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

DONALD R. UZARSKI

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 Navel 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 proccess 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.

Details of such a system used by public works personnel and how the system improved management and engineering procedures are presented in this paper. The results to date are discussed.

SELECTING THE PAVER PMS

Several features were desired in the PMS to be selected. Because of funding limitations, the PMS chosen would have to be an established, low-cost system that would permit simple technology transfer. The PMS also would have to be simple enough to be maintained and used by in-house personnel.

The capability to evaluate surface distress was desired because it is the prime indicator of pavement condition and can be easily accomplished by public works inspectors. Also observed distress is strongly correlated to its cause, to other indicators of condition (e.g., skidding and roughness), and to structural deficiencies. Thus the ability to evaluate pavement distress would make it easier to focus on a proper repair. Therefore the PMS selected should permit the use of other condition and nondestructive testing (NDT) data as required.

Finally a rating index would be mandatory so pavement condition could be tracked and predicted over time. Accordingly the PAVER PMS was chosen as the system that most nearly fulfilled the requirements. The technical aspects of PAVER, which are beyond the scope of this paper, are well documented (1-3).

IMPLEMENTATION

Implementation began in November 1980 and was completed in three phases that eventually included all paved areas on the base. The consulting firm of ERES Consultants, Inc. was employed to assist in the implementation process. The contract work cost approximately $130,000 and took 2 years to complete.

The initial data collected consisted of pavement structure, traffic, construction history, and pavement rank information. Based on these data and geographical layout, the 200 lane-mile network was ultimately divided into 604 unique sections. Unfortunately, and this is typical of most communities, much of the information on pavement structure and maintenance history was unavailable. Therefore assumptions and extrapolations had to be made. Limited corings and nondestructive testing (NDT) were used to verify the pavement structure for many of the sections. Once the sections were finalized and secondary structure and drainage data were collected, an initial standardized inspection was performed and a pavement condition index (PCI) was calculated for each section.

The remaining implementation activities included establishing a maintenance policy for each PAVER distress type and severity level, developing a repair alternative decision tree (which will be discussed later), developing a priority scheme, and establishing an initial 5-year maintenance and repair plan. Complete details of the implementation activities and procedures have been well reported (4-6).

TRAINING

PAVER did not require additional personnel or alter the duties and responsibilities of the existing engineers, managers, and technicians. Specific training was needed, however, to ensure acceptance and proper, efficient use by the in-house staff. Supervisory and technical personnel attended the 3-day PAVER course offered by the Corps of Engineers at the University of Illinois. Other technical and clerical personnel received on-the-job training by the consultant on data collection techniques and computer terminal use, as appropriate.

Most importantly, the consultant prepared user manuals tailored for each specific user group as they interrelated in the pavement management process. Each group was trained with manual in hand on his or her role as it related to pavement management. Emphasis was placed on report generation and, especially, report interpretation as an aid in the judgmental decision-making process. Training averaged 2 days for most personnel. In addition the pavement inspectors receive annually a half day of refresher training on distress identification before the beginning of the inspection cycle.

COMPUTER HARDWARE AND SOFTWARE

Currently PAVER is run on a mainframe computer by Boeing Computer Services. This requires the user to interface on a time sharing basis. Virtually any desk top terminal or microprocessor with modem and appropriate communications software packages can be used. Several different local systems have been used at NTC Great Lakes.

USE OF PAVER

When all available data were loaded into the computer, an initial assessment of all sections had been made, and personnel trained, PAVER became an indispensable tool for managers. Management workflow procedures as shown in Figure 1 have not been changed, but PAVER has had a profound effect on the productivity and quality of the day-to-day management efforts. The remainder of this paper is a discussion of how PAVER, with its wide variety of reports, specifically aids those users. Table 1 provides a listing of all PAVER reports along with a short descriptive title. Many of the reports will be referred to throughout this paper. Detailed discussions of PAVER reports are presented elsewhere (2,3).

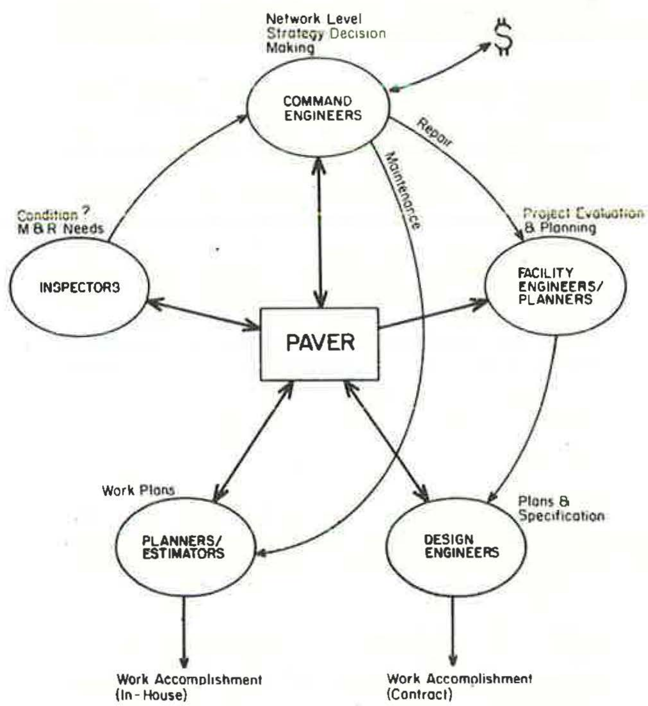


FIGURE 1 Management workflow.

