

Maintenance Management System Evaluation

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ABSTRACT

A comprehensive evaluation of the Alabama Highway Department maintenance management system was performed. Performance standards, budgeting procedures, and system reports used in 33 other states were examined as part of the research. A statistical analysis of crew productivities was conducted and the potential for generating reports using inexpensive microcomputers was investigated.

Most state highway departments have sophisticated computerized maintenance management systems (MMS) that track maintenance expenditures, plan work loads, define work procedures, allocate project resources, and budget future work activities. In today's economic climate, a properly designed maintenance management system that is enthusiastically supported by field maintenance personnel is an essential tool for optimizing highway maintenance expenditures.

The primary objective of the research described here was to compare the overall capabilities and limitations of the State of Alabama Highway Department (AHD) maintenance management system with the capabilities and limitations of systems used in other states. The comparison focused on performance standards, budgeting procedures, work reporting methods, and system reports.

In the initial phase of the research investigation, a letter requesting descriptive information was mailed to the maintenance engineers of each of the 50 state highway departments. The specific request was for information that would provide a basic overview of the system, sample performance standards, and typical system reports. Thirty-three states responded with publications, manuals, reports, and sample computer program printouts.

Highway maintenance management systems typically process and store large volumes of information. The systems are therefore almost always implemented on mainframe computers. In the last few years, however, the capacity of the inexpensive microcomputer has expanded to the point where many tasks are more efficiently handled with the microcomputer. It allows an engineering manager to create reports and summarize data in a format that will be most meaningful to their own personnel. For this reason the state of the art in microcomputer data processing was briefly explored as a part of the research, and actual management microcomputer reports were generated.

The AHD MMS, like most other systems, is capable of generating a wide range of reports that summarize labor productivity and expenditures for maintenance. These reports are based on average values, however, and dispersion characteristics of cost and productivity data are generally unavailable. To examine the dispersion characteristics of representative productivity data, all maintenance operations performed by AHD during the month of June 1982 were evaluated using the standard statistical package for social sciences (SPSS) and the Auburn University IBM 3032 mainframe computer.

The results of the research were published in a report submitted to the State of Alabama Highway

Department in September 1983 (1). The principal findings are briefly summarized in this paper.

OVERVIEW OF THE AHD MMS

In February 1972 the State of Alabama Highway Department contracted with Roy Jorgensen Associates, Inc., Gaithersburg, Maryland, to develop a maintenance management system. The AHD MMS was put into operation in April 1973 with follow-up and adjustment activities continuing until March 1974. The AHD MMS is one of at least 16 state systems that have been developed by Roy Jorgensen Associates, Inc. It is a complex and comprehensive system that provides an efficient management tool for the following:

- Work program and budget development,
- Resource allocation, and
- Work scheduling and authorization.

The annual work program and budget are basically developed by computing the number of crew days per year required to accomplish a given work activity. If a quantity standard is defined as the number of units of work planned per year for a given activity (say 1 ton of premix per bituminous lane mile) and the system includes an accepted average daily crew production rate (say 5 tons per day, based on an assumed standard crew size), then the work program is developed by performing calculations of the form:

$$(\text{quantity standard}) (\text{roadway inventory}) / \text{average daily production} = \text{crew days.}$$

For example,

$$(1 \text{ ton premix per bit. lane mile}) (1,200 \text{ bit. lane miles}) / 5 \text{ tons premix per crew day} = 240 \text{ crew days.}$$

After the annual work plan has been developed, a budget and resource allocation plan can be formulated for each geographical subunit of the highway system. (For the purpose of performing maintenance operations, the Alabama state highway system is made up of nine separate geographical units or divisions. A number of districts, typically four or five, are located within each division.) A subunit within the system that has 1,200 bituminous lane miles, for example, would be allocated the resources to accomplish the equivalent of 1 ton of premix patching for each bituminous lane mile within the unit.

The maintenance work plan is authorized by issuing crew day cards (240 premix patching cards to the unit with 1,200 bituminous lane miles) for each activity. A work calendar is used for scheduling the work. The calendar shows the number of crew days of work anticipated for each activity during each month of the year.

The AHD MMS generates numerous reports for the purpose of evaluating work performance. Expenditures for each maintenance activity are compared to amounts budgeted by a division, district, and statewide. Expenditures for labor, equipment, and materials are summarized separately on the reports.

PERFORMANCE STANDARD COMPARISONS

Performance standards are one of the most essential elements of a highway maintenance management system. Most performance standards list the size crew and mix of equipment and materials that under normal circumstances, will most efficiently perform the maintenance task. Performance standards also contain information pertaining to field procedures that should be followed and the average work accomplishment that can be expected.

