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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, roadmeter 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 ITD's HWYNEEDS model. The computation of ESAL is based on tables of load distribution factors.

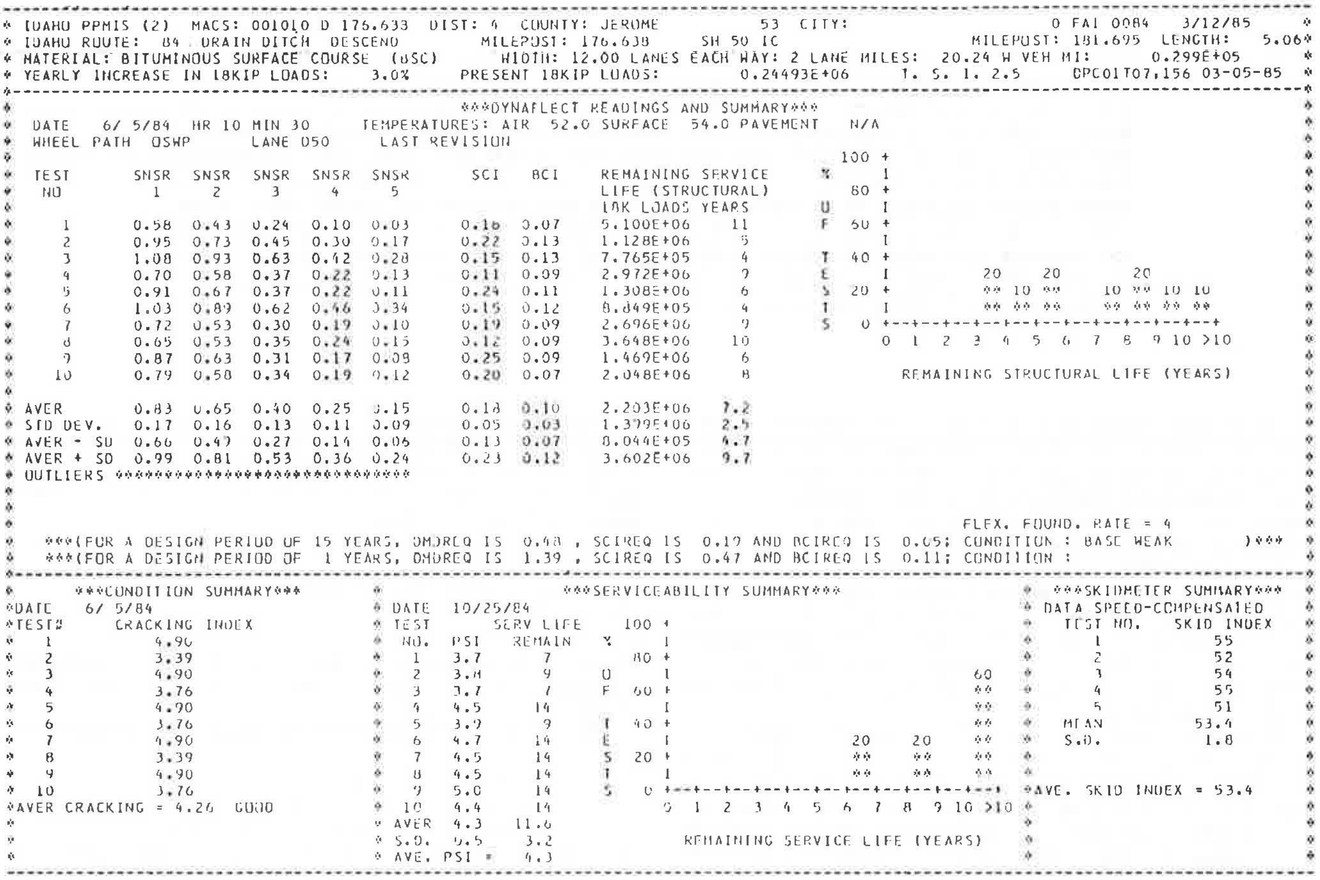
The part of the report headed ***DYNAFLECT READINGS AND SUMMARY*** pertains to the structural adequacy calculations. On the left are the Dynaflect sensor readings (temperature corrected by SYSTDY) for the tests made in this section. The Dynaflect works as follows: pavement deflections caused by an eccentric 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 that appear 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 SCI 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. ITD 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 program. 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



```
-------------------------------------------------------------------------------------------------------------------------------------
* IDAHO PPMIS (2)  MACS: 001010 D 176.633  DIST: 4  COUNTY: JEROME             53  CITY:                      0 FAI 0084   3/12/85   *
* IDAHO ROUTE:  84  DRAIN DITCH  DESCEND          MILEPOST: 176.638      SH 50 IC                 MILEPOST: 181.695  LENGTH:   5.06*
* MATERIAL: BITUMINOUS SURFACE COURSE  (BSC)      WIDTH: 12.00 LANES EACH WAY: 2 LANE MILES:  20.24 H VEH MI:        0.299E+05   *
* YEARLY INCREASE IN 18KIP LOADS:     3.0%      PRESENT 18KIP LOADS:          0.24493E+06     T. S. I. 2.5     DPC01T07,156 03-05-85 *
*-----------------------------------------------------------------------------------------------------------------------------------*
*                                                  ***DYNAFLECT READINGS AND SUMMARY***                                             *
*  DATE    6/ 5/84  HR 10 MIN 30      TEMPERATURES: AIR  52.0 SURFACE  54.0 PAVEMENT    N/A                                         *
*  WHEEL PATH  OSWP         LANE 050       LAST REVISION                                                                            *
*                                                                                         100 +                                     *
*  TEST        SNSR  SNSR  SNSR  SNSR  SNSR        SCI   BCI    REMAINING SERVICE     %      I                                      *
*   NO           1     2     3     4     5                      LIFE (STRUCTURAL)         80 +                                      *
*                                                               18K LOADS YEARS       U      I                                      *
*     1        0.58  0.43  0.24  0.10  0.03       0.16  0.07    5.100E+06    11       F   60 +                                      *