TABLE 1 PAVER Reports

PAVER Report	Title
LIST	List of Branches
INV	Inventory of Pavement Sections
INSPECT	Summary of PCI and Distress Information for Pavement Sections
SAMPLE	Detailed Summary of PCI and Distress Information for Pavement Sections
WORKREQ	Work Requirements for Pavement Sections
WORKHIS	Past Work Performed on Pavement Sections
RECORD	Non-Inspection Data on Pavement Sections
POLICY	Distress Maintenance Policy
PCI	List of Section PCIs Ranked by PCI (low to high)
PCIA	List of Section PCIs in Alphabetical Order
INSPCUR	Summary of Latest PCI and Distress Information for Pavement Sections
SAMPCUR	Detailed Summary of Latest PCI and Distress Information for Pavement Sections
FREQ	PCI Frequency
BUDPLAN	Budget Planning
SCHED	Inspection Schedule
CNDHIST	PCI History for a Section
MRG	M&R Guidelines, Localized Repair, and Overlay Cost for a Section
ECON	Economic Analysis Report
ECON 1	Economic Analysis Report with Uniform Annual Cost
VOL 7	PCI Prediction of Airfield Pavements
PREDICT	Prediction of Individual Distresses
EVAL	Recommended Feasible Alternatives for Airfields
CONLOC	Consequence of Local Repair
BENEFIT	Benefit Analysis for Airfields
BUDOPT	Budget Optimization
ANALOC	Analysis of Localized Repair, PCI After Repair Report and MRG Report
PCICALC	Calculate PCI from Data on File TAPE70 Without Entering the Data into the Data Base
PCICHEC	Check TAPE70 for Format Errors
PCIRES	Print Results from PCICALC

NETWORK LEVEL INSPECTION

Pavement inspectors have become a critical link in the facilities management process at the network level. The first use of PAVER in the annual cycle is to identify which sections to inspect in a given year. For this, the inspection scheduling (SCHED) report is used to list the sections to be inspected. The input data required are a minimum PCI (below which the section should be inspected) and the maximum number of years that should elapse between inspections depending on the rate of deterioration. With the list in hand, copies of the section identification records (Figure 2) are obtained for the files and reviewed.

At the network level, the purpose of the inspection is to ascertain the general condition of each section so that a maintenance and repair strategy can be formulated. To minimize inspection hours, statistical sampling techniques were used to select the sections to be inspected. Approximately 20 percent of the sample units were chosen for inspection through systematic random procedures. Also before going out into the field, a daily inspection route is planned. This maximizes efficiency in the field.

With the inspection plan prepared, the inspection teams, consisting of one or two members, are ready to do the actual inspections. The inspectors take copies of the identification records into the field to aid in locating the sections and sample units. To aid the inspectors, the limits of the sections and sample units are painted on the curbs or edge of pavements. Each inspector also takes along a copy of the distress identification manual (2) to ensure that consistent standardized procedures are followed.

ROAD SECTION IDENTIFICATION RECORD
GI-PWC-10-11210/2 (2-82) 19650

Installation Name	Date	Branch Name	Section Area	Number Of Sample Units	Section Number
Great Lakes	07 14 81	ILLINOIS STREET (ILLI)	29 Feet Wide x 1119.5 Feet Long; 3573 Square Yards	13	01

Zone		Traffic Types and Uses		General Information		
				Curb and Gutter	Sidewalks	Surface Type
○ PWMT	○ RTCM	● Vehicular	● Primary	● Left	○ Left ___ ft.	○ PCC
○ PWUT	○ SSCM	● Real Property	○ Secondary	● Right	● Right 10 ft.	● AC
○ PWOT	○ NRMC	○ Family Housing	○ Tertiary	○ None	○ None	○ Surface Treatment
● ADCM	○ HSNG		○ Parking – Storage			○ Other
○ OTHR ______			○ Other			

Sketch
On sketch: note any subsurface drainage structures (type, location) and secondary structures, such as manholes, water shutoffs, etc

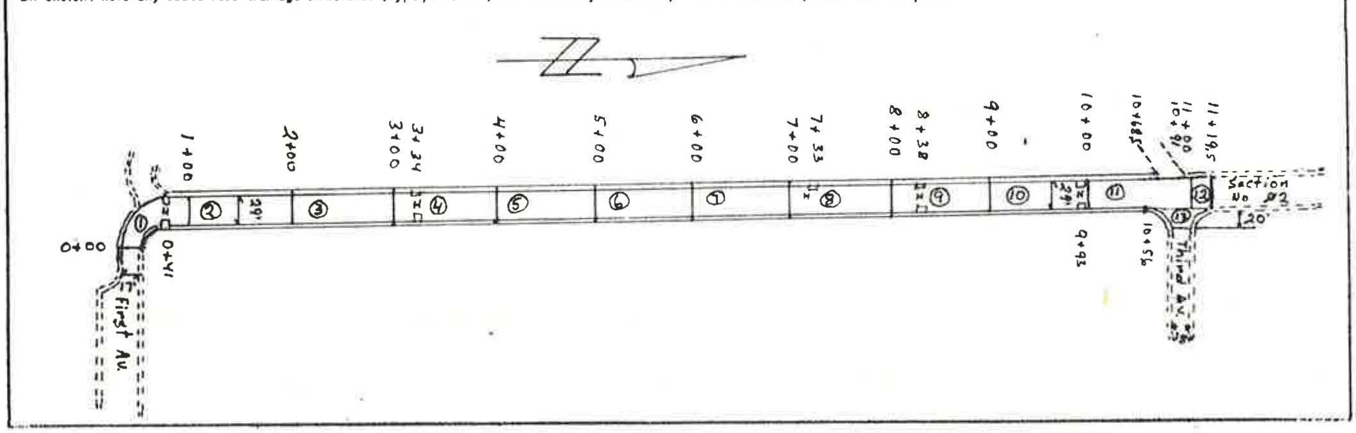


FIGURE 2 Section identification record.

