Overview of Saskatchewan's Maintenance Management Information System

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Saskatchewan Highways and Transportation operates a maintenance management information system that provides up-to-date resource usage, accomplishments, and expenditures at any organizational level. The system captures data for the department's equipment management information, expenditure distribution, and pavement management information systems. Currently, the system operates on a mainframe computer located in the provincial capital. Data are entered daily at each area office on a microcomputer and communicated in batch mode to the mainframe. After the data pass certain validation tests, the system's year-to-date file is updated and a report is immediately returned to the area office. The system contains some unique features, including holding accounts that provide up-to-date expenditures even though payroll is processed biweekly and equipment nightly. Saskatchewan's approach to data entry and the philosophy used in designing the system are described. The type of data captured, the level at which the data are captured, hardware and software used, interfaces with other systems, and how the system itself is managed are reviewed. It is concluded that the system's success is due to its design philosophy of meeting the needs of the frontline maintenance manager.

Saskatchewan is set in the Great Plains region in the interior of Canada. Agriculture and resource industries such as petroleum, uranium, potash, and timber are the mainstays of the provincial economy. The province has an area of 653 000 km^2 (252,000 mi^2) and a population of approximately 1 million. Nearly all reside in the southern half of the province, dispersed among 63,400 farms and 1,000 communities. The resulting population density is only three persons per square kilometer and only a few hundred per community. The largest centers are Regina and Saskatoon, with populations of 170,000 and 180,000, respectively.

Saskatchewan has a surveyed rural road network of 200 000 km (124,000 mi), which gives it the largest road network per capita in Canada and one of the largest in the world. Much of this network consists of graded and graveled roadways serving the agricultural regions of the province. Seventy-six percent of rural travel is carried by the 25 639 km (15,931 mi) of provincial highways maintained by Saskatchewan Highways and Transportation.

Building, maintaining, and rehabilitating this large highway network within the limits of a small tax base have been a constant challenge. Saskatchewan has met the challenge by constructing a variety of pavement standards that vary in design life to meet the needs of the varying classes of highways. These standards range from standard pavements with a 15-year design life to thin (40-mm) cold-mix surface treatments requiring extensive annual maintenance. Table 1 lists the length of the various pavement standards, typical construction costs, and average annual surface maintenance costs.

Another important aspect of this challenge has been to develop a system to provide managers timely information necessary for maintaining the highway system as efficiently as possible.

The department's maintenance operations are managed through six district offices. Each district is divided into 3 to 6 maintenance areas for a total of 28 area offices located in 25 cities or towns throughout the province. Each area supervises up to 6 sections for a total of 164 section crews.

A section is the first level of management organization involved in the delivery of the maintenance program. It is essentially a discrete crew of one to five persons with an established equipment fleet and is responsible for an assigned portion of the highway system. Each asphalt section handles an average of 192 km (119 mi), whereas gravel sections (generally remote northern locations) maintain an average of 111 km (69 mi).

Saskatchewan manages the maintenance of its diverse mix of pavement structures by setting measurable objectives in terms of a riding comfort index (RCI). Traffic, weather, subgrade quality, and age are the major factors that determine performance of road surfaces. Saskatchewan has found that weather is often the most significant factor determining the performance of old or thin pavements. Because of the degree of variation encountered, standards for funding surface repair have been established on a basis of per kilometer dollar allotments adjusted for surface type and region of the province. Over the years, the department has determined that its RCI objectives will be achieved, on the average, with the standard allotments. This method of managing surface maintenance increases the need for maintenance supervisors to have accurate and timely information on their input costs.

HISTORY OF SASKATCHEWAN'S MAINTENANCE MANAGEMENT SYSTEM

Saskatchewan's first maintenance management information system (MMIS) was developed in-house in 1977 and implemented in 1978. The system was plagued with several problems from its inception, the most significant being that constraints originating in other systems precluded a design that provided timely information for the field. The system failed to provide adequate editing procedures and report formats and required a laborious hard copy data input from the field to the district office. District clerical staff, who were unfamiliar with the data because they were not directly involved with the maintenance organization, did the final keying.

