Overview of PAVER Pavement Management System

M.Y. SHAHIN AND S.D. KOHN

A brief overview of the PAVER pavement management system and the capabilities it offers its users is presented. PAVER is designed for use by military installations, cities, and counties. The system capabilities discussed are data storage and retrieval, pavement network definition, pavement condition rating, project prioritization, inspection scheduling, determination of present and future network condition, determination of maintenance and repair needs, performance of economic analysis, and budget planning.

PAVER is a pavement management system designed for use by military installations, cities, and counties. The system was developed and tested over the past 10 years and is currently being implemented by several agencies, including Fort Bragg, the Great Lakes Naval Training Center, and the City of Mesa, Arizona. This system was developed by the U.S. Army Construction Engineering Research Laboratory under the auspices of the Office of the Chief of Engineers, U.S. Army Corps of Engineers. It has been extensively tested prior to its implementation. The objective of this paper is to provide an overview of PAVER with emphasis on what is available to system users. Details of the system's development and results of an economic analysis of its implementation have been documented in a paper by Shahin and Kohn (1) and a paper by Kohn and Shahin in this Record.

PAVER provides the engineer with a practical decisionmaking procedure for identifying cost-effective maintenance and repairs on roads and streets. The System 2000 is the data base manager. This system and other "interface" programs provide the user with report generation capability for critical information. This information allows objective input to the decisionmaking process.

PAVER provides its users with many important capabilities. These include data storage and retrieval, pavement network definition, pavement condition rating, project prioritization, inspection scheduling, determination of present and future network condition, determination of maintenance and repair (M&R) needs, performance of economic analysis, and budget planning. This paper describes these capabilities and presents example reports for each area.

DATA STORAGE AND RETRIEVAL

The PAVER data base is a custom-designed data structure defined on a commercially available computer data base manager called System 2000 (System 2000 is a registered trademark of the Intel Corporation).

The data structure consists of 12 data groups that are linked together to form a tree structure (see Figure 1). Storing the data in this structure enables the user to retrieve information based on its connection to other data in the data base. Storage is available in each data group to store specific items related to that data group. The Pavement Structure data group shown in Figure 2 is an example.

The data can be stored and retrieved through special "interface" programs (FORTRAN or COBOL) or through the access language of the data base manager. Since these programs are interactive, the user has immediate access to the data base. The programs are designed to supply the information in useful formats.

DEFINITION OF PAVEMENT NETWORK

An installation's (city's) pavement network consists of all surface areas that provide access ways for ground or air traffic (airfield pavements). This network must be divided and identified in order to use the data base. Networks are divided into branches, sections, and sample units, which can be briefly defined as follows:

1. A branch is any identifiable part of the network that is a single entity and has a distinct function, such as an individual street.
2. A section is a division of a branch that has consistent structural characteristics, construction history, and traffic volume.
3. A sample unit is the smallest unit of the network and is an area of the pavement section used during inspection.

The data base provides information on the pavement network through reports such as "lists" or "inventories." Figure 3 shows a typical output of the inventory report. This report provides general information about specific branches or sections, thus providing the user with overall inventory information.

PAVEMENT CONDITION RATING

A key component of any pavement management system is a condition rating procedure. The PAVER system uses the pavement condition index (PCI), a composite index of the structural integrity and operating condition of the pavement. It is a numerical index from 0 to 100, where 100 represents excellent condition. The PCI is determined based on quantity, severity, and type of distress, as shown in Figure 4. The PCI was developed to agree closely with the collective judgment of experienced pavement engineers.

The PCI has been divided into seven condition categories, ranging from "excellent" to "failed", as...
shown in Figure 5. These categories are useful for developing maintenance policies and guidelines.

The PAVER database uses reports such as PCI, Inspect, and Sample to provide PCI information. Figure 6 shows a typical output of the Inspect report, which provides the user with PCI and distress information. The report can be used to prepare desk estimates of repairs and to determine history of pavement condition.

PROJECT PRIORITIZATION

Project prioritization is an immediate payoff of pavement network definition and pavement condition order of PCI. Figure 7 shows an example report output. The information in the report can be sorted based on pavement surface type, pavement rank (functional class), traffic type and volume, PCI range, or a combination of factors. Therefore, the report can be used to prioritize projects based on the user's policy.

INSPECTION SCHEDULING

The Inspection Schedule report has been developed to maintain current condition data with efficient inspection level. This report produces a plot and list of the pavement sections to be surveyed for the next six years for any type of branch use (roadway, parking, etc.) and surface type (asphalt, portland cement, concrete, etc.).

The schedule is based on two criteria. One is the minimum PCI that a given pavement type is allowed to reach, and the second is the rate of deterioration (loss of PCI points per year). The user inputs the minimum PCI values and the years allowed between inspections for various deterioration rates. The PCI for the selected sections is then predicted by a straight-line extrapolation based on

Figure 1. PAVER data structure.

Figure 2. Pavement Structure data group.

Figure 3. Example output of Inventory report.

Figure 4. Steps for determining PCI of a pavement section.

Figure 5. Correlation of M&R zones with PCI and condition rating for airfield pavements.
the maximum slope from either the last inspection or construction-overlay date (see Figure 8). Sections reaching the minimum PCI within six years of reaching the time limit based on the rate of deterioration are selected for inspection in the appropriate year.

Figure 9 shows a typical Inspection Schedule output with plot and list of cases. The example shown is for primary roadways with asphalt concrete surfaces. By using this report, the engineer can keep the pavement network data base up to date with minimal effort.

