

# UTAH'S PAVEMENT DESIGN AND EVALUATION SYSTEM

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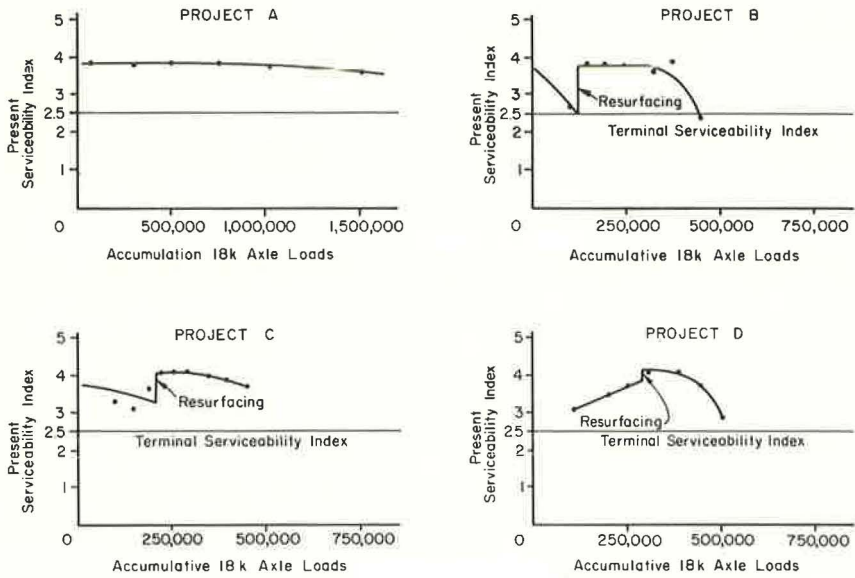
The system developed for evaluating existing pavement condition and determining future needs considers structural adequacy, serviceability, slipperiness, and surface defects of each pavement section. The data are processed through the computer, and output tables show existing condition and predicted life, thickness requirements for a specified life period, surface defects or distress, and a priority rating. Statewide data have been gathered and analyzed each year since 1970. The pavement design procedures have been computerized so that data can be entered at a remote terminal and the pavement design can be determined through the computer and printed out by the terminal. Under development is a pavement management system that considers all highway department operations that could possibly affect pavement performance.

THE UTAH State Department of Highways adopted the AASHO interim pavement design guide in the fall of 1962 for the design of all pavements. In 1964 a study (5, 12) was initiated by the department to evaluate the pavements that had been designed with the AASHO guide. The present serviceability index (PSI) was determined yearly for each project. During its first few years, the research study was concerned with evaluating each pavement and determining its performance characteristics. Performance curves were plotted for each project, and several new projects were added to the study each year as they were completed. Performance varied considerably from project to project and from year to year. Not all projects exhibited level trends (same PSI each year) or descending trends (decreasing PSI), but some showed fluctuations up or down or an increase in PSI (Fig. 1). This condition had also been observed in other states. Because of the variations, evaluating the pavement design procedures in a limited number of years was difficult if not impossible. Rather, a continuing effort was required to evaluate each project until failure or the end of its design life. Many projects were built in staged construction, and when resurfaced the performance trends were altered. As a result of these factors, we felt the full potential was not being obtained from the research study.

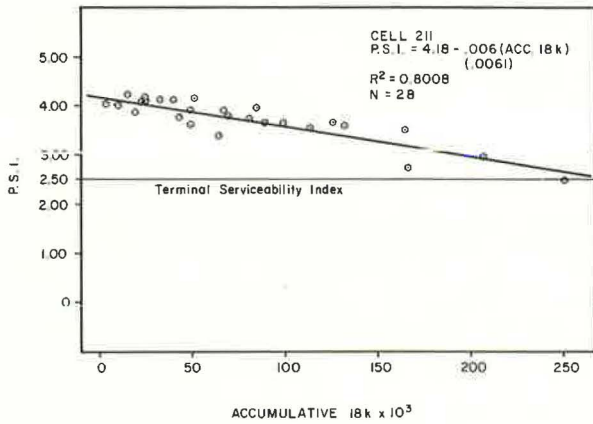
Beginning in 1969 the study was modified by a statistical experimental design that considers factors of age, soil support values, traffic design 18-k (80-kN) loads, and terminal serviceability index (TSI). This type of experimental design permitted the use of statistical procedures in the data analysis. The projects being studied were placed in appropriate cells within the experimental design. Individual projects are strongly influenced by various factors such as pavement age, accumulated traffic loads, construction quality, maintenance quality, climatic conditions, and pavement design. The cell design helps to temper the extremes from these factors for projects within a cell. A typical performance curve for one of the cells is shown in Figure 2.