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TABLE 1 SASKATCHEWAN'S PAVEMENT STANDARDS, APRIL 1989

Pavement Standard	Length (km)	Estimated Life (years)	Typical Construction Cost ($/km)	Annual Surface Maintenance ($/km)
Standard Pavement	5 448	22	164,000	1,453
A Pavement	2 302	17	100,000	1,433
B Pavement	2 394	8	75,000 [1]	1,742
C Pavement	1 674	N/A	47,000	2,113
Oil Treatment	7 993	N/A	32,000 [1]	3,155 [2]
Gravel	5 828	N/A	2,000	1,823
Total	25 639	N/A	N/A	2,136

1. Estimated, standard no longer constructed.
2. Includes an annualized cost for seal coating.

The lack of timely and accurate reports coming back from the system resulted in most field managers relying on their own manual ledgers. The quality of data being entered into the system eroded as field managers viewed the system as uncompensated extra work. The needs of the most important users were not being met.

In 1983 a committee of the system's users was mandated to review the system and those with which it interacted to produce an effective MMIS. The committee conducted interviews at all levels of the maintenance organization to uncover the basic problems and lack of support. It concluded that the primary user of the system was the lowest level in the management chain. It determined that all senior management's needs could be met by consolidating information of the lower levels and that the organizational level responsible for entering data had the most right to satisfaction with the system.

Some of the committee's recommendations were considered fairly radical at the time. The recommendation to use microcomputers located in the area offices for data entry was not easily accepted by the department's mainframe-oriented data processing unit. However, after a successful pilot project the committee's recommendations for a revised system were implemented beginning in the summer of 1984, and full integration with other systems was completed by the spring of 1985.

OVERVIEW OF CURRENT SYSTEM

The primary purpose of the MMIS is to provide the information required by all levels of maintenance management for effective, responsible decisions. The objective of the system is to provide timely, accurate information that is collected as efficiently as possible.

The system is a resource management system that tracks four primary resource inputs: labor, equipment, materials, and external costs. Physical accomplishments are entered to provide measures of cost-effectiveness. The system records resource usage and accomplishments for each maintenance activity. Saskatchewan has limited the number of maintenance activities it uses to 47. They are grouped into 18 work classes (the lowest level used for budget control) and 5 main program components. For most work classes the information is captured for each surface type on each segment of highway within a maintenance section. The resulting provincewide total possible combinations of activity, management unit, highway segment, and surface type is more than 11,200. The maintenance activities used and their associated data elements are listed in Table 2.

Using these data, the system can provide the three types of management information required: costs (accounts, equipment, and labor), resource usage and inventory, and accomplishments.

The information is available in reports for any combination of organizational grouping, highway network classification, or pavement type. Valid combinations of these elements are reviewed annually by head office and district staff. Once made final, this chart of accounts becomes a key element of the edit checking routines.

SYSTEM ARCHITECTURE

Hardware and Software

The core of the system is operated on an IBM Model 3090 mainframe located in the provincial capital. The master file and inventory files are updated on verification of daily transaction files, after which the transaction files are discarded. The master files are kept on disk and backed up nightly.

Remote data entry is done on four types of terminals: IBM-compatible personal computers, DEC Rainbow personal computers, Northern Telecom terminals, and Mohawk terminals. Several software packages and languages are used throughout the system. Data are entered through a data base package called DataStar on the Rainbows and through a dedicated data entry package called Entry Point 90 on the IBM PC compatibles.

Data are verified on the mainframe using a number of custom procedures written in COBOL. Similarly, interaction with data files in other systems is accomplished using COBOL source code.

All standard reports are produced with Mark IV. Recently, SAS (Statistical Analysis System) has been introduced to the maintenance organization and is now being used extensively to produce custom reports at the head office and district level. Both of these software packages lend themselves well to summarizing and reporting the many possible combinations of data.