*     2        0.95  0.73  0.45  0.30  0.17       0.22  0.13    1.128E+06     5              I                                      *
*     3        1.08  0.93  0.63  0.42  0.28       0.15  0.13    7.765E+05     4       T   40 +                                      *
*     4        0.70  0.58  0.37  0.22  0.13       0.11  0.09    2.972E+06     7       E      I         20    20       20            *
*     5        0.91  0.67  0.37  0.22  0.11       0.24  0.11    1.308E+06     6       S   20 +         ** 10 **    10 ** 10 10      *
*     6        1.03  0.89  0.62  0.46  0.34       0.15  0.12    8.849E+05     4       T      I         ** ** **    ** ** ** **      *
*     7        0.72  0.53  0.30  0.19  0.10       0.19  0.09    2.696E+06     9       S    0 +--+--+--+--+--+--+--+--+--+--+--+    *
*     8        0.65  0.53  0.35  0.24  0.15       0.12  0.09    3.648E+06    10              0  1  2  3  4  5  6  7  8  9  10 >10  *
*     9        0.87  0.63  0.31  0.17  0.09       0.25  0.09    1.469E+06     6                                                     *
*    10        0.79  0.58  0.34  0.19  0.12       0.20  0.07    2.048E+06     8                REMAINING STRUCTURAL LIFE (YEARS)    *
*                                                                                                                                   *
* AVER         0.83  0.65  0.40  0.25  0.15       0.18  0.10    2.203E+06   7.2                                                     *
* STD DEV.     0.17  0.16  0.13  0.11  0.09       0.05  0.03    1.379E+06   2.5                                                     *
* AVER - SD    0.66  0.49  0.27  0.14  0.06       0.13  0.07    8.044E+05   4.7                                                     *
* AVER + SD    0.99  0.81  0.53  0.36  0.24       0.23  0.12    3.602E+06   9.7                                                     *
* OUTLIERS ******************************                                                                                           *
*                                                                                                                                   *
*                                                                                                                                   *
*                                                                                     FLEX. FOUND. RATE = 4                         *
*   ***(FOR A DESIGN PERIOD OF 15 YEARS, DMDREQ IS  0.48 , SCIREQ IS  0.19 AND BCIREQ IS  0.05; CONDITION : BASE WEAK        )***  *
*   ***(FOR A DESIGN PERIOD OF  1 YEARS, DMDREQ IS  1.39 , SCIREQ IS  0.47 AND BCIREQ IS  0.11; CONDITION :                        *