Two research projects were started in 1968 (7, 9) in which the Dynaflect was used for deflection measurements. One study was concerned with the application of deflection measurements to pavement overlay design and analysis, and the other was concerned with predicting performance from deflection measurements. The study for predicting performance used the same experimental design and pavements as the serviceability study. The AASHO Road Test (1) equations that related deflections to performance of a pavement under a number of axle load applications of various sizes were

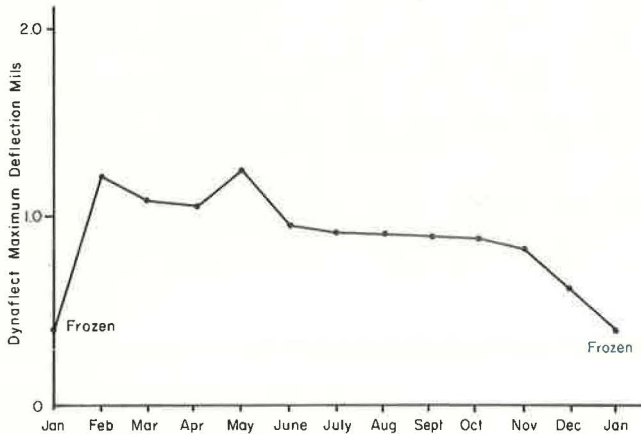
**Figure 1. Variations in performance curves.**



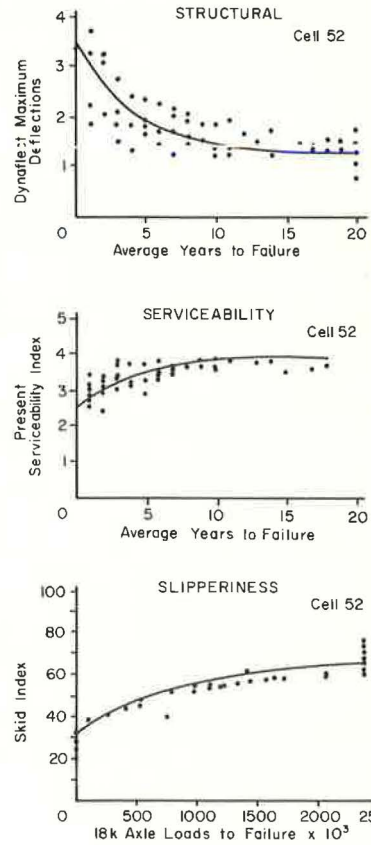
**Figure 2. Performance curve for 1 cell from the experimental design.**



**Figure 3. Typical pavement deflection characteristics for a 1-year cycle.**



**Figure 4. Typical prediction curves.**



modified for use with the Dynaflect in Utah. We soon discovered that deflection measurements taken in the spring were unreliable because of the rapid changes in temperature and moisture that occurred at that time of the year. To measure the deflections on a pavement at the precise time when they were the highest in the spring period was difficult and sometimes impossible. The high deflection might last only a few days, and we could not tell whether the measurement taken was actually the maximum spring deflection. The changes occurring in deflections during a year are shown in Figure 3. Because of the impracticality of monitoring deflections every few days on every project in the state during the spring period to find the maximum or average deflection, we use fall deflections for pavement evaluation. The relatively arid climate in Utah permits deflections to be taken from June to November.

In 1969 we acquired a Mu-meter, which proved to be a reliable tool for evaluating skid resistance on pavement surfaces (11, 13). In the fall of 1969, we combined the results from the various research projects (1, 3, 4, 5, 6, 7, 10, 16) into a system that could be used as an aid for managing all pavements throughout the state (8). The system included structural adequacy determined from deflections, PSI, and slipperiness from the skid resistance measurements. These factors were based on concepts developed from the previous research. Typical prediction curves are shown in Figure 4. We anticipated that the system would provide answers to the following major questions:

1. When will pavement improvements be required?
2. What type of improvement is required?
3. How much of a correction is required?
4. What are the priority ratings for improvements?