TABLE 2 CHART OF ACCOUNTS

Work Class	Activity	M_Unit	Control Section	Type	Liq	Agg	Mix	Stockpile Used	Stockpile Prod	Sq, m	Hrs
Section Surface Repair	Other	DAMU	#	12-17	*	*	*	*			*
	Spot Sealing	DAMU	#	13-17	*	*		*		*	*
	Machine Patching	DAMU	#	13-17	*	*	*	*			*
	Hand Patching	DAMU	#	13-17	*		*	*			*
	Crack Sealing	DAMU	#	14-17	*	*		*			*
	Gravel Blading	DAMU	#	12-17						#	*
	Spot Regravel	DAMU	#	12-17		#		#			*
	Sand Sulphur Patching	DAMU	#	15-17			*	*			*
	Flushing	DAMU	#	13-17	*					*	*
	Thin Overlays	DAMU	#	13-17			*			*	*
Stockpile Aggregate		DA				*			*		*
Stockpile Asphalt Mix		DA			*	*	*	*	*		*
Seal Coat on Oil Treatments		DA	#	13	*	*		*		*	*
Dust Treatment		DAMU	#	12	*	*		*			*
Subgrade Stabilization		DAMU	#	12		*		*		*	*
Railway Crossing Maintenance		DAMU	#	12-17	*	*	*	*			*
Deep Patching		DAMU	#	13-17	*	*	*	*		*	*
Snow and Ice Control		DAMU	#	12-17	*	*	*	*	*		*
Mowing		DAMU	#							*	*
Pavement Marking		DAMU			*			*	*	*	*
Sign Rehabilitation		D									*
Sign & Guardrail Preservation		DAMU	#								*
Highway Illumination		D									*
District General Services	Hotline	D									*
	Non-Expendable Items	D									*
	Supplemental Pay	D									*
	Communications	D									*
	Training Programs	D									*
	Staff Travel	D									*
	Other	D									*
	Eqpmt. Repair Tptn.	D									*
Holding Accounts	Labour	D									
	Asphalt	D			#						
	Salt	D									
	Calcium Chloride	D			#						
	Beaded Paint	DA			#						
Area General Services	Area Administration	DA									*
	Non-Expendable Items	DA									*
	Communications	DA									*
	Electrical Power	DA									*
	Training Programs	DA									*
	Other	DA									*
Tourist Facilities		DAMU			*						*
Airports		DAMU									*

* indicates data items which may be entered for a particular activity
\# indicates required data items

Operation

Each of the 164 regular section crews telephones or radios its area office each day and provides the area office clerk with all the data pertaining to the work that the crew accomplished the day before. The information is collected and summarized by the 28 area clerks on data entry forms similar to the sample shown in Figure 1.

After data are collected for the previous day's work, they are entered at the area terminal and transmitted to the mainframe for processing. If the data contain errors, processing stops and an error listing is sent back to the area terminal for correction and resubmission to the mainframe. When the data are error free, processing automatically takes place. On completion of processing, a daily work report is automatically sent to the terminal that submitted the data, the provincial year-

Record 1 Expenditure Distribution

Date YY MM DD	Vote	Management Unit	Control Section	Project I.D.	Type	Activity	Accounts Costs	Hours of Work	
								Service	Salaried

Record 2 Material Quantities

Litres of Asphalt		Tonnes of Aggregate -Sand		Tonnes of Asphalt Mix - Salt		Stockpile Production	m^2 of any Measurable Work
	Stockpile		Stockpile		Stockpile		

Record 3 Equipment Usage

Unit No.	Assigned Management Unit	Usage Hours / km	Down Hours	End Meter Reading

FIGURE 1 MMIS-EMIS data entry forms.

to-date file is updated, and inventories are adjusted. The daily work report is reviewed, certified correct, and then filed chronologically for audit purposes at the area office. Although these duties are normally performed by the area clerk, the area maintenance supervisor can enter the data and will take over this duty if the clerk is on sick or vacation leave.

The six district maintenance planning supervisors are responsible for supplying and updating material unit costs for items such as asphalt, salt, and calcium chloride. Major contracted items such as seal coats and crushing and stockpiling aggregates and thin overlays are entered at the district level in the same manner as in the areas. The district maintenance planning supervisor is also responsible for the general supervision of the system at the district level and represents the district on the user's support committee.

In keeping with the philosophy that the system belongs to the frontline maintenance managers, data entry from the head office is not permitted. Even data from operations such as pavement marking that are managed from the head office must be entered through regional headquarters. All adjustments that may be required are performed at the area or district level. This reinforces the concept that the areas are responsible for their own data.