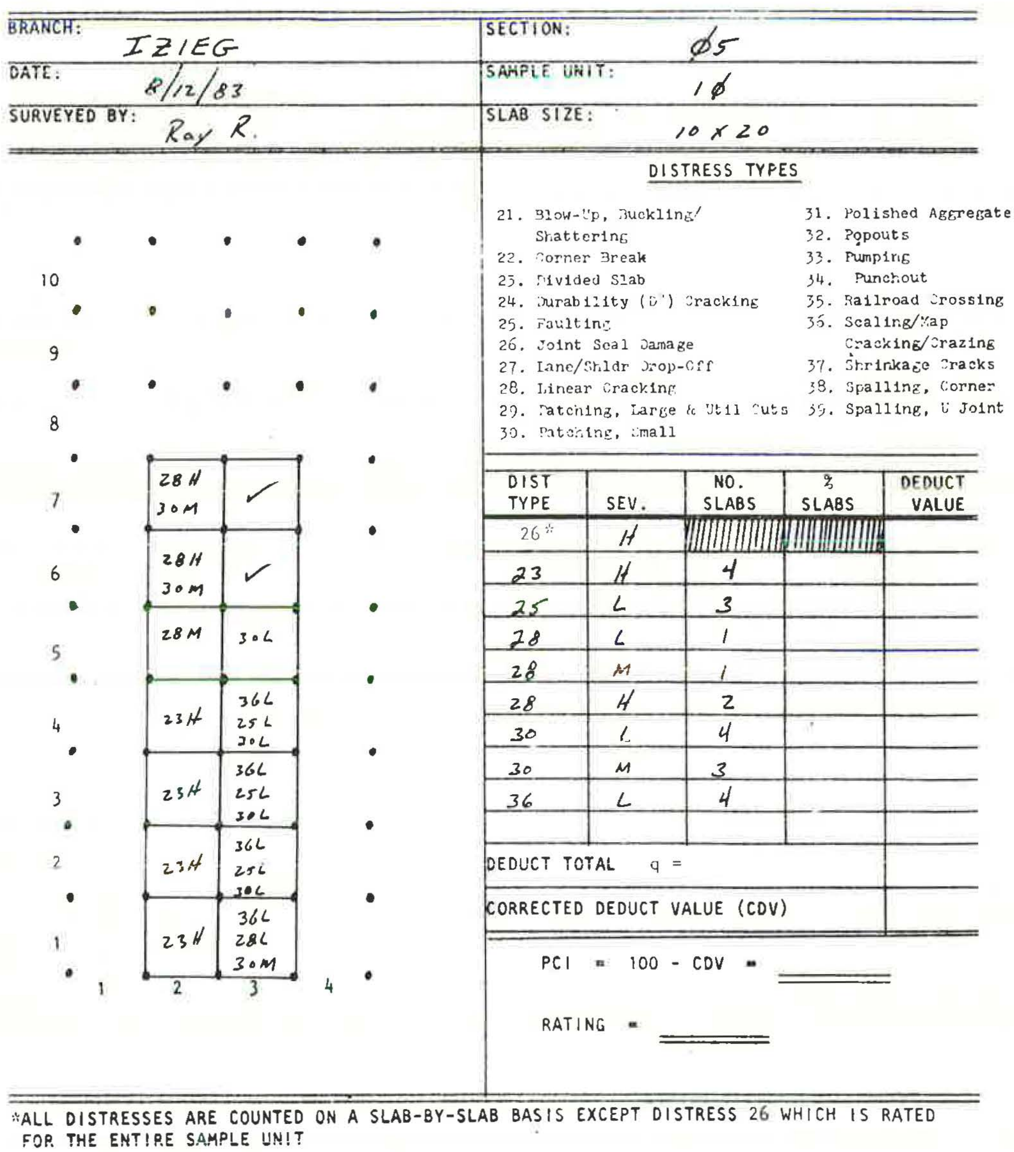
When the section to be inspected is located, it is first walked end to end for a quick determination of whether the surface distress is uniform, localized, or has systematic variation throughout the section. If the distress appears to be uniform, the previously selected sample units are inspected. If variation in distress appears to exist, specific additional sample units are inspected so a more representative section PCI can be calculated and the variation can be properly catalogued.

Figures 3 and 4 represent completed inspection sheets for concrete and asphalt surfaces, respectively. A sheet is completed for each sample unit inspected. For the examples shown in Figures 3 and 4, the concrete sample unit consists of 20 slabs and the asphalt sample unit of 2,450 square feet. For the concrete sample unit, each slab is inspected and the type and severity of the distresses indicated on the sketch. These are then summarized in the table. Distress is counted on a slab-by-slab basis. For the asphalt sample unit, distress type and severity are marked on the sheet as they are was encountered. Measurements are in either square feet (SF) or linear feet (LF) depending on the distress type. The sheet shows distress type as a circled number under which the amount and severity are recorded. A severity level listed more than once for a distress type indicates that the distress was encountered more than once in the sample unit.

While inspecting each sample unit, the inspection team also collects other pertinent information including the condition of the curb and gutter, curb height remaining, catch basin condition, and so forth. This information will be used later in formulating a maintenance and repair strategy.

PRELIMINARY EVALUATION

The collected inspection data are given to a clerk who codes and loads them into the data base; then the detailed inspection results (SAMPCUR) and condition history (CNDHIST) reports are generated. SAMPCUR allows the inspector to compare the data actually entered into the data base with his field notes and also provides section PCI, PCI variation information, and the percentages of distress attributable to load, climate, and other. The CNDHIST report gives historical PCI versus time plot and predicts, by extrapolation, what the PCI will be in 5 years.