DETERMINATION OF PRESENT AND FUTURE NETWORK CONDITION

An overall PCI Frequency report has been developed to help plan future MR and to inform management of...
the network condition. The report shows an estimated frequency of condition (based on the PCI scale) for the year requested. The pavement sections included in the report can be selected based on branch use, pavement rank, and surface type.

The frequency is estimated as in the Inspection Schedule report by using a straight-line extrapolation of the PCI. Figures 10 and 11 show typical outputs of this report. These two figures show the estimated frequency of occurrence for the same set of pavement sections for two different years. The extrapolation presumes that no major repairs (such as slab replacement or overlay) have occurred between the last inspection and prediction dates. Thus, the impact of performing no major repairs can be seen.

DETERMINATION OF M&R NEEDS

A decision process has been devised for determining the M&R needs of a pavement section. Figure 12 shows a flow diagram of this process. A first-level decision can be made, based on the PCI value, type of distress, and deterioration rate. PAVER provides reports such as PCI and Condition History to help the user make the first decision. The PCI report is an ordered listing of sections ranked by PCI (Figure 7). Figure 13 shows an example of this report. The type of distress can be determined from the inspect report, shown in Figure 6.

If a pavement section does not require further analysis, routine maintenance practices can be continued. Routine maintenance includes practices such as spall repair and crack filling. By using maintenance guidelines for specific distress types, such as those given in Table 1, the user can input a repair policy. This policy is used in a program called MRG (Maintenance and Repair Guidelines) to estimate the type and cost of routine repair to specific sections. The MRG report can also be used to compute the cost of overlay after distress repair. Figure 14 shows an output of the MRG report.

If a section requires further analysis, an evaluation summary is completed for the section. The evaluation is based on structural capacity, roughness, skid problems, and other relevant factors, as shown in the top half of Figure 15. Complete guidelines for performing the evaluation are presented elsewhere. Feasible M&R alternatives are identified based on the results of the evaluation, as shown in the bottom half of Figure 15. This figure is an output of the Evaluation Summary report that was developed based on input from many experiences (maintenance engineers). The output from the report is general. Therefore, the engineer needs to select specific alternatives and perform the design based on the user agency policy. This may include using nondestructive testing.
PERFORMANCE OF ECONOMIC ANALYSIS

Several repair (or construction) alternatives may be considered feasible for any given pavement section. To help select the appropriate alternative, an Economic Analysis program has been developed and added to the system. The program allows the user to input initial costs, periodic maintenance costs, and separate future maintenance costs. Figure 16 shows a typical input, and Figure 17 shows a corresponding output.

Table 1. Maintenance guidelines for asphalt pavement distresses.

<table>
<thead>
<tr>
<th>Distress Type</th>
<th>Do Nothing</th>
<th>Crack</th>
<th>Partial-depth Patch</th>
<th>Full-depth Patch</th>
<th>Skin Patch</th>
<th>Pothole Filling</th>
<th>Apply Heat and Roll Sand</th>
<th>Apply Surface Emulsion</th>
<th>Apply Reclamation</th>
<th>Apply Aggregate Seal Coat</th>
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<tbody>
<tr>
<td>Alligator cracking</td>
<td>L</td>
<td></td>
<td></td>
<td>M,H</td>
<td></td>
<td>L</td>
<td>L</td>
<td>L</td>
<td>L,M,H</td>
<td></td>
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<td>Bleeding</td>
<td>L</td>
<td></td>
<td></td>
<td>M,H</td>
<td>M,H</td>
<td>L</td>
<td>L</td>
<td>L</td>
<td>LM</td>
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<td>Block cracking</td>
<td>L</td>
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<td>L</td>
<td>L</td>
<td>L</td>
<td>LM</td>
<td></td>
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<tr>
<td>Bumps and sagas</td>
<td>L</td>
<td></td>
<td></td>
<td>M,H</td>
<td>M,H</td>
<td>L</td>
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<td>Corrugation</td>
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<td></td>
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<td>Lane-double drop-off</td>
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<td></td>
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<td>M,H</td>
<td>L</td>
<td>L</td>
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</table>

Note: L = low severity; M = medium severity; H = high severity; and A = has only one level of severity.

Figure 14. Example output of MRG report.

Figure 15. Example output of Evaluation Summary report.
output. As shown, the user is provided with the initial cost, present value, equivalent uniform annual cost, and equivalent uniform annual cost per square yard. The Economic Analysis program allows the user to vary interest rates, inflation rates, repair costs, and timing so that their effect on alternatives can be easily analyzed.

BUDGET PLANNING

A budget planning report was developed to provide an estimate of the rehabilitation dollars required over a 10-year period for a given level of condition. The report is based on the user's input of minimum PCI levels for various branch uses and pavement ranks. The user also inputs unit repair costs based on pavement surface type and the PCI scale; i.e., the cost of repair can be varied, depending on the PCI value. Thus, the increased cost of differing rehabilitation can be anticipated. The program also takes into account the inflation rate. Figure 18 shows an example output of this report.

This program predicts, for each pavement section, the year in which the minimum PCI is reached and calculates the cost of repair. The prediction is the straight-line prediction procedure explained in the Inspection Schedule report.

SUMMARY

This paper has presented a brief overview of PAVER, a pavement management system for military installations, cities, and counties. PAVER assists engineers and planners with pavement management by providing the data base and computational capabilities. These capabilities are data storage and retrieval, pavement network definition, pavement condition rating, project prioritization, inspection scheduling, determination of present and future network condition, determination of NHR needs, performance of economic analysis, and budget planning.

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