A fourth factor of sufficiency, based on tolerable levels from design standards, provides the basic criteria for determining reconstruction of the roadway. Sufficiency determinations are made by the Transportation Planning Section (14, 15). Knowing the remaining life from the structural adequacy, serviceability, and slipperiness factors, we can determine the additional needs and correct for all the factors. We found that the various factors could not be related to produce one number that would indicate overall pavement condition. A pavement could fail in one area but be in good condition in another. The resulting number could indicate that the pavement was in fair to good condition when in fact it was not. A failure in any area is critical and, therefore, all must be looked at individually as well as collectively when recommendations are made for improvements or rehabilitation.

The effect of all the factors is sometimes overlooked because it is extremely difficult to determine the exact deficiencies of a pavement by visual observation. A pavement can have a weak base, yet the surface will appear to be good, or the surface can be deteriorated when the base has adequate strength. If the structural strength of the in-place pavement is ignored when it is weak, the correction will be short-lived, resulting in early failure. A design requiring additional structural strength should include an overlay that would correct the 3 major factors.

Data for the system were first gathered on a statewide inventory basis in 1970. The data were analyzed by the computer, and output tables covered average condition and predicted life, thickness requirements for a 10-year life, and priority listing. The priority listing included a condition statement based on the shape of the deflection basin. The 1970 system output was used by the Highway Systems Planning Division to help develop the required information for the 1990 functional plan and needs estimate for Congress.

The output was also used to evaluate the recommendations from the districts for roadway improvements. The recommendations from the system did not agree with those from the districts in some cases. In some of those cases the districts modified their recommendations, but in others they indicated they could not. The pavements in question were shown to be in good condition in all areas by the system data, yet the districts claimed they were highly distressed. A further evaluation showed that those sections did have a high PSI, based primarily on a relatively smooth riding surface, but had extensive cracking. Therefore, the basic conflict was the difference in the user's viewpoint of performance as evidenced by a high PSI and the maintenance engineer's

concern for distress as shown by extensive cracking. Performance and distress are comparable on many pavements but not all. As a result of this experience, additional field data were gathered on pavement surface defects or distress for the system in 1971, 1972, and 1973, and another output table was produced showing the surface defects.

The system was designed so that information developed on all pavements in the state could be used as feedback data to improve the system. Additional experience by the users of the system output allows them to make recommendations for further improvements and refinements. The system was initially designed for the benefit of planning and programming, maintenance, materials and tests, research, and pavement design.

#### PAVEMENT DESIGN

The pavement design process has been computerized, and the input information consists of

1. Traffic data for the design year including a breakdown for heavy trucks, light trucks, and passenger cars;
2. Load distribution factors;
3. Percentage of traffic in heaviest lane;
4. Dynamic CBR values;
5. Unit costs for various materials;
6. Terminal serviceability index;
7. Regional factor; and
8. Structural coefficients.

The data are processed by the computer, and the output consists of structural number required, design 18-k (80-kN) axle loads, and a series of acceptable pavement designs, including costs, from which the best or most economical design is selected. Computer terminals are being placed in the district offices so that the pavement designs can be directly obtained.

#### PAVEMENT EVALUATION SYSTEM

All pavements in the state are evaluated according to a set schedule. New pavements are evaluated only every second or third year, and old pavements are evaluated each year because they deteriorate rapidly. Each pavement is evaluated according to deflection, serviceability, skid resistance, and surface defects. The measurements are made during the relatively stable climatic period between June and November; nonetheless, climatic conditions differ from year to year and cause some variation in results.

The field data gathered by the Dynaflect crew include for each mile (1.6 km) of pavement tested the deflection readings from the 5 sensors and the pavement and ambient temperatures. A Cox roadmeter is used to gather continuous roughness data (12) for the pavements tested. The Mu-meter is used to measure skid resistance of the pavement surface. The pavement surface is wet, and  $\frac{1}{4}$  mile (0.4 km) out of each mile is tested. A crew evaluates a 500-ft (150-m) section out of each mile to obtain data on the type and extent of cracking, patching, and rutting and rates the surface condition for uniformity, aggregate pop-out, surface wear, weathering, and crack condition. Data on present traffic and projected increases are obtained for all test sections.

All test sections are assigned to cells according to an experimental design that permits the use of the proper prediction equations. The data are then processed by the computer, and the following information is produced for each project. The deflection information includes

1. The deflection readings of 5 sensors at each test site,
2. Average Dynaflect maximum deflection (DMD),
3. Surface curvature index (SCI) (the numerical difference between sensors 1 and 2, which provides an indication of the strength of the surface layers),
4. Base curvature index (BCI) (the numerical difference between sensors 4 and 5, which provides an indication of the strength of the subgrade),

5. Predicted remaining structural life in 18-k (80-kN) axle loads and years,
6. Bituminous overlay thickness required for the pavement to achieve 10 years of structural life from the time the measurements are taken, and
7. Condition statement based on DMD, SCI, and BCI, which indicates the relative strength of the pavement system, e.g., pavement weak, subgrade strong.