BRANCH: IZIEG
SECTION: Ø5
DATE: 8/12/83
SAMPLE UNIT: 1Ø
SURVEYED BY: Ray R.
SLAB SIZE: 10 X 20

DISTRESS TYPES

21. Blow-Up, Buckling/Shattering
22. Corner Break
23. Divided Slab
24. Durability ("D") Cracking
25. Faulting
26. Joint Seal Damage
27. Lane/Shldr Drop-Off
28. Linear Cracking
29. Patching, Large & Util Cuts
30. Patching, Small
31. Polished Aggregate
32. Popouts
33. Pumping
34. Punchout
35. Railroad Crossing
36. Scaling/Map Cracking/Crazing
37. Shrinkage Cracks
38. Spalling, Corner
39. Spalling, Joint

DIST TYPE	SEV.	NO. SLABS	% SLABS	DEDUCT VALUE
26*	H			
23	H	4		
25	L	3		
28	L	1		
28	M	1		
28	H	2		
30	L	4		
30	M	3		
36	L	4		

DEDUCT TOTAL q =

CORRECTED DEDUCT VALUE (CDV)

PCI = 100 - CDV =

RATING =

*ALL DISTRESSES ARE COUNTED ON A SLAB-BY-SLAB BASIS EXCEPT DISTRESS 26 WHICH IS RATED FOR THE ENTIRE SAMPLE UNIT

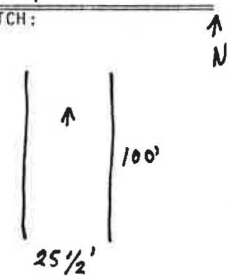
FIGURE 3 Concrete pavement inspection sheet.

FACILITY: IMDON	SECTION: 02
DATE: 7/26-83	SAMPLE UNIT: 06
SURVEYED BY: Ray R.	AREA OF SAMPLE: 2450 sf

DISTRESS TYPES

1. Alligator Cracking
2. Bleeding
3. Block Cracking
*4. Bumps and Sags
5. Corrugation
6. Depression
*7. Edge Cracking
*8. Jt Reflection Cracking
*9. Lane/Shldr Drop Off
*10. Long & Trans Cracking
11. Patching & Util Cut Patching
12. Polished Aggregate
*13. Potholes
14. Railroad Crossing
15. Rutting
16. Shoving
17. Slippage Cracking
18. Swell
19. Weathering and Raveling

SKETCH:



EXISTING DISTRESS TYPES

	1	6	7	10	11	19
	16 M	12 M	50 H	25 M	770 L	1680 M
	6 H		20 L	12 L		
	24 M		30 M	35 M		
	18 M		20 M	58 M		
			30 L	36 M		
TOTAL SEVERITY L			50	12	770	
TOTAL SEVERITY M	58	12	50	154		1680
TOTAL SEVERITY H	6		50			

PCI CALCULATION

DISTRESS TYPE	DENSITY	SEVERITY	DEDUCT VALUE
DEDUCT TOTAL			
CORRECTED DEDUCT VALUE (CDV)			

PCI = 100 - CDV =

RATING =

FIGURE 4 Asphalt pavement inspection sheet.

These reports are used by the inspector to prepare the pavement evaluation summary sheet, Figure 5. This sheet simply consolidates the pertinent inspection information needed in developing a maintenance and repair strategy.

IDENTIFYING PRELIMINARY MAINTENANCE OR REPAIR REQUIREMENTS

The next step for the inspector is to determine preliminary maintenance or repair requirements for each section. The basic criteria for determining whether or not major repair or preventive or rountine maintenance is warranted is the minimum acceptable PCI and pavement rank. For primary and secondary roads, this minimum acceptable PCI is 60 and for tertiary roads and parking lots, the minimum acceptable PCI is 40. These are target numbers used to ensure that sections remain functional while at the same time minimizing repair costs. Should the current or projected 5-year PCI be below the minimum, the section is a candidate for major repairs. If the PCI is above the minimum, the section is a candidate for routine or preventive maintenance.

Should major repairs be warranted within 5 years, flow diagrams are used to help focus on a proper, economical repair. Diagrams exist for each pavement type, rank, and PCI grouping below the minimum acceptable. Figure 6 is an example of the flow diagram for primary pavements that are asphalt concrete over portland cement concrete (PCC) and have a PCI of less than 25. Each diagram displays feasible repair alternatives with a complete life-cycle cost analysis for the specific conditions present. The alternatives and the cost analysis were formulated by the consultant in the implementation process. Based on the consultant's judgment, alternatives were developed after studying the various pavements at NTC Great Lakes. The alternatives take into consideration factors such as patching, PCC slab deteri-

I FARR Ø1

PCI: 38	RATING: Poor	M&R ZONE:

PCI VARIATION	✓	UNIFORM		LOCALIZED		SYSTEMATIC
PCI RATE OF DETERIORATION						
LONG TERM		LOW	✓	NORMAL		HIGH
SHORT TERM		LOW		NORMAL	✓	HIGH

DISTRESS EVALUATION	CAUSE	PERCENT DEDUCT
	LOAD	24
	CLIMATE	72
	OTHER	4

STRUCTURAL CAPACITY DEFICIENCY		NO	✓	YES				
SURFACE ROUGHNESS	✓	MINOR		MODERATE		MAJOR		
SKID POTENTIAL	✓	NONE		NOT DEFINED		EXISTS		HIGH
PREVIOUS MAINTENANCE	✓	LOW		NORMAL		HIGH		

EFFECT ON MISSION

Curb + Gutter filled with AC. This section is busiest on base. Pavement beginning to show structural failure resulting in high short term deterioration. Section reopened to truck traffic this past year.

