Computerized Pavement Performance Evaluation Data Base Development for Structural Adequacy, Present Serviceability, and Distress Analysis

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ABSTRACT

Idaho Transportation Department's (ITD) Pavement Performance Management Information System (PPMIS) program requires input data (deflection, roughness, cracking, skid) collected in the field to be integrated with data from various agency data bases. The collection of the field data has been automated: Hewlett-Packard HP-85 microcomputers are used aboard the test vehicles to simplify data gathering and ensure uniformity. Field data are transferred from microcomputer tape cartridges to mainframe disk files without need of manual data entry with its attendant labor costs and errors. IBM 4381 mainframe programs format and augment the data for entry into the final data set for input to the PPMIS program. This entails queries to ITD data bases for traffic volumes, temperatures, section descriptions, and so forth.

In 1978 the Idaho Transportation Department (ITD), with the assistance of the Utah Department of Transportation, began adaptation of the Pavement Performance Management Information System (PPMIS) to Idaho conditions. This paper will begin with a brief description of the PPMIS system.

In July 1981, with the support of Boise State University (BSU), ITD began development of a computerized system for the capture of field data and for the inclusion of the field data with information from ITD data bases in an input data set for the PPMIS program. The building of this input data set is described here.

This computerized system has several advantages. It can be made to prompt field personnel for data (in some cases the system actually carries out the sequence of tasks necessary to deploy the measuring instruments). It has eliminated much need for human interpretation and recording of instrument readings. Data are consequently more accurate and uniform, and less effort is required of testing personnel. The mainframe reformatting and query programs have eliminated the need for human data search and translation—except to correct errors and handle rare special cases. The process also enables considerable personnel cost savings.

PAVEMENT PERFORMANCE MANAGEMENT INFORMATION SYSTEM OVERVIEW

Detailed information on the Idaho PPMIS is contained elsewhere (1,2). Offered here is a brief and oversimplified summary.

The Idaho PPMIS consists of three main components:

- The SYSTDY program, which makes up section-by-section reports based on the data;
- The SUMMARY program, which receives SYSTDY's section reports and sorts them into ranked lists according to various criteria; and
- The input data set, which includes section-
by-section data from Dynaflect testing of the structural condition of the pavement and subgrade, surface distress estimation, roadbed testing of the roughness and rideability of the pavement surface, and testing of the skid resistivity of the pavement surface.

SYSTDY Program

The PPMIS SYSTDY program provides section-by-section reports on the road network. Figure 1 shows an example of such a section report. Along with location and environmental data, the top part of the report gives computed values for the current number of 18,000-lb equivalent single axle loadings (ESALs) per year on this section. The rate of increase of ESAL is also given. These vehicle-loading data are brought into the SYSTDY input stream from the IDT MACS/ROSE data base and from the data set built as part of IDT's HWYNEEDS model. The computation of ESAL is based on tables of load distribution factors.

The part of the report headed ***DYNAFLECT READINGS AND SUMMARY*** pertains to the structural adequacy calculations. On the left are the Dynaflect sensor readings (temperature corrected by SYSTDY) for the tests made in this section. The Dynaflect works as follows: pavement deflections caused by an eccentric flywheel are sensed by five geophones, one at the center where the maximum deflection is produced and the other four successively farther from the center. The geophone signals are filtered and amplified to produce the five readings computed for each test on the SYSTDY report. The remaining entries are computed from the Dynaflect data and traffic data. The most important of these is the "REMAINING SERVICE LIFE (STRUCTURAL)," which uses the Dynaflect deflection to estimate the remaining number of 18,000-lb ESALs the tested pavement can support before failure. Compounding the current level of annual 18,000-lb ESALs at its predicted rate of increase gives an estimate of the "years to failure" for the pavement at this test point. It is this "life" that is plotted in the histogram at the far right.

For later use in the aggregate network calculations, SYSTDY computes a structural index based on section averages of the maximum Dynaflect deflections (Sensor 1), of the BCI values (Sensors 1 and 2), and of the BCI values (Sensors 4 and 5). The ***CONDITION SUMMARY*** in the lower left part of the SYSTDY report contains the surface distress indices estimated visually in the field. The Dynaflect crew estimates the surface distress according to a system developed by the Arizona Department of Transportation (3). The field crew is guided in their visual assessment of the surface condition by a set of photographs each associated with an estimated amount of cracking and a "survey photo index number." The operator decides which of the photographs most nearly matches the surface condition near the test point. The operator may find it necessary to interpolate between two of the photographs. IDT hopes eventually to replace this subjective judgment process by image and pattern assessment machinery. SYSTDY computes an average of the cracking indices to pass on to the SUMMARY report. The cracking index enters SYSTDY's remaining life prediction model for concrete pavement.

The bottom center portion of the SYSTDY section report (**SERVICEABILITY SUMMARY**) summarizes

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**Figure 1 SYSTDY single-section report.**
This is one of several PSI formulas of this general form in which XL is the logarithm of the roughness count. The current number of equivalent 18,000-lb ESALs is compounded to give a prediction of how soon the PSI will fall to a terminal serviceability index value (TSI). This gives an estimate of the years to serviceability failure for the pavement at the test point. It is these lifetime estimates that are shown in the histogram at the right. The current SYSTDY version has PSI as a function only of the roadometer roughness value, a PSI formula using cracking as well has been used in earlier versions.