*-----------------------------------------------------------------------------------------------------------------------------------*
*       ***CONDITION SUMMARY***              *                 ***SERVICEABILITY SUMMARY***                          *  ***SKIDMETER SUMMARY***  *
*DATE    6/ 5/84                             *  DATE  10/25/84                                                       * DATA SPEED-COMPENSATED    *
*TEST#       CRACKING INDEX                  *  TEST        SERV LIFE      100 +                                     *   TEST NO.    SKID INDEX  *
*   1             4.90                       *   NO.   PSI   REMAIN     %      I                                     *      1            55      *
*   2             3.39                       *    1    3.7      7           80 +                                     *      2            52      *
*   3             4.90                       *    2    3.8      9       U      I                              60     *      3            54      *
*   4             3.76                       *    3    3.7      7       F   60 +                              **     *      4            55      *
*   5             4.90                       *    4    4.5     14              I                              **     *      5            51      *
*   6             3.76                       *    5    3.9      9       T   40 +                              **     *    MEAN          53.4     *
*   7             4.90                       *    6    4.7     14       E      I                  20    20    **     *    S.D.           1.8     *
*   8             3.39                       *    7    4.5     14       S   20 +                  **    **    **     *                           *
*   9             4.90                       *    8    4.5     14       T      I                  **    **    **     *                           *
*  10             3.76                       *    9    5.0     14       S    0 +--+--+--+--+--+--+--+--+--+--+--+   *AVE. SKID INDEX = 53.4     *
*AVER CRACKING = 4.26  GOOD                  *   10    4.4     14               0  1  2  3  4  5  6  7  8  9  10 >10 *                           *
*                                            *  AVER   4.3   11.6                                                    *                           *
*                                            *  S.D.   0.5    3.2                  REMAINING SERVICE LIFE (YEARS)    *                           *
*                                            *  AVE. PSI =    4.3                                                    *                           *
-------------------------------------------------------------------------------------------------------------------------------------
```