The serviceability information includes

1. Summation of the roughness count per mile,
2. Cracking,
3. Patching,
4. Rutting,
5. PSI, and
6. Predicted remaining serviceability life in 18-k (80-kN) axle loads and years until the pavement reaches the terminal serviceability index.

The skid-resistance information includes

1. Skid index values from the Mu-meter, and
2. Predicted remaining safe skid-resistance life in traffic loads and years.

The surface defect information includes

1. Transverse cracking (1 ft/1,000 ft<sup>2</sup>, 1 m/93 m<sup>2</sup>);
2. Longitudinal cracking (1 ft/1,000 ft<sup>2</sup>, 1 m/93 m<sup>2</sup>);
3. Load-associated cracking, map or alligator (1 ft<sup>2</sup>/1,000 ft<sup>2</sup>, 1 m<sup>2</sup>/93 m<sup>2</sup>);
4. Patching (1 ft<sup>2</sup>/1,000 ft<sup>2</sup>, 1 m<sup>2</sup>/93 m<sup>2</sup>);
5. Average condition of the transverse and longitudinal cracks, including opening, multiplicity, and abrasion on a scale from 1 to 5, where higher values indicate a better condition;
6. Average surface wear on a scale from 1 to 5;
7. Average weathering on a scale from 1 to 5;
8. Average pop-outs per square foot on a scale from 1 to 5;
9. Average uniformity on a scale from 1 to 5; and
10. Average rut depths.

The results from the field evaluation and data analysis are then combined; a typical table for one of the projects tested is shown in Figure 5. This table gives a summary of all data, the average condition and expected remaining life in terms of deflection, serviceability, skid resistance, and surface defects.

A computer program provides a priority need listing for all projects. This program gives first priority to structural needs and then to serviceability and slipperiness needs because structural rehabilitation is generally more costly. If structural rehabilitation is required, a detailed project evaluation is made to determine the exact needs.

#### PAVEMENT MANAGEMENT SYSTEM

A research study was started in July 1972 to develop a pavement management system. This has evolved into more than a simple pavement management system because of the necessity to coordinate a number of existing systems in the department. The pavement information storage and analysis program (PISAP) will function with a data bank, in which data are primarily stored according to a road section. The types of data proposed for the data bank are geometrics, pavement design, construction control, environmental conditions, maintenance activities, pavement rehabilitation, traffic data, and pavement evaluation.

Subprograms of PISAP will analyze the data and provide information to appropriate offices on the condition of each pavement section. As the road section deteriorates, it will move up in the priority list provided by PISAP. Each year the road sections with the highest priorities will be slated for reconstruction or rehabilitation based on available funds.

The PISAP data bank will contain 3 major files: historical, management, and operational. With the information PISAP provides, management will be able to make more

Figure 5. Typical output from pavement evaluation system for a road section.