When reviewing performance standards from approximately 30 different states, it was noted that the basic content of the performance standards was quite similar. The recommendations for optimal crew size and equipment mix and average expected productivity values, however, were found to be quite different. Comparisons among six states for a premix spot patching activity are given in Table 1. More detailed comparisons for six other activities are given by the AASHTO Committee on Maintenance (2).

TABLE 1 Performance Standard Comparisons for Spot Patching

State	Crew Size	Equipment	Daily Productivity
Alabama	2 truck drivers 1 laborer 2 flagmen	1 hot pot 1 flat truck 1 dump truck 1 portable roller	4 to 6 tons
Arizona	1 driver/loader operator 1 worker 1 flagman ^a	1 loader 1 distributor 1 compressor 1 1-ton truck or 1 2-axle truck	1 to 4 yd ³
Arkansas	1 truck driver/worker 2 maintenance men	1 dump truck	3.3 yd ³
Georgia	5 workers including foreman	1 pickup truck 2 dump trucks 1 steel sheeled roller 1 asphalt dist. or kettle 1 air compressor	4.5 to 5.5 tons
Idaho	2-6 ^b	1 loader; 1 pickup 2 dump trucks 1 portable roller 1 asphalt kettle 1 compressor 1 pavement breaker 1 sign trailer 1 heater mixer	3 to 9 yd ³ (1.5 tons per yd ³)
Illinois	2 equip. operators/ laborers 1 flagman ^c	1 dump truck 1 small patching roller	5 to 7 tons

^a Add flagmen as required.

^b Flagmen as required.

^c Two flagmen may be required in some situations.

It is difficult to draw any conclusions from the performance standard comparisons because of the varying geographic, demographic, and climatic conditions that exist in the different states. These factors affect the recommendation for equipment and materials mix that are specified in the performance standards. An additional complication in this comparison is that not all states organize their work activities in the same manner. For example, some states consider general right of way and interchange mowing as separate activities and others do not. Centerline and edgeline striping are separate activities in some states but not in others. Comparisons of expected labor productivity are also complicated by variances in travel time (and thus productive work time), which varies as a function of the size

of the geographical subunit to which the crews are assigned.

WORK PERFORMANCE AND LABOR PRODUCTIVITY REPORTS

Most maintenance management systems generate periodic reports that are in some way related to work accomplishment, cost distribution, equipment and materials use, labor productivity, or budget status. The AHD MMS generates 15 such reports. One of the most useful is the work performance report. It is common practice to print the expenditures (or tons, man-hours, and so forth) planned for the entire fiscal year, the expenditures planned to date, and the amount actually expended to date, for each activity in each geographical subunit of the state.

Many reports are structured so that the accomplishment ratios of the various subunits can easily be compared. Some states carefully note situations when actual work accomplishment varies significantly from planned accomplishment. The Delaware Performance Exception Report, for example, prints an explanation when actual accomplishment varies more than 20 percent from planned accomplishment.

A second useful report is the report that displays labor productivity or unit cost comparisons for the various geographical subunits. The Georgia Maintenance Evaluation Report, for example, computes both unit costs and average daily productions for all districts within the state. It is not uncommon to generate MMS reports that call attention to activities that have productivities out of the normal range. The Kentucky Performance Summary Report flags productivities that exceed the standard by more than 20 percent with a single asterisk (*) and productivities that fall more than 20 percent below the standard with a double asterisk (**).

SUPPLEMENTAL MICROCOMPUTER REPORTS

When comparing Alabama MMS reports with those used in other states, no serious deficiencies or major omissions were found. It was noted, however, that the AHD reports do not readily permit unit cost or labor productivity comparisons among the various divisions or districts. The information needed to compute unit costs was being printed but the unit costs were not. This situation could be remedied by rewriting the mainframe MMS computer programs. A second alternative would be to generate productivity or unit cost comparison reports periodically on an inexpensive microcomputer. Reports of this type can be quickly written and updated using electronic spreadsheet programs such as VisiCalc.

Microcomputer spreadsheet programs provide the microcomputer user with a large tabular worksheet that consists of 254 rows and 63 columns of coordinate locations. Labels, values, or formulas are input into the worksheet coordinates by moving a cursor (lighted box) to the desired coordinate location. Formulas written for a given coordinate location may reference other coordinate designations or one of the many special functions available to the program user. Persons with no formal experience with computers or computer programming can easily generate their own customized tabular reports using VisiCalc.