The ***SKIDMETER SUMMARY*** in the lower right of the SYSTDY report page gives readings collected using ITD’s locked-wheel skidometer. SYSTDY merely averages these readings; it does not contain any models to predict slipperiness failure of the pavement and the skid index does not enter into any of the models mentioned.

### SUMMARY Program

The SYSTDY program analyzes the pavements section by section. Along with the printed report described previously, SYSTDY also makes a section record to be passed on to the SUMMARY program for network analysis of an aggregate of many sections (an entire route, or an entire district). This record includes an abbreviated environmental description for the section; milespost, gross description, district, county, route number, pavement material type, length of analysis period, and functional class. SYSTDY fills out the record with average values for structural index, PSI, cracking index, and skid index. Except for the skid index, these indices are normalized to a value between 0 and 5.

The sequential data set of these records is read by the SUMMARY program. SUMMARY then proceeds to make ranked lists of the sections for each of the indices. For PSI, for example, SUMMARY produces a list of all the sections in order of increasing average PSI (Figure 2). This means that the list will start out with the sections with the lowest average PSI; the sections whose PSI has dropped below or near the TSI will be at the top of the list as candidates for pavement rehabilitation improvements.

This theme is pursued for the other indices. SUMMARY also attempts to calculate a “final index” that uses a weighting formula to combine all the indices into a meaningful average. Although it

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**NOTE:** | MLANS: TSI | TLE: PSI | LE: TSI | TLE: TSI
---|---|---|---|---
**SUMMARY** | **PSI** | **PSI** | **PSI** | **PSI**
---|---|---|---|---
**RANK OF** | **AVG** | **MIN** | **RANK OF** | **MIN PSI**
---|---|---|---|---

**FIGURE 2 SUMMARY rank listing.**
is unlikely that a final index satisfactory for all situations can be found, SUMMARY produces a ranked list of sections.

SUMMARY also draws some three-dimensional histograms to show the percentages of mileages in various ranges of the various indices (Figure 3).

Sections that SUMMARY flags as below acceptable standards are taken up by the pavement overlay design (POD) program. This program requires that Dynaflect tests be made more frequently in the suspect sections. Its model uses these data to make recommendations for amounts of rehabilitative overlays.

ITD is working to interface the PPMIS system with other systems to do long-range total-network maintenance cost optimization and financial analysis. The hoped-for result is a system that could dictate the least expensive schedule of rehabilitative and capital improvements subject to meeting certain minimal performance criteria.

DATA SET DEVELOPMENT FOR STRUCTURAL ADEQUACY AND DISTRESS ANALYSIS

The structural adequacy and distress analysis data preparation are described in the most detail here. The other data are gathered in an analogous manner.

ITD's structural adequacy analysis rests primarily on deflection data obtained from Dynaflect (5) readings. In the field the deflection inventory is done under the control of an HP-85 BASIC program named DYNA (6). At the beginning of a sequence of tests, the Dynaflect operator "boots" DYNA on the on-board HP-85. DYNA prompts the operator for various items that describe the test environment:

- Equipment identifier--ITD maintains more than one Dynaflect;
- Date of test series;
- Time of day of test--flexible pavement Dynaflect readings are sensitive to temperature; time of day is needed for the corrections done in the PPMIS program;
- MACS code for the first section to be tested--this keys into ITD's mainframe data bases;
- State highway route number;
- Lane and direction--two-lane roads have been tested in one direction only, but both sides of the four-lane divided Interstate highways have been tested;
- Material code--concrete or asphalt;
- Air temperature, surface temperature, and (optionally) pavement temperature--also needed for temperature corrections;
- Wheelpath of tests--"inside" or "outside"; and
- Operator's initials.

DYNA remembers most of these items from section to section, so after the initial start-up, the operator needs to enter only those items that change. As soon as the operator is satisfied with this environmental description, he can begin testing. DYNA writes these data onto a cartridge tape and prints them out to an on-board printer for the sake of redundancy.

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EVALUATION INDICES FOR STRUCTURAL INADEQUACY AND DISTRESS ANALYSIS

SUMMARY also draws some three-dimensional histograms to show the percentages of mileages in various ranges of the various indices (Figure 3).
The Dynaflect test vehicle is halted at each test location in the section. As the test is done, the Dynaflect sensor readings appear on digital displays located at the control unit. Whereas formerly a data-recording crewman would write the Dynaflect readings on a code sheet, DYNA now writes them out to the cartridge tape and prints them. By watching DYNA's printouts, the field crew can catch errors and either correct them on the spot or make notes so they can be corrected in the office. DYNA has considerable facilities for field error correction and recovery—few field errors, if noticed in time, have to be left for office correction.