FIGURE 1 SYSTDY single-section report.

data collected by ITD's Cox Ultrasonic Ranging Roadmeter (4). This is a Portland Cement Association roadmeter, a device that counts bumps in the roadway as a measure of the rideability of the pavement. These readings have been correlated with the judgment of a panel of highway users. This correlation is expressed as a present serviceability index (PSI) for each test:

$$PSI = 8.9845 - 1.0144(XL)$$

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 roadmeter roughness value; a PSI formula using cracking as well has been used in earlier versions.

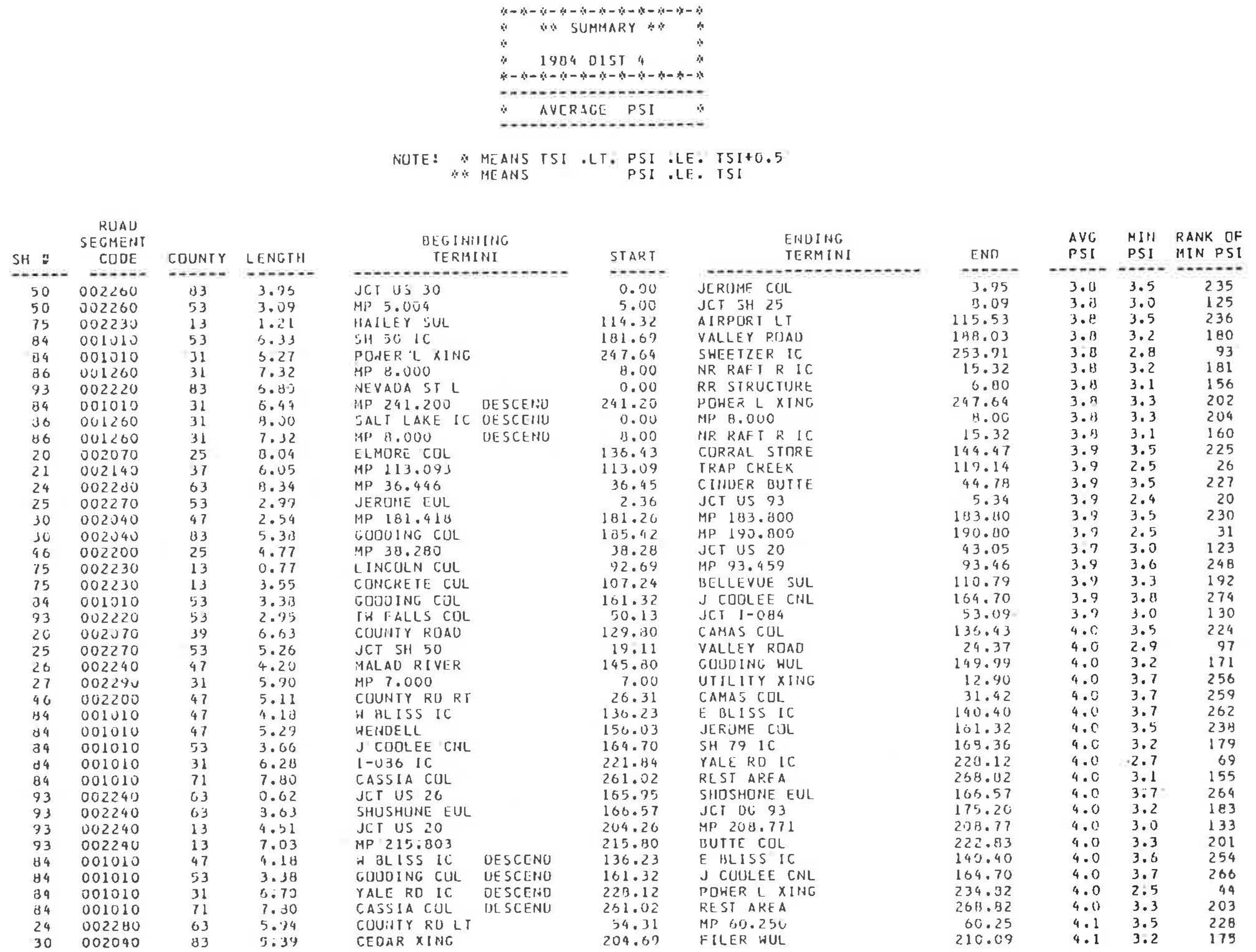
The ***SKIDMETER SUMMARY*** in the lower right of the SYSTDY report page gives readings collected using ITD's locked-wheel skidmeter. SYSTDY merely averages these readings; it does not contain any models to predict slipperiness failure of the pavement and the skid index does not enter into any of the 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, an entire district). This record includes an abbreviated environmental description for the section: mileposts, prose 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


```
                                   *-*-*-*-*-*-*-*-*-*-*
                                   *    ** SUMMARY **   *
                                   *                    *
                                   *    1984 DIST 4     *
                                   *-*-*-*-*-*-*-*-*-*-*
                                   ---------------------
                                   *    AVERAGE  PSI    *
                                   ---------------------

                        NOTE!  * MEANS TSI .LT. PSI .LE. TSI+0.5
                              ** MEANS          PSI .LE. TSI

        ROAD
       SEGMENT                          BEGINNING                        ENDING                         AVG   MIN   RANK OF
 SH #   CODE   COUNTY  LENGTH            TERMINI              START      TERMINI              END      PSI   PSI   MIN PSI
------ ------  ------ -------  ---------------------------   ------  -------------------     ------   ----- ----- -------
  50   002260    83     3.95   JCT US 30                       0.00  JEROME COL                3.95    3.8   3.5     235
  50   002260    53     3.09   MP 5.004                        5.00  JCT SH 25                 8.09    3.8   3.0     125
  75   002230    13     1.21   HAILEY SUL                    114.32  AIRPORT LT              115.53    3.8   3.5     236
  84   001010    53     6.33   SH 50 IC                      181.69  VALLEY ROAD             188.03    3.8   3.2     180
  84   001010    31     5.27   POWER L XING                  247.64  SWEETZER IC             253.91    3.8   2.8      93
  86   001260    31     7.32   MP 8.000                        8.00  NR RAFT R IC             15.32    3.8   3.2     181
  93   002220    83     6.80   NEVADA ST L                     0.00  RR STRUCTURE              6.80    3.8   3.1     156
  84   001010    31     6.44   MP 241.200     DESCEND        241.20  POWER L XING            247.64    3.8   3.3     202
  86   001260    31     8.00   SALT LAKE IC   DESCEND          0.00  MP 8.000                  8.00    3.8   3.3     204
  86   001260    31     7.32   MP 8.000       DESCEND          8.00  NR RAFT R IC             15.32    3.8   3.1     160
  20   002070    25     8.04   ELMORE COL                    136.43  CORRAL STORE            144.47    3.9   3.5     225
  21   002140    37     6.05   MP 113.093                    113.09  TRAP CREEK              119.14    3.9   2.5      26