19648

FIGURE 5 Pavement evaluation summary.

oration, and joint transfer. Proposed overlay thicknesses were based on traffic data and measurements of deflections taken from a large sampling of pavement sections by using the falling weight deflectometer (FWD). To keep the costs and life-cycle cost analysis current, each alternative is reanalyzed annually by the engineering staff.

To choose the proper repair alternative, the inspector, by using the evaluation summary, simply follows the appropriate flow diagram until he locates the repair with the lowest average annual cost per square yard. Once obtained, the inspector multiplies the initial cost per square yard by the area of the section to obtain an estimate of the repair costs. Additional costs are added to accommodate other repairs to sidewalks, curb and gutter, and so forth noted during the inspection. The recommended fiscal year for repair is the year in which the section PCI drops below the minimum acceptable.

A similar procedure is used for determining preventive maintenance needs over the next 5 years. Flow diagrams (for an example see Figure 7) were also prepared by the consultant to aid in determining the preventive maintenance requirements. The basic information needed for the diagram is available from the pavement evaluation summary, Figure 5, and work history (WORKHIS) report. Unit costs are estimated. Total costs are obtained by combining unit costs with the area of the distress or the area of the section, as appropriate. The fiscal year recommended for accomplishment depends on the age of the pavement.

Routine maintenance requirements are obtained from the maintenance and repair guidelines (MRG) report. This report matches a previously established maintenance policy to the extrapolated distress for each inspected section and provides an estimated total cost. Routine maintenance work to be accomplished in the next fiscal year is recommended.

The inspection cycle is completed when the required work and costs per section are summarized and loaded into the computer data base. Finally a computer-generated work summary (WORKREQ) report is generated and forwarded along with the other PAVER reports and the evaluation summary to a command engineer. These reports assist in forming strategy

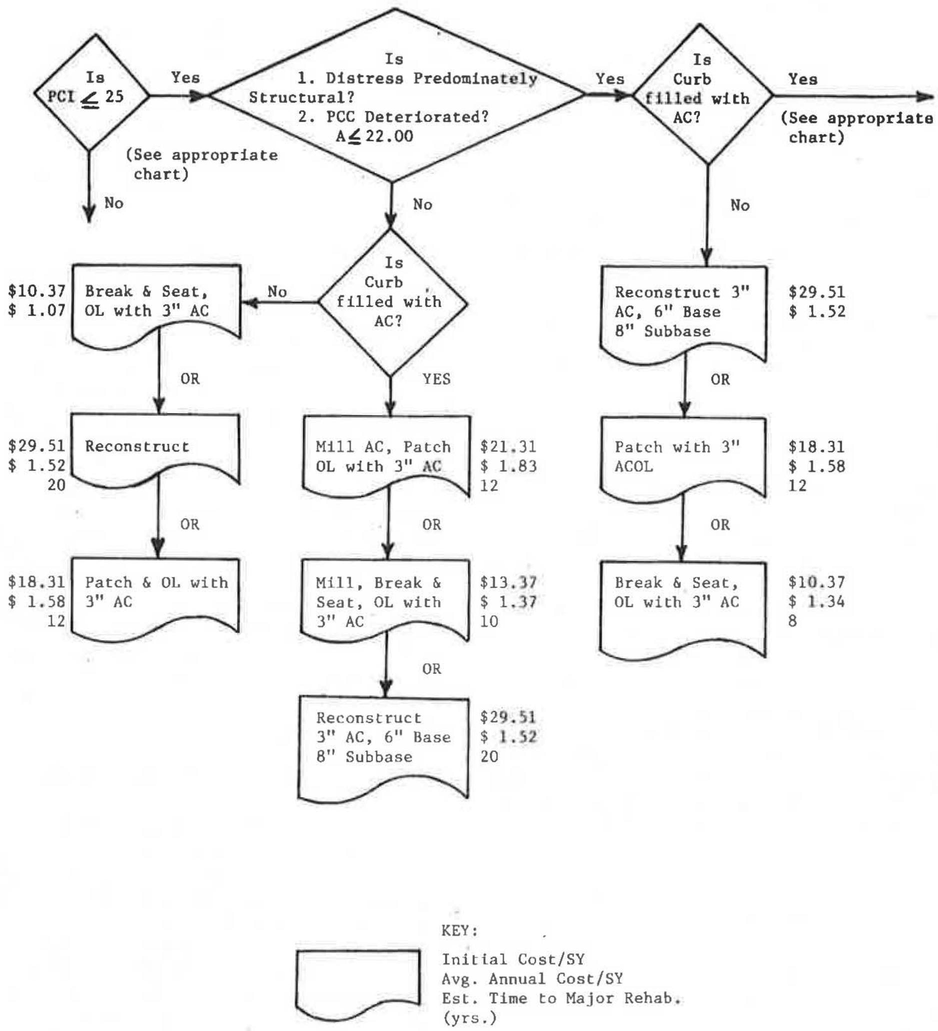


FIGURE 6 Major repair flow diagram.