A typical VisiCalc report that was created to permit productivity comparisons among AHD divisions is given in Table 2. Data from an AHD Cost Distribution Report are entered in columns B, C, D, and E of the VisiCalc worksheet. The simple VisiCalc commands are then used to compute labor, equipment, and materials costs per ton in columns F through I. The report can be continued as shown in Table 3 to compute percent deviations from statewide averages

TABLE 2 VisiCalc Unit Cost Report for Spot Patching

Div. No.	Amount (tons)	Labor Cost (\$)	Equip. Cost (\$)	Materials Cost (\$)	Labor/Ton Cost (\$)	Equip./Ton Cost (\$)	Materials/Ton Cost (\$)	Ton/Ton Cost (\$)
1	2,323	144,634	36,780	7,229	62.26	15.83	3.11	81.21
2	781	40,534	14,830	13,964	51.90	18.99	17.88	88.77
3	2,797	181,437	52,008	83,725	64.87	18.59	29.93	113.40
4	1,317	101,833	22,937	30,880	77.32	17.42	23.45	118.19
5	1,690	133,614	26,509	41,017	79.06	15.69	24.27	119.02
6	1,397	90,712	29,012	30,432	64.93	20.77	21.78	107.48
7	1,478	126,228	32,912	12,868	85.40	22.27	8.71	116.38
8	783	45,499	13,972	28,064	58.11	17.84	35.84	111.79
9	1,200	86,211	22,522	2,338	71.84	18.77	1.95	92.56
				Maximum	85.40	22.27	35.84	119.02
				Minimum	51.90	15.69	1.95	81.21
				State average	69.06	18.27	18.20	105.53
A	B	C	D	E	F	G	H	I
				(Spreadsheet Column)				

TABLE 3 VisiCalc Report Indicating Deviations from Statewide Unit Cost Averages for Spot Patching

Deviation from Statewide Averages				
Div. No.	Labor (%)	Equip. (%)	Material (%)	Total (%)
1	-10	-13	-83	-23
2	-25	4	-2	-16
3	-6	2	64	7
4	12	-5	29	12
5	14	-14	33	13
6	-6	14	20	2
7	24	22	-52	10
8	-16	-2	97	6
9	4	3	-89	-12
A	J	K	L	M
	(Spreadsheet Column)			

It should also be noted that the output from the spreadsheet package can be input into an inexpensive color plotter to create histograms for report summaries or oral presentations.

CREW PRODUCTIVITY ANALYSIS

Most maintenance management system reports focus on productivity averages. If a crew places 5 tons the first day and 7 tons the second day, an average of 6 tons per day will be reported. If a crew places 1 ton the first day and 11 tons the second day, the same 6 tons per day average will be reported. In analyzing work performance quite often the dispersion, or spread, of the new productivities is of interest.

To examine the dispersion characteristics of typical AHD maintenance productivity data, all crew day cards that were submitted statewide in the month of June 1982 were analyzed using the SPSS software. Histograms for herbicide treatment, mowing, and spot patching were generated for various combinations of road class and crew size. A typical histogram is shown in Figure 1. Plots of this type show how actual performance compares to the average expected

in columns J through M. Unit cost comparisons such as those shown may be helpful in identifying field conditions that need management attention. In many computer installations it is possible to download mainframe files directly to the microcomputer before manipulating the data or creating the custom report.