Each time that a Dynaflect "stop-and-test" is made, DYNA prompts for the operator's judgment of the degree of surface distress. At this point the operator has the option of estimating the surface distress or cracking index when it is calculated by the National Climatic Data Center, Asheville, North Carolina. When these highs and lows are in hand, the relevant ones are entered into a file.

As soon as the temperature data problem is handled, the formatting and query programs can be run. These programs move the field data into eventual input records for PPMIS. It has been extremely helpful to write these programs using the SAS package (Statistical Analysis System, SAS Institute, Cary, North Carolina).

The formatting and query programs first copy the field data and the relevant thickness and temperature data into place in SYSTDY's sequential input stream. They go on to query ITD data bases HWYNEDS and MACS/ROSE (milepost and coded segment/road segment) for prose description of section, average daily traffic (ADT), anticipated rate of change of ADT, functional class, lane configuration, speed limit, and federal assistance code. This process yields enough input data for SYSTDY to make structural adequacy analyses of the sections tested. The prose description of the section is brought from the HWYNEDS data to make the reports intelligible to managers and others. In particular, the section location is made clear.

SYSTDY and SUMMARY are arranged to accept sequential input including data for Dynaflect, traffic, cracking, roughness, and skid. They can also accept input streams without skid data, or without cracking, or without roughness, or without all three.

**DATA DEVELOPMENT FOR PRESENT SERVICEABILITY**

Preparation of PPMIS input data for present serviceability analysis parallels the regime described previously: field data collection is carried out with the aid of the on-board HP-85 BASIC program ROAD (6), which, like DYNA, prompts the test vehicle operator for day, time, place, and environmental information and then captures roughness readings from ITD's Cox Ultrasonic Ranging Roadmeter (4) on a cartridge tape. The tapes are sent to ITD headquarters to be transferred to files on the IBM mainframe system. These files are combined with HWYNEDS and MACS/ROSE information to make up the serviceability portion of the PPMIS sequential input data set.

Unlike the Dynaflect tests, which are done from a stopped vehicle, the roadometer "counts per mile," the speed of the test vehicle, and the air temperature. The operator can proceed without regard to test section boundaries (except that he must note MACS/ROSE key changes); the tests are allocated to their proper sections when the formatting and query programs sort them on MACS/ROSE code and mile point. Whereas the Dynaflect
requires flagmen and frequent stops, the roadmeter can be managed by one person operating more or less continuously.

Figure 5 is a sample of the printed "echo" from the program ROAD. This is entirely analogous to the DYNA printout discussed previously (BMP = beginning milepost of the tests). After the environmental information come the test lines giving, for each test, the ending milepost, the length of the test, the roadmeter counts per mile, the speed of the test, and the air temperature (which is not used by any PPMIS models).

**ROADMETER**

<table>
<thead>
<tr>
<th>DA</th>
<th>TP1785</th>
<th>WC</th>
<th>BMP</th>
<th>LA</th>
</tr>
</thead>
<tbody>
<tr>
<td>10/1/84</td>
<td>925</td>
<td>002040</td>
<td>436.00</td>
<td>A50</td>
</tr>
<tr>
<td>EQ</td>
<td>OP</td>
<td>RC</td>
<td>MT</td>
<td>EMP</td>
</tr>
<tr>
<td>436.00</td>
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<td>437.50</td>
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<tr>
<td></td>
<td>437.50</td>
<td>580</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**FIGURE 5 ROAD printout from HP-85 used in roadmeter inventory.**

The skid inventory will not be discussed here, except to mention that it uses an automated data gathering regime analogous to those of the Dynaflect and the roadmeter.

**COSTS AND ADVANTAGES**

As was pointed out earlier, the automated data capture has the advantages of

- Relieving the data collection crew of much fine detail work in the field;
- Increasing the uniformity, speed, and accuracy of data collection;
- Decreasing the size of the data collection crews; and
- Decreasing the amount of human data handling both in the field and in the office.

These systems have also placed the reports more immediately in the hands of managers: formerly data were collected during the summer and the computations and reporting work done over the winter so as to make the reports available by spring. The automated regime makes it possible to generate most reports almost immediately on receipt of the cartridge tapes from the field.

The HP-85 microcomputers cost about $2,800 when equipped with the necessary interfaces for installation in the test vehicles. For each of the data types collected, the initial version of the HP-85 software (like DYNA and DYTRAN) required about 3 man-months to develop. Fine tuning and adapting to changes in other parts of the system have used up another 12 man-months per data type.

Headquarters needs an HP-85 ($2,800) dedicated to reading the field tapes and sending their data to the Kennedy tape drive ($7,000), which makes a tape for the IBM mainframe.

As the PPMIS data capture project has progressed, other projects have begun to use the same sort of data collection methods. The ITD photo-log van now uses the HP-85 to record the notations that go with the roadway pictures. There is now open a general channel for data collection; the cost-to-benefit ratio of the regime will decrease steadily.

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**REFERENCES**

6. D.G. Lamet. HP-85 Field Inventory Program Operating Guide. (a) Dynaflect, (b) Roadmeter. Department of Mathematics, Boise State University; Idaho Transportation Department, Boise, 1981.

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