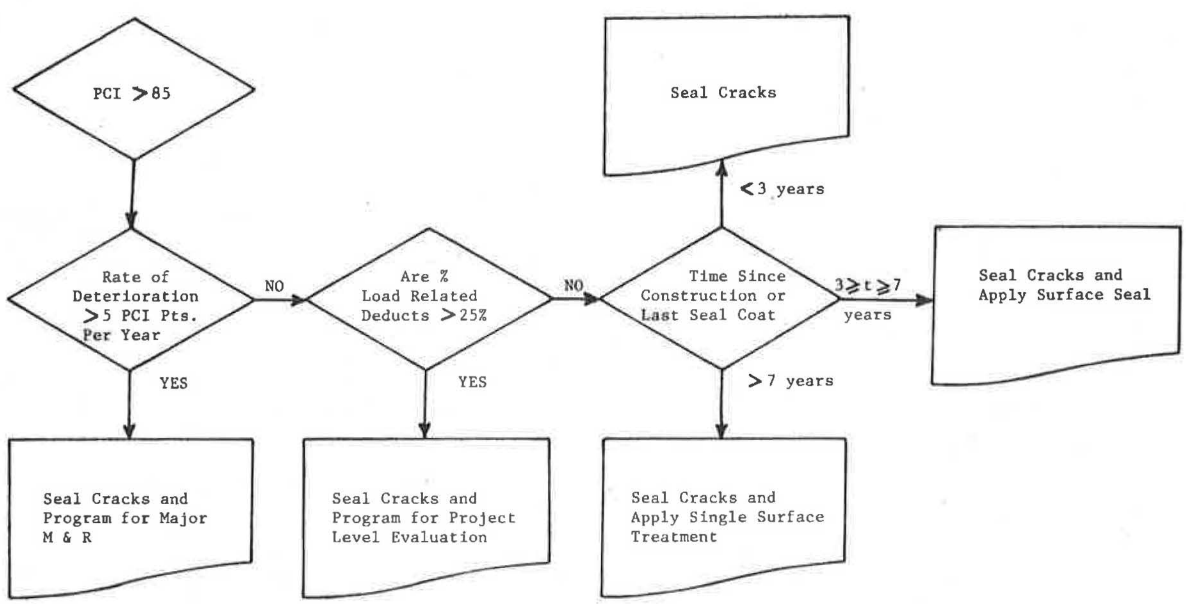


FIGURE 7 Preventive maintenance flow diagram.

at the network level. All of the tasks described for the inspectors take approximately 1.5 hours per inspected section per year.

FORMING STRATEGY AT THE NETWORK LEVEL

When the inspection reports are received by a command engineer, each is reviewed and the 5-year maintenance and repair plan is updated. This is generally based on the inspector's recommendation but can be adjusted, as appropriate, by the engineer. This 5-year network planning encompasses several tasks. Priorities are set for appropriate maintenance and repair of the sections; the sections are grouped into logical projects; budgets and justifications are prepared; and the decision to execute the plan is made.

Setting Priorities

Sections requiring major repairs could be funded from the local budget at the discretion of the command engineer or could be grouped into a large project requiring approval and funding from a higher authority. Projects over $75,000 must go to the higher authority. Additionally, for pavement repairs, the higher authority generally prefers to put a monetary ceiling on each project. Keeping the major repair projects fenced in this way provides flexibility in funding and in geographical grouping.

The result of limiting the maximum costs on a given project is that projects have been identified but not accomplished until there is now a backlog; thus priorities must be established. By using the scheme shown in Figure 8, a priority is set for repairs. For example, primary road sections in "failed" condition are grouped until the monetary ceiling is reached; at that time a second project is created. If there are not enough primary "failed" sections to reach the ceiling, those primary sections that are "very poor" are added and so on. When all candidate projects are formed, they are plotted on the station map showing all sections. Using engineering judgment, sections are then adjusted between projects to accommodate geographical criteria, work type, and political considerations.

PCI	RANK		
	PRIMARY (1)	SECONDARY (2)	TERTIARY (3)
GOOD 70 - 56	10	13	X
FAIR 55*- 41	7	11	14
POOR 40 - 26	4	8	12
VERY POOR 25 - 11	2	5	9
FAILED 10 - 0	1	3	6

*50 - 41 FOR TERTIARY

FIGURE 8 Priority scheme.

Budgeting

Preparing a budget for maintenance and repair of the network is a crucial management step for the command engineers. Although a meaningful budget can be prepared from the inspection reports by summarizing the estimated costs for the fiscal year desired, the budgeting planning (BUDPLAN) report is more efficient and allows more flexibility in analyzing the data. By inputting an average cost per square yard for repair at various PCI levels for each surface type and by setting minimum PCI levels, a 5-year projected budget can be obtained. The costs per square yard are developed from costs obtained from the inspection reports. BUDPLAN works equally well for projecting costs of routine and preventive maintenance and those for major repairs. The flexibility and efficiency of BUDPLAN enable the budget planner to analyze the effects of a planned gradual increase or decrease in maintenance level for various minimum PCI levels.

Justification

Major repair projects and budgets will not be approved unless they are fully justified. Several PAVER reports can aid the command engineers in this purpose. One report in particular, the frequency (FREQ) report, provides in a graphic display or a listing of the overall network condition at any future time for the "do nothing" alternative for major repairs and "continue historical" alternative for routine and preventive maintenance.

Unfortunately at this time, a graphic display showing the effects on network condition by doing major repairs or increasing maintenance cannot be produced directly from PAVER. It can, however, be developed manually by using information from other PAVER reports. (Figure 9 is an example.) Specific reports that aid in the process are the PCI after repairs (ANALOC) report, consequences of local repair (CONLOC) report, condition history (CONDHIST), and the frequency (FREQ) report. All of these reports provide a predicted PCI based on certain criteria.

Execution

A major task for each command engineer is executing the local budget. Whether or not the budgeted amount is actually available will determine local strategy for the current year. If the actual budgeted amount is available for maintenance and repair, the current year's portion of the 5-year plan is executed. Situations may arise, however, when the amount of funds available for pavements in a given year is less than required. This may be due to underfunding by higher authority or to reprogramming of funds for repair to other facilities. When this occurs, a decision must be made on what work to do and what work to defer.

For sections needing major repairs that are to be funded locally, the priority scheme previously discussed is used. Also, for those sections, an analysis can be made at the project level to determine whether to continue with the original plan of repairing for a resulting "excellent" condition or to embark on a plan of temporary or interim repairs.