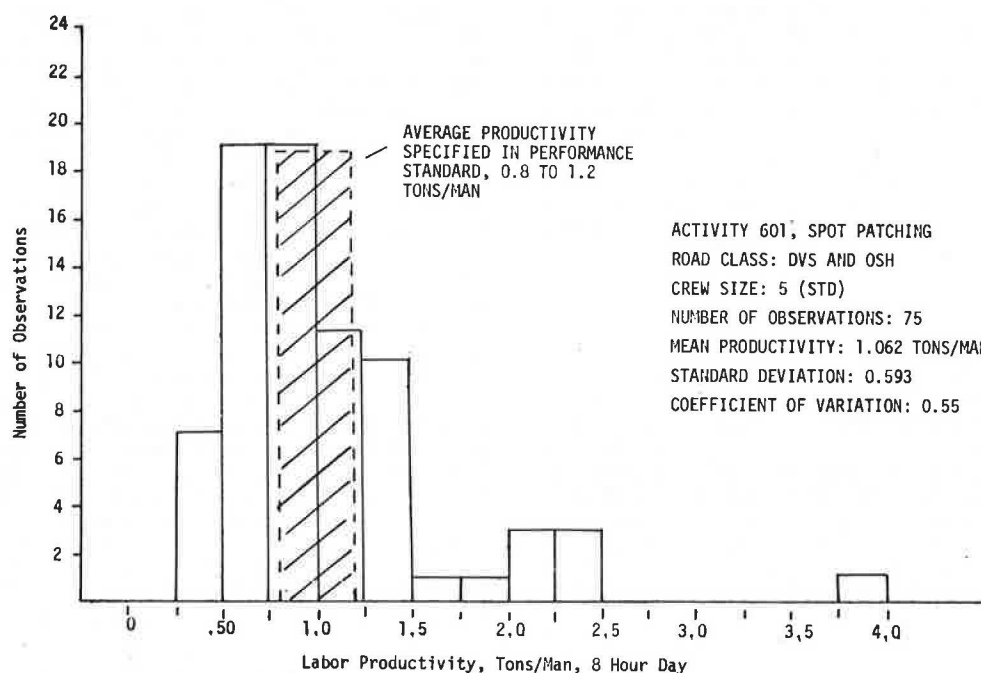


FIGURE 1 Productivity data histogram.

TABLE 4 Labor Productivity Analysis for June 1982

Activity	Road Class	Crew Size	Mean Productivity	Observations	Standard Deviation	Coefficient of Variation
625 (Mowing)	INT ^a	4 (std)	10.1 acres/man	42	4.6	0.46
	INT	5 (+1)	10.4 acres/man	22	3.5	0.34
	INT	3 (-1)	13.9 acres/man	31	4.1	0.29
	DVS ^b & OSH ^c	4 (std)	8.3 acres/man	284	3.7	0.45
	DVS & OSH	5 (+1)	7.9 acres/man	124	3.4	0.43
	DVS & OSH	3 (-1)	9.6 acres/man	147	4.1	0.43
	DVS & OSH	6 (+2)	8.1 acres/man	35	3.4	0.42
	DVS & OSH	2 (-2)	12.9 acres/man	29	6.9	0.53
626 (Herbicide)	ALL	— ^d	16.0 acres/man	64	6.5	0.41
Low-Vol. Sprayer	ALL	— ^d	51.9 acres/man	143	37.2	0.72
High-Vol. Sprayer	INT	3	22.6 acres/man	16	13.7	0.61
	INT	2	59.2 acres/man	14	36.7	0.62
	DVS	3	20.2 acres/man	62	13.0	0.64
601 (Patching)	DVS & OSH	5 (std)	1.062 tons/man	75	0.59	0.55
		6 (+1)	0.861 tons/man	61	0.34	0.39
		4 (-1)	0.990 tons/man	38	0.48	0.48
		3 (-2)	1.08 tons/man	31	0.54	0.50
		7 (+2)	0.90 tons/man	21	0.46	0.51

^aINT = interstate highway.^bDVS = divided state highway.^cOSH = other state highway.^dCrew size varies.

performance specified in the performance standards.

An indication of the dispersion of the data shown in Figure 1 can be obtained by computing the standard deviation of the observations. A more useful parameter, the coefficient of variation, can be computed by dividing the standard deviation by the mean. As shown in Table 4, the coefficient of variation remains fairly constant for all activities, regardless of the units being measured. When the coefficient of variation is quite large, say greater than 0.7, it indicates that erratic or widely dispersed productivity values are being reported. Conversely when the coefficient of variation is very small, it indicates no dispersion to the data which means the crew day cards or time sheets are probably being completed with expected rather than actual crew productivities.

Again examining Table 4, it can be seen that one AHD operation, high volume herbicide spraying, does have a coefficient of variation greater than 0.7. This means that productivity was erratic for this operation during the time period indicated. Interviews with division maintenance engineers confirmed this fact; many divisions had just begun high volume spraying and were not familiar with the equipment or sources of water to refill the tanks. It seems logical, therefore, that if the coefficient of variation was printed periodically on some MMS reports, this would help division and district engineers locate activities with potential productivity problems.

CONCLUSION

The research activities cited above resulted in a balanced, comprehensive, and objective evaluation of the State of Alabama Highway Department maintenance management system. The results of this research indicate that microcomputer spreadsheet programs can be used to manipulate efficiently MMS data and generate custom reports. It was also observed that computing indicators of productivity dispersion in MMS reports will identify field conditions that are contributing to erratic labor productivity.

ACKNOWLEDGMENT

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REFERENCES

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2. AASHTO Committee on Maintenance. Maintenance Management Survey. Maintenance Aid Digest No. 26, June 1982.