  24   002280    63     8.34   MP 36.446                      36.45  CINDER BUTTE             44.78    3.9   3.5     227
  25   002270    53     2.99   JEROME EUL                      2.36  JCT US 93                 5.34    3.9   2.4      20
  30   002040    47     2.54   MP 181.418                    181.26  MP 183.800              183.80    3.9   3.5     230
  30   002040    83     5.38   GOODING COL                   185.42  MP 190.800              190.80    3.9   2.5      31
  46   002200    25     4.77   MP 38.280                      38.28  JCT US 20                43.05    3.7   3.0     123
  75   002230    13     0.77   LINCOLN CUL                    92.69  MP 93.459                93.46    3.9   3.6     248
  75   002230    13     3.55   CONCRETE CUL                  107.24  BELLEVUE SUL            110.79    3.9   3.3     192
  84   001010    53     3.38   GOODING COL                   161.32  J COOLEE CNL            164.70    3.9   3.8     274
  93   002220    53     2.95   TW FALLS COL                   50.13  JCT I-084                53.09    3.9   3.0     130
  20   002070    39     6.63   COUNTY ROAD                   129.80  CAMAS COL               136.43    4.0   3.5     224
  25   002270    53     5.26   JCT SH 50                      19.11  VALLEY ROAD              24.37    4.0   2.9      97
  26   002240    47     4.20   MALAD RIVER                   145.80  GOODING WUL             149.99    4.0   3.2     171
  27   002290    31     5.90   MP 7.000                        7.00  UTILITY XING             12.90    4.0   3.7     256
  46   002200    47     5.11   COUNTY RD RT                   26.31  CAMAS COL                31.42    4.0   3.7     259
  84   001010    47     4.18   W BLISS IC                    136.23  E BLISS IC              140.40    4.0   3.7     262
  84   001010    47     5.29   WENDELL                       156.03  JEROME COL              161.32    4.0   3.5     238
  84   001010    53     3.66   J COOLEE CNL                  164.70  SH 79 IC                169.36    4.0   3.2     179
  84   001010    31     6.28   I-086 IC                      221.84  YALE RD IC              228.12    4.0   2.7      69
  84   001010    71     7.80   CASSIA COL                    261.02  REST AREA               268.02    4.0   3.1     155
  93   002240    63     0.62   JCT US 26                     165.95  SHOSHONE EUL            166.57    4.0   3.7     264
  93   002240    63     3.63   SHOSHONE EUL                  166.57  JCT DG 93               175.20    4.0   3.2     183
  93   002240    13     4.51   JCT US 20                     204.26  MP 208.771              208.77    4.0   3.0     133
  93   002240    13     7.03   MP 215.803                    215.80  BUTTE COL               222.83    4.0   3.3     201
  84   001010    47     4.18   W BLISS IC     DESCEND        136.23  E BLISS IC              140.40    4.0   3.6     254
  84   001010    53     3.38   GOODING CUL    DESCEND        161.32  J COULEE CNL            164.70    4.0   3.7     266
  84   001010    31     6.70   YALE RD IC     DESCEND        228.12  POWER L XING            234.32    4.0   2.5      44
  84   001010    71     7.30   CASSIA COL     DESCEND        261.02  REST AREA               268.82    4.0   3.3     203
  24   002280    63     5.94   COUNTY RD LT                   54.31  MP 60.250                60.25    4.1   3.5     228
  30   002040    83     5.39   CEDAR XING                    204.69  FILER WUL               210.09    4.1   3.2     175
```