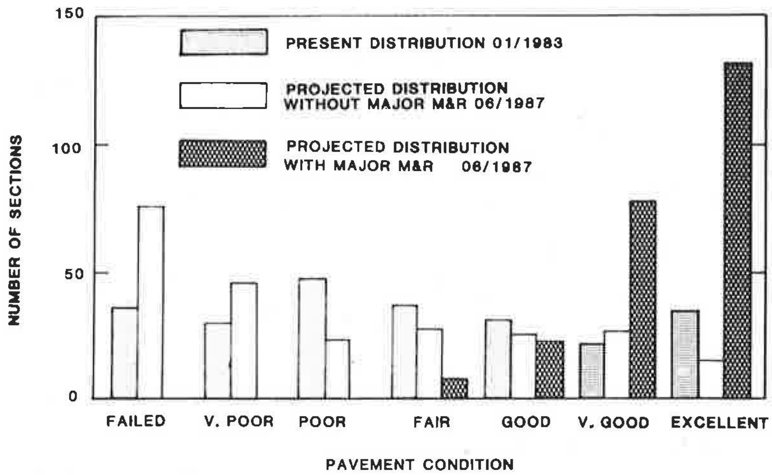


FIGURE 9 Condition histogram.

The PCI after repair (ANALOC) report is used to determine the rise in PCI and costs for a given local repair. The consequences of local repair (CONLOC) report can be run to help estimate the life of the repair in terms of loss in PCI, and an economic analysis (ECON or ECON1) can be run to analyze costs. The same procedure is used for sections needing minor repairs. Because preventive maintenance work is considered vitally important in preserving the investment and useful life of pavement sections, the current policy is not to defer such work.

Even though the above procedures provide considerable assistance to the command engineer, he must still use judgment in deciding how to allocate available funds; and it remains unknown whether optimum use is made of those funds. Although minimum life-cycle costs are weighed heavily in this decision process, a true benefit analysis has not been accomplished. To help rectify this, the benefit analysis (BENEFIT) report which calculates the weighted area under the PCI-time curve and the budget optimization (BUDOPT) report which matches benefit to least cost are used. Because the benefit program was developed for airfields, some revision was required before it could be adapted to roads and streets. The revisions took the form of modifying the utility values or "levels of satisfaction" that weigh the true area under the PCI-time curve. Revised utility values have been developed for NTC Great Lakes and are being field tested. If successful, BENEFIT and BUDOPT will provide powerful tools for determining the optimum use of available funds. A detailed discussion of these concepts has been published. (7).

PROJECT LEVEL EVALUATION AND PLANNING

Once major repair projects are approved by higher authority, or command engineers as appropriate, facility engineers/planners or consultants make a detailed project evaluation. At this stage each section is critically evaluated to assess the nature and cause of the distress, a most reasonable repair is identified, the key project elements are planned, and a fundable estimate is prepared.

Site visits to each section are essential to gain first-hand knowledge of the true condition, and detailed standardized inspections are made when necessary. At this stage sampling procedures are not used as virtually 100 percent inspection is necessary to obtain a true PCI, conduct the distress evaluation, and accurately quantify repair requirements. Standard inspection procedures as previously discussed apply.

Maximum effort is expended in ensuring that the most cost-effective alternatives are chosen. This analysis is required at the project level because the flow diagram alternatives considered at the network level represent only generalized conditions.

All available data must be reviewed and a listing of all feasible alternatives compiled to determine the best solution per section. Historical distress and PCI information is available from the PAVER inspection history files (SAMPLE or INSPECT reports) plus the information gathered from the on-site visit. Other nondistress information such as traffic, secondary structures, pavement structure, and so forth is obtained from the nondistress information (RECORD) report.

Feasible alternatives are compiled from the flow diagrams previously discussed, the feasible alternatives (EVAL) report, guides and texts, and engineering judgment. Life-cycle costs are calculated for the feasible alternatives and are analyzed by using the economic analysis (ECON or ECON1) report. The most economical life-cycle cost solution is generally chosen. As this progresses section by section for the project, occasionally the solution for a given section is altered for practical reasons. For example, a project might consist of repairs to seven sections where six sections have the economical solution of cold milling and overlay and one section calls for surface recycling. If that odd section were small, it would not be practical or economical to have a contractor bring in recycling equipment. An overlay similar to that for the other six sections would be more practical.

Consultants are occasionally employed to aid in the evaluation process. Generally, this would be dictated by one of three situations: (a) an excessive engineering workload, (b) a need for nondestructive testing (NDT) data for analyzing the condition of overlayed PCC slabs and to serve as a basis to determine overlay thicknesses for flexible pavement sections, (c) an overly complex project may need a consultant to analyze the sections and develop the project documentation.

The importance of traffic data to proper evaluation and design is clearly recognized. This information is collected by the facility engineers or planners but not on a project-by-project basis. Total vehicle and truck counts and surveys for the entire network are completed approximately every 3 years.

PROJECT DESIGN

Ultimately, all projects, other than those for routine maintenance, reach a design engineer's desk. These engineers prepare final design drawings and documents for contractor or in-house completion. All data used by facility engineers are provided to the design engineer. The facility engineering effort is reviewed and altered, if necessary. Because a project may not go to design for 2 or 3 years after the project has been developed, some additional analysis is always necessary. The pavement will have deteriorated further even though the preliminary design is based, in part, on predicted future conditions. Life-cycle costs remain of prime importance.

The additional inspection discussed earlier becomes useful in the design stage. It is used to quantify patching requirements, drainage problems, and so forth so they can be properly indicated and accounted for in the contract drawings and documents. This inspection also helps in the analysis of local (within section) engineering problems requiring a specific or unique design solution. All data collected are entered into the data base.