INTERACTION WITH OTHER SYSTEMS

Figure 2 diagrams the relationship between MMIS and other systems.

Equipment Management Information System

Data from the department's equipment management information system (EMIS) is used to validate equipment identification as part of the edit-checking process. Invalid unit numbers are trapped at this step. After the edit-checking process, EMIS provides equipment rental rates to MMIS so that equipment costs can be calculated and used in MMIS. In turn, the equipment usage entered through MMIS is passed on to EMIS to update equipment usage logs and standard transaction documents.

Expenditure Distribution System

This is the official accounting system of the department. It records all expenditures by the organizational unit responsible for the expenditure and the highway segment on which the expenditure was made. The system contains a table of allowable distributions against which MMIS data are validated as part of the edit-checking process.

Expenditures by the payroll system are distributed in the expenditure distribution system on the basis of the labor hours reported through MMIS. This process is discussed in greater detail later in this paper.

Pavement Management Information System

Annual maintenance effort is one of the key factors considered in the department's pavement management information system (PMIS). MMIS provides annual quantitative measures of deep patching, spot sealing, hand patching and thin overlays, and total costs of other maintenance items. This information, along with ride, surface condition, and traffic data, is used to model pavement performance.

Geographic Information System

Links are being developed to report maintenance information using the department's geographic information system. Main-

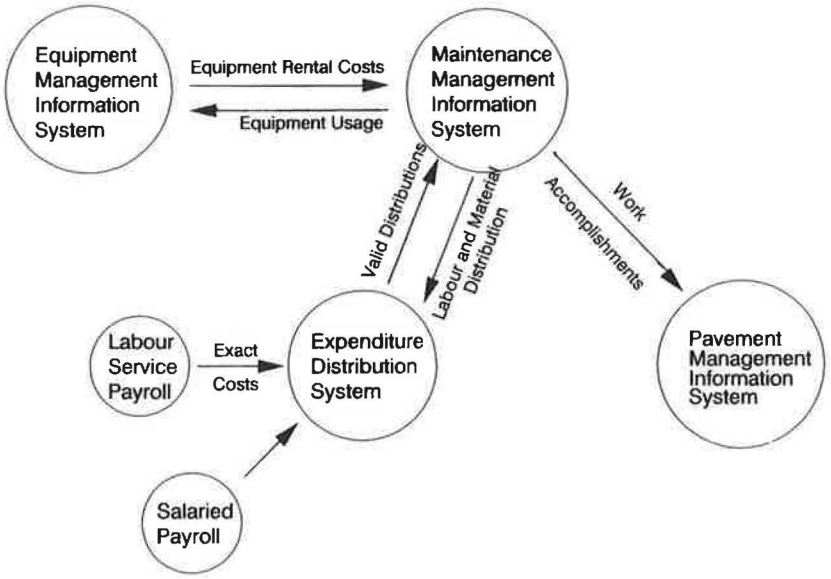

FIGURE 2 Interfaces with other systems.

tenance area and section boundaries have been digitized and preliminary reports produced.

UNIQUE FEATURES

Providing timely and accurate information required several unique solutions and compromises in system design. Although some of these may appear to reduce accuracy, it was determined that timeliness and an acceptable degree of accuracy were more important to the end users than absolute precision. An example of this can be found in the processing of accounts. An area office will record an invoice in MMIS to the nearest dollar before it is passed on to the district and eventually the head office, where it is processed through the accounting systems to the nearest cent. It is more important for the area supervisor to know costs today to the nearest dollar than two weeks hence to the nearest cent.

Other innovative solutions are found in the methods of estimating labor costs and material usage.

Labor

A major problem of the original system was that labor expenditures were obtained from the payroll system. This had two serious drawbacks:

1. It required a detailed breakdown of activities on each employee's time sheet. These were most often hastily prepared at the end of the pay period and consequently inaccurate.
2. It caused a serious lag in labor cost entries into the system.

