this time almost all sand spreaders are mounted on contractors' tracks. Approximately 23 percent of the snowplow trucks are now supplied and operated by contractors. In the large urban areas, large contracts are awarded for the stockpiling and spreading of winter sand and salt. Most surface treatment, liquid calcium chloride application, crushed gravel supply, dome construction, and picnic site maintenance is done by contract. In addition, some grass mowing, street sweeping, catchbasin cleaning, and brush clearing is contracted. Almost all of this work was done by the highway department at one time. The increased use of contracts has resulted from a number of changes, both internal and external to the Ministry. It is a strategic policy of the Ministry to use contractors where financial analysis and assessment indicate that the total cost will be reduced. Maintenance management system costs are used in these analyses.

The trend toward use of private contractors to maintain parts of the highway system started in the 1950s in Ontario. This trend has been accelerating during the past few years, particularly in the large summer operations such as surface treatment, gravel crushing, and hot-mix patching and in winter maintenance. Many service functions are now carried out by contract. These changes have led to a need to reorganize many maintenance activities and a need for a comprehensive maintenance management system to