ESTIMATING COSTS AND PREPARING WORK ORDERS FOR IN-HOUSE PROJECTS

Planners and estimators also use PAVER. Occasionally in-house forces will be tasked to do major repairs to a section. In this case, the design engineer will have done the additional inspection and design based on the procedures previously discussed. All that remains for the planner or estimator is to translate the effort into a work order. The work order breaks the project into labor hours by trade, identifies material requirements, and sequences the work.

Generally in-house work consists of routine and some preventive maintenance. This work does not require any additional engineering effort other than that established for the preventive maintenance plan and maintenance policy of a given work type for a given distress type and severity level (POLICY). For example, medium-severity alligator cracking will be deep patched. Because this type of work is preengineered, the cost estimator receives this project directly from the command engineer.

At this stage the sections requiring maintenance will have received only the network level (20 percent) inspection, and accordingly a project level inspection must be made. The additional inspection is performed to determine the true PCI, to gather more accurate information, and to estimate work quantities on the distress to be corrected. Once the data are collected and loaded, the maintenance and repair guidelines (MRG) report is used to develop the job plan. The MRG report provides a detailed breakdown of work quantities and estimated costs.

If the results of the additional inspection indicate, based on PCI, that major repairs are needed instead of the planned routine maintenance, the estimator is responsible for making the decision to contact the command engineer for a clarification of strategy. The section may remain for interim repairs or be withdrawn and placed in a major repair project.

The planners or estimators prepare one final type of work order used in managing pavements at NTC Great Lakes. Recognizing that potholes form rapidly in the spring and need quick repair, the estimator prepares a standing or open-end work order for pothole repairs. The use of PAVER has no bearing on this strategy. At a later date the inspectors recognize the patches as a distress, and the patching work is noted and entered into the data base, which keeps the history file up to date.

PAVER BENEFITS

The need for a structured pavement management system at NTC Great Lakes was obvious. Procedures are definitely improved and there have already been many benefits.

Strategy

Based on PCI and the rate of deterioration, sections are classified by whether they need routine maintenance or major repair. Sections are flagged as to when such work should be accomplished. Sections needing repair are grouped into logical projects and each section receives a proper design. With the aid of the computer, the engineering effort is much more efficient and less subjective. At NTC Great Lakes, the inspection performed during the initial implementation indicated repair needs totaling $3.3 million for roads and streets. A logical repair program of several projects was quickly developed. With the aid of PAVER, the facility engineers and planners developed one such project for $800,000 in a matter of hours when funding became imminent. Also, strategy now places emphasis on life-cycle costing and on preventive versus corrective action.

Budgeting

PAVER was used for the first time in developing the budget for fiscal year 1984. The budget was based on quantified projected needs and was developed in a fraction of the time normally expended.

Justification

Knowing the current overall network condition and its projected condition is an invaluable parameter in justifying budgets and projects. This quantification of conditions versus the usual subjective and vague approach has been a prime factor in NTC Great Lakes currently receiving from higher authority the funds needed to execute the 5-year plan for road repairs.

Priorities

Priorities for sections and projects are now based on rational thought and logic. This has been a tremendous asset for the command engineers in convincing the commanding officers, who are not engineers, that work is accomplished based on identified need.

Data

Because all available pavement data were collected and loaded into the PAVER data base during implementation, an as-built condition has been recorded in the data base. This will prevent data from being lost in the future. Additionally countless manhours are saved by not having to search scattered files for pertinent data during the process of developing and designing the projects. This has permitted the engineers to spend more time in analyzing alternatives.

Monetary Savings

Implementing and operating PAVER has, and continues to, cost money; but those costs are being amortized through proper design, timely recognition for needed maintenance and repair, and logical project development. The savings are primarily through cost avoidance due to eliminating waste of overdesign and the cost of premature repairs due to underdesign. This was clearly demonstrated in the design process for the current $2 million received for road repairs. Traditional designs that previously would have been accepted were independently considered and compared to alternatives developed with the aid of PAVER. The traditional designs did represent both overdesign and underdesign for given sections and proved to be costly.

Additionally by using a minimum acceptable PCI, sections are flagged for repairs in a timely fashion. Identifying sections that need major repairs and accomplishing those repairs before complete failure will also save considerable money. Repair costs increase in a curvilinear relationship with decreasing PCI. Logical project development groups sections into efficient construction projects of similar work and geographical confines. That should keep bid prices down.

MANAGEMENT CONCLUSION

Finally, the investment for PAVER, which consists of the $120,000 implementation cost and approximately $10-20,000 per annum in computer support costs, has proved to be a worthwhile investment for the Navy at Great Lakes. Flexible and easily understood, PAVER is a powerful tool for meeting the maintenance challenges of modern public works managers. Effective management has resulted; and for the first time, network and project level management has become a reality. The shortcomings of traditional methods, which had not been fully recognized, were eliminated. At the same time no increase in public works staff has been necessary nor has this placed an unreasonable burden on the existing staff. Time spent by the various groups are approximately the same as before but much more has been accomplished. All will agree they are managing better with PAVER.

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Abridgment

A Management Information System to Monitor Routine Maintenance Productivity

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ABSTRACT

Measures are discussed that are most suitable for reflecting maintenance productivity and a procedure that produces straightforward reports of maintenance unit productivity levels is presented. The generated information is then examined to identify maintenance units with low productivity; these units can then be compared on a statewide basis. Higher levels of management will be able to relay this information to individual units, indicating each unit's production level and how it compares with other units and the statewide average. Providing maintenance unit personnel with a guideline to evaluate their operations, in the form of a checklist of factors found to contribute to low productivity, will help them to identify areas for improvement. The