The revised system addressed this issue by introducing a labor holding account. All time sheets are now charged to a single holding account through the payroll system. MMIS captures daily hours of productive work and charges them to the appropriate distribution at an average labor rate for each district. This method offers an immediate estimate of labor costs in MMIS. "Productive" means that only time worked is entered; costs associated with sick leave and statutory holidays are assimilated through the average labor rate.

The department's expenditure distribution system requires an accounting of actual labor costs. This is accomplished by redistributing the balance of the labor holding account using the hours and estimated labor expenditures contained in MMIS. Reports of undistributed balances between the two systems go to each district, where necessary adjustments are made to the average labor rate. The two systems must balance at the end of the fiscal year.

The concept of charging an average labor rate is difficult for persons outside the maintenance organization to understand. Use of this method and productive hours simplifies accounting for items such as sick leave, overtime, and different earning rates because of seniority. In addition, the concept of productive hours gives the true labor requirement for performing activities regardless of the pay schedules for the particular employees who did the work. This method has significantly reduced the paperwork required to allocate labor costs.

Materials

Costs to purchase materials such as asphalt, salt, calcium chloride, and beaded paint are also charged to holding accounts. These transactions are passed to the distribution system holding accounts and accumulated throughout the year as new material is purchased or produced.

Usage of materials is charged to the various distributions on the basis of a stockpile price and the estimated quantity used. Both of these are recorded in the MMIS year-to-date master file.

At the end of the fiscal year, the total purchase cost of each material in each district as reported in the distribution system is divided by the total quantity used that has been recorded in the MMIS system. This district average price is then applied

to the quantities used for each highway segment. The result is debited to that distribution in the distribution system and credited to the material holding account.

MANAGEMENT OF THE SYSTEM

The system is managed by a committee of users. The committee is composed of one representative from each district, two from Operations Services Branch and one each from Maintenance Branch and the department's data processing unit. Currently the committee is chaired by Operations Branch. The committee identifies problems with the system, recommends enhancements and revisions and determines their priority, and coordinates annual year-end and start-up procedures. The committee's role in training and encouraging uniformity of procedures may be its most important, because training of new staff is accomplished solely through job experience.

Total costs (after volume discount) for central processing and data storage for the 1989–1990 fiscal year were $62,543. Estimated communications costs, including modem rental, were $58,100, for a total estimated annual operating cost of $120,643. This amount is categorized in the following table.

Category	*Percentage*
Communications	48.1
Processing	33.6
Tape and disk storage	14.4
On-line connect time	2.0
Maintenance and development	1.9

FUTURE ENHANCEMENTS

Saskatchewan has come a long way in gaining the support of the field staff that is necessary for meaningful data input to its MMIS. Unfortunately, many area supervisors are now manually reentering data from MMIS reports into their own personal computers to track various trends and obtain summary reports. This is counterproductive and indicates that the system is not fulfilling a need. The next challenge will be to make the data more accessible so that a manager with a personal computer can tap into the system and analyze or generate custom reports.

There is considerable room to improve the accuracy of the data collected. A recent study found asphalt application rates for spot sealing to be exactly the prescribed rate of 1.50 L/m^2 in a number of maintenance areas. This was because most sections were calculating the square meters of accomplishment by multiplying the metered asphalt quantities by the application rate to determine the number of square meters of work completed.

Senior managers also want the ability to record the location of maintenance activities within a control section. The current proposal is to record the start and end kilometer locations of each day's work. Field personnel view this negatively as more, and unnecessary, data for them to collect. The trade-off for data entry would be the elimination of management unit, highway classification, and pavement type codes. The advantage would be more accurate matching of information for PMIS and the department's geographic information system.

SUMMARY AND CONCLUSIONS

Saskatchewan's strategy has been to enable its area maintenance supervisors to do their jobs effectively by providing them with the necessary information and tools. They are given clear guidance in the form of manuals containing department policies, standards, practices, procedures, and budget guidelines. They are given qualitative objectives such as ride, and finally, they are given an information management tool that enables them to manage their area efficiently.

The movement of the data entry and editing processes to area offices has made frontline supervisors responsible for their data. The system has gained their support by providing them with timely information that they need to do their jobs. The quality of information collected by the system has improved by forgoing precise data in favor of timely information.

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