Discussion

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Mr. Bell's paper describes the results of an evaluation of the Alabama Highway Department maintenance management system (AHD MMS). The general conclusion of this research was reported to be that the AHD MMS was about as good as the maintenance management systems being used in the other states. That really does not surprise me because the maintenance management systems used throughout the United States have been designed by a handful of people. The facet of Mr. Bell's paper that is different from the other papers presented in Session 3 of the workshop is that unit cost and labor productivity are not readily available for comparison among divisions and districts within the AHD. Mr. Bell found that there were two ways of providing this needed function.

The first possible solution to the problem of missing unit costs and labor productivity output was the "people dominated" solution. Leave the procedures alone at the lower levels of operation and rewrite the mainframe computer program to calculate and output the needed information. The second possible solution identified was the "computer dominated" approach by generating the desired reports on a microcomputer using an electronic spreadsheet analysis. This is the third type of spreadsheet use presented in this session. In the first example the spreadsheet was used as a device to organize filed inventory data; in the second example it was used to

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test changes in plans to allocate resources. Mr. Bell has proposed to take data already resident in a larger computer system and do further analysis on it.

Of particular interest to me would be whether an assessment was made of the relative cost trade-off of rewriting the mainframe computer program compared with initiating an analysis system on the microcomputer to establish unit cost and labor productivity reports. Is crew productivity analysis primarily a local office management tool? If it is, has there been any assessment of the potential to conduct this analysis locally with data transmitted from the mainframe down to a microcomputer through communication terminal connections? The types of statistical analyses shown are also available on microcomputers and can be performed quite easily on the smaller amounts of data found in local engineering offices.

Although Mr. Bell's paper focuses on an evaluation of an overall maintenance management system program, it indicates that prudent use of the microcomputer has the potential to bring about changes in

the execution of highway maintenance management that could be beneficial to all. Perhaps Mr. Bell could direct some thought and remarks to the issue of exactly at what level the evaluation of maintenance management should be taking place and what role the microcomputer plays in conducting the evaluation at that level? From my own biases, I prefer the evaluation and, therefore, the management control to be at the lowest possible level. That requires me to be in favor of more computing and analysis power at the local engineering management office independent of central control.

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This report reflects the views of the author who is responsible for the facts and accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the State of Alabama Highway Department. This report does not constitute a standard, specification, or regulation.

Managing Better with PAVER

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ABSTRACT

Pavement deterioration at the Naval Training Center, Great Lakes has far surpassed the maintenance resources available to retain the network in a stable condition. Existing management practices and policies failed to provide for needed proper maintenance and repair strategies and cost-effectiveness. Because it was believed that benefits could be gained by using a structured pavement management system, the PAVER system was selected and implementation was completed in September 1982. The diverse but interrelated groups of inspectors, planners, and engineers that now use PAVER in their routine management tasks have become more efficient and effective. Managers at the network level are using PAVER to select sections for standardized inspections, quantify maintenance and repair problems, establish priorities, and formulate budgets. At the project level, attention is focused on the selection of the most cost-effective alternatives. The results have been most rewarding. A rational, dynamic, fully supportable 5-year maintenance and repair plan has been developed. The plan, which summarizes sound strategies for routine and preventive maintenance as well as major repairs, has resulted in favorable funding of needed projects. The life-cycle costing used in the design of repairs and in planning preventive maintenance will lead to considerable savings when compared to past designs, management practices, and policies.

The entire pavement network of streets and parking lots at the Naval Training Center (NTC), Great Lakes, Illinois, has been deteriorating at an increasing rate. Unfortunately the maintenance management procedures and practices used did not chart adequately the trend or provide for timely cost-effective repairs. The management process relied almost exclusively on engineering judgment. Although engineering judgment is fundamental to decision making, the various engineers and technicians lacked a systematic, quantitative procedure for identifying and analyzing pavement problems to ensure timely and cost-effective repair. This subjective approach led to standard fixes such as a 2-inch overlay. Neither life-cycle costing nor preventive maintenance was considered.

To reverse that trend a structured pavement management system (PMS) that permitted management at both the project and network levels was needed. Management at both levels is considered necessary to ensure success. Project level management considers cost-effective maintenance and repair alternatives and schemes in the formulation of given projects. Network level management establishes priorities for those projects, inventories the pavement sections, establishes budgetary needs, analyzes the current and future overall network condition, and projects annual inspection requirements. Once minimum acceptable pavement conditions are established, the management system should facilitate the forming of cost-effective maintenance and repair schemes within the limitations of the budget and provide rational justification for repair projects or additional funds. The result would be an improved, well-maintained pavement network at a lower life-cycle cost.