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.

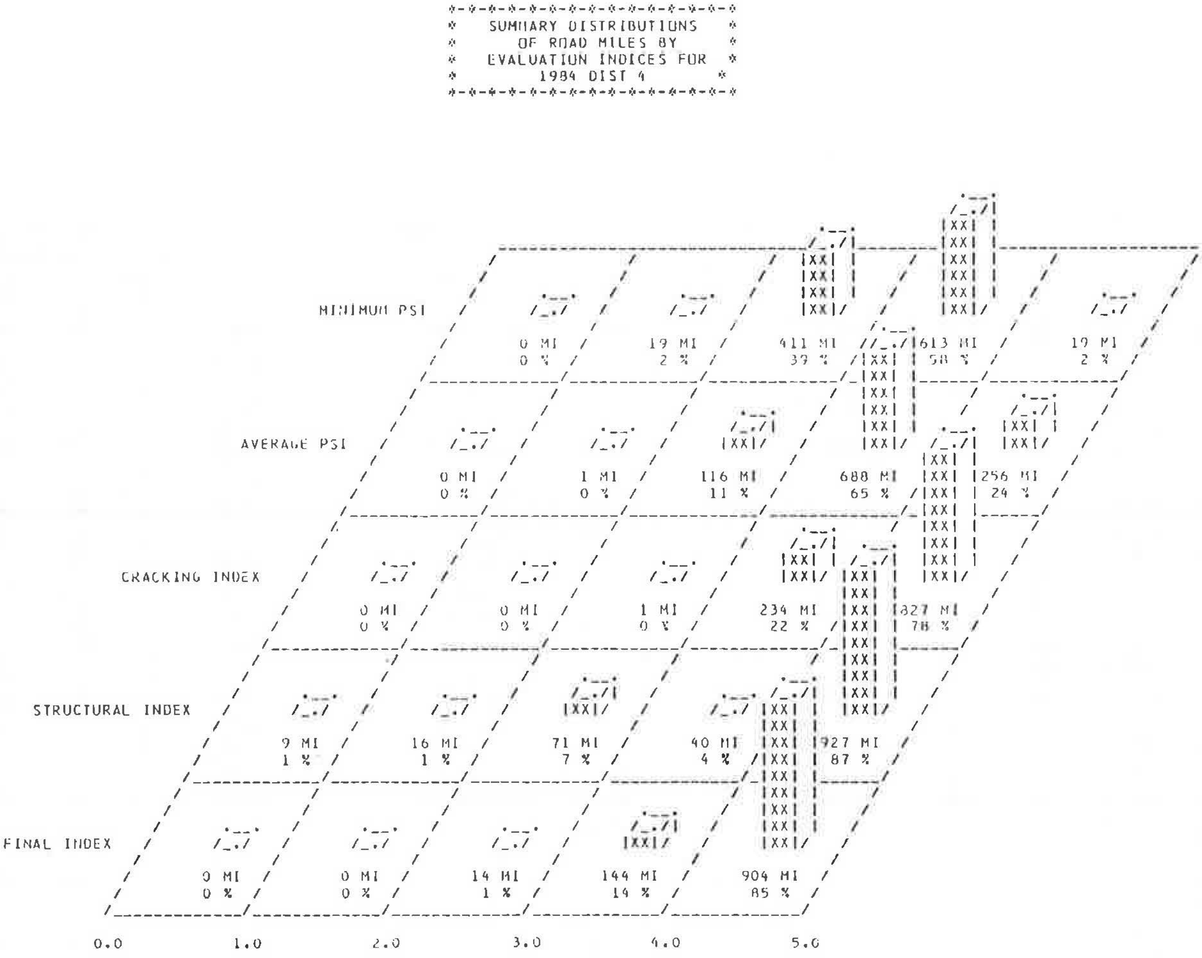


FIGURE 3 SUMMARY histogram.

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 printout, 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 also 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 (cracking) according to the Arizona method outlined earlier. The field operator's surface distress number is written to the cartridge tape by DYNA.