PAVEMENT EVALUATION FOR STATE ROUTE 501 SECTION 53										SUB SECTION 0			WEBER COUNTY (29)			DISTRICT 1		FAI-0	
FROM BRIGHAM					MILEPOST 367.13					TO ELWOOD			MILEPOST 377.00			LENGTH		9.87	
MATERIAL COVER AGGREGATE BITUM. SRFACE (CABS)					MAINTENANCE SHED 123					I.D. NO. 106			WIDTH		12.	T.S.I.		2.5	
YEARLY INCREASE IN 18K LOADS 5.0 %					PRESENT 18K LOADS 0.20827E+06														
* * DYNAFLECT TEST DATA * *										* * DYNAFLECT SUMMARY AND AVERAGE CONDITIONS * *									
NO. OF TESTS 10 DATE 8/28/73 HR 14 MIN 15																			
TEMPERATURES: AIR 84.00, SURFACE 99.00, PAVEMENT 96.00																			
WHL PATH JSWP LANE SBL LAST REVISION																			
F= 2.248																			
										DMD SCI BCI 18K LOADS									
										MIN 0.38 0.08 0.02 TO FAILURE									
										MAX 1.14 0.30 0.17 1.9005E+07									
										AVE 0.63 0.14 0.05 6.5179E+05									
DUTYLING VALUES										STRUCTURAL NO. REQUIRED FOR 10. YEARS ADDITIONAL LIFE IS									
MEAN 0.63 0.50 0.35 0.27 0.21										AVERAGE SCI & BCI INDICATE PAVEMENT AND SUBGRADE STRONG.									
STANDARD DEVIATION 0.26 0.24 0.18 0.11 0.06										IF PRESENT TRENDS CONTINUE, THE STRUCTURAL NEEDS ARE									
VARIANCE 0.07 0.06 0.03 0.01 0.00										MODERATE AND THE ROAD WILL PROBABLY LAST FROM SIX TO TEN Y									
T(N) 1.98 2.08 2.44 2.40 2.21																			
ACTUAL READINGS										SCIREQ= 0.20 BCIREQ= 0.06 DMDREQ= 0.64 IDSYRS= 13									
0.98 0.86 0.55 0.39 0.29																			
1.14 0.99 0.78 0.52 0.35																			
0.46 0.38 0.26 0.21 0.17																			
0.38 0.30 0.25 0.20 0.16																			
0.58 0.40 0.25 0.21 0.19																			
0.46 0.30 0.23 0.21 0.17																			
0.48 0.36 0.28 0.24 0.22																			
0.52 0.42 0.28 0.20 0.17																			
0.82 0.52 0.30 0.25 0.19																			
0.52 0.44 0.30 0.24 0.21																			
* * SERVICEABILITY SUMMARY AND AVERAGE CONDITIONS * *										* * SERVICEABILITY SUMMARY AND AVERAGE CONDITIONS * *									
NO. TESTS 10 DATE 6/21/73 MPH 50.										PSI: AVERAGE 3.4 MINIMUM 3.2 MAXIMUM 3.6									
AVERAGE SURFACE WEAR 3.3 AVERAGE POPOUTS 4.										AVERAGE P.S.I. INDICATES THAT THE SERVICE NEEDS ARE MODERATE									
AVERAGE WEATHERING 3.3 AVERAGE UNIFORMITY 3.4										AND WILL PROBABLY FALL BELOW THE T.S.I. IN SIX TO TEN YEARS.									
AVERAGE RUT DEPTH (IN) 0.10 YN 6 YX 10 YA 9																			
AVERAGE CRACKING PER 1000 SQ. FT.										AVERAGE PATCHING PER									
TRANSVERSE LONGITUDINAL										OF TRANSVERSE AND									
SEALED NOT SEALED NOT										LONGITUDINAL									
(FT) SEALED (FT) SEALED										CRACKS									
0. 20. 0. 7.										OPEN. ABRAS. MULT.									
										4.2 3.8 3.7									
* * SKIDMETER TEST DATA * *										* * SKIDMETER SUMMARY AND AVERAGE CONDITIONS * *									
NO. TESTS 5 DATE 5/31/73 TEMPS: AIR 67.00 ASPHALT 74.0										SKID INDEX: MINIMUM 34 MAXIMUM 64 AVERAGE 56									
TEST 01 02 03 04 05 06 07 08 09 10 11 12 13										AVERAGE SKID INDEX INDICATES THAT THE ROAD IS									
SKD IND 59 62 64 34 63 ** * *										MARGINAL, FURTHER MONITORING SUGGESTED.									
										HOWEVER, MINIMUM SKID INDICATES PORTIONS THAT ARE									
										CRITICAL, SLIPPERINESS FAILURE INDICATED.									

informed decisions, causes of premature failure can be readily determined, and proper corrective action can be taken more quickly.

#### SUMMARY

A pavement evaluation system to determine existing condition and future needs has been the outgrowth of research conducted in Utah beginning in 1964. Improvements will be made in the system as additional information becomes available. Certain assumptions that were made during the development of the system will be modified or verified as additional data are gathered and analyzed.

In field inventories, sampling and testing must be carefully planned and executed. Data of poor quality can destroy the effectiveness of a pavement evaluation system. A good experimental design is necessary for classifying the projects tested and for ensuring reliable results.

Utah's pavement information storage and analysis program has the potential for becoming a valuable tool for personnel concerned with the design and management of pavements. Further research is needed to relate the performance of a pavement to distress. A pavement distressed because of cracking may have a high performance level because of a smooth riding surface. The distress of the pavement surface may cause a rapid deterioration in performance. Performance is the primary item of concern to the user, and distress is of concern to the maintenance engineer.

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