Figure 4 is an example of a DYNA printout. At the top is the "echo" of the environmental setup (OP = operator's initials; EQ = license number of the Dynaflect test vehicle; LA = lane code; MT = roadway surface material; AT, ST, and SS = air, surface, and subsurface temperature; MC = ITD MACS code; RC = state highway number; and WP = wheelpath). The lines following arise from the Dynaflect tests. For each test there is the milepost of the test, followed by the five Dynaflect sensor readings, followed in turn by the surface distress or cracking index when it is entered.

```
DYNAFLECT
PPMIS                      ON ASPHALT
DA 05/16/84                AT 057
TI 0906                    ST 059
OP EEB                     SS 057
EQ T02194                  MC 002190
LA A50                     RC SH78
MT 1                       WP 0

      082.78  100 064 039 026 019  1.5
      082.88  097 063 034 019 013
      083.78  110 066 031 014 007  3.5
      083.88  143 093 052 030 019
      084.78  102 066 037 025 018  1.5
      084.88  117 074 042 029 021
      085.78  125 072 036 019 011  0.5
```

FIGURE 4 DYNA printout from HP-85 used in Dynaflect field inventory.

Several Dynaflect distress tests are made in each highway section. One cartridge tape has room to hold many sections' tests, but it is safer not to put great volumes of data on a single tape.

The next stages of data development take place at ITD headquarters in Boise. Formerly it was necessary for data entry personnel to keypunch the data from the field crews' code sheets onto cards. The new system eliminates this slow and error prone operation: an HP-85 program, DYTRAN (6), is used in the office to transfer data from the field crews' cartridge tapes to a standard 1600-bpi tape drive. The tape output of this process is then read by the IBM 4381 mainframe. The mainframe copies these data into its own disk files, which are more suitable for long-term storage than are the HP-85 cartridges (which can now be recycled to the field crews).

Using the field crews' printouts, corrections can be made at headquarters using word processing and file maintenance programs on the IBM mainframe.

The first augmentation to be made to the field data concerns temperature correction of the Dynaflect readings (7). PPMIS needs to know the thickness and internal temperature of the pavement at the time and place of the test in order to correct the Dynaflect readings to a standard 60°F. A file of thickness estimates, based on the history of the section's construction and maintenance, has been compiled. If the field crew was able to take the actual internal pavement temperature (by drilling a test hole, filling it with oil, then taking an equilibrium temperature, which is also written to the cartridge tape by DYNA), then all temperature correction data are in place.

If the internal pavement temperature has not been measured in the field, PPMIS can estimate it from a model (developed by the Kentucky Department of Transportation), which depends on the previous five days' high and low temperatures. These are available (some months after the fact) from the monthly climatological data for Idaho that are compiled and circulated 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 HWYNEEDS 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 HWYNEEDS data to make the reports intelligible to managers and others. In particular, the section location is made clear.

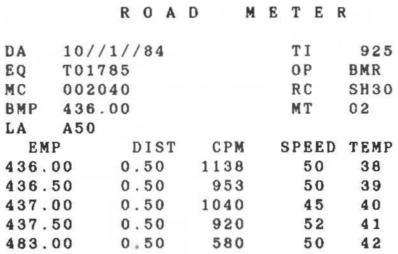
SYSTDY and SUMMARY are arranged to accept sequential input including data for Dynaflect, traffic, cracking, roughness, and skid. They can also accept input streams without skid data, or without cracking, or without roughness, or without all three.

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 HWYNEEDS 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, these roadmeter tests are done "on-the-fly" at half-mile intervals. Program ROAD automatically records and prints the mile point for each of these tests, the distance between tests, the roadmeter "counts per mile," the speed of the test vehicle, and the air temperature. The operator can proceed without regard for 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).



```
            R O A D   M E T E R

DA    10//1//84              TI     925
EQ    T01785                 OP    BMR
MC    002040                 RC    SH30
BMP   436.00                 MT    02
LA    A50
  EMP        DIST    CPM     SPEED TEMP
436.00       0.50   1138       50   38
436.50       0.50    953       50   39
437.00       0.50   1040       45   40
437.50       0.50    920       52   41
483.00       0.50    580       50   42
```

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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