TECH**BRIEF**

Variability of Pavement Distress Data From Manual Surveys

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Introduction

A goal of the Long Term Pavement Performance (LTPP) program is to provide the data necessary to improve our ability to predict pavement performance. Performance prediction is a critical element in effective pavement design and management; however, it suffers from a lack of accuracy in the models and a high degree of variability in the input data used to drive the predictions. The eventual objective is a set of distress-specific performance models that can be used to reliably predict pavement performance related to traffic, the environment, material properties, etc. These models can only be developed using reliable, good-quality pavement distress measurements.

Several measures have been carried out in the LTPP program to ensure uniform distress data collection and interpretation, including the development and revision of the *Distress Identification Manual* and the conducting of rater accreditation workshops. However, no systemic evaluation has been done to quantify the variability (bias and precision) associated with both the manual and film-derived pavement distress data. In view of this, a study was undertaken to assess the variability of the LTPP distress data, consisting of the assessment of manual distress data variability, assessment of film-derived distress data variability, and assessment of the agreement between manual distress data and film-derived distress data. The full report is contained in *Study of LTPP Distress Data Variability, Volume I*, Report No. FHWA-RD-99-074, September 1999. The focus of this TechBrief is variability in manually collected pavement distress data.

Data Source

Data used for evaluating manual distress data variability were obtained from 9 LTPP rater accreditation workshops, including 119 individual manual distress ratings on 18 accreditation pavement test sections (9 on asphalt concrete (AC) and 9 on portland cement concrete (PCC) test sections). From 6 to 16 individual raters per workshop performed the ratings on the same day on the same test sections. Reference surveys of these 18 test sections were also conducted by the workshop instructors immediately before each workshop using a consensus rating method; distress data from these surveys were used as a surrogate for ground truth data in the study.

The Long Term Pavement Performance (LTPP) program is a 20-year study of in-service pavements across North America. Its goal is to extend the life of highway pavements through various designs of new and rehabilitated pavement structures, using different materials and under different loads, environments, subgrade soil, and maintenance practices. LTPP was established under the Strategic Highway Research Program, and is now managed by the Federal Highway Administration.

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Global Trends

Plots of distress quantity at each severity level and total across all severity levels for a distress type were developed to provide overall trends of variability associated with manually collected distress data. Key observations that emerged from this analysis are:

- Individual rater variability for any given distress type/severity level combination is typically large and increases as the distress quantity increases.

- Total distress group means are generally close to the reference value, while the scatter of the individual raters is more narrow than that for the individual distress severity levels. This shows significant differences in distinguishing severity levels.

- For closely related distress types, such as fatigue cracking and longitudinal cracking in the wheelpath, compensatory differences between the group ratings and reference values were observed, i.e., group ratings indicated a higher quantity of fatigue cracking and a lower quantity of longitudinal cracking as compared to the reference values.

Pavement Condition Index

Variability in distress data collection is not a new discovery. To put this variability into perspective, the widely used Pavement Condition Index (PCI)[1] was calculated for these surveys. When all distress type/severity level combinations are viewed through this single composite number, there is excellent agreement between the individual raters, the group mean, and the reference value. The difference between the group mean and the reference value was less than 6 PCI at six of the nine workshops and less than 14 PCI at the remaining three workshops. The individual rater variability is also small when viewed in terms of this composite value; the standard deviation was less than 5 PCI at five of the nine workshops and did not exceed 8 PCI at the remaining four workshops.

Bias and Precision

The variability of manual distress data, expressed in terms of bias and precision, was quantified in this analysis and is presented in tables 1 and 2 (be-

Table 1. Indicators of precision and bias for AC pavement distresses.

Distress Type	Unit	Distress Severity	Pooled Ref.	GROUP Mean	Std. Dev.	COV (%)	Bias
Fatigue Cracking	sq. meters	All Levels (Total)	14.2	16.5	6.2	38	2.3
Longitudinal Cracking WP	meters	All Levels (Total)	18.4	18.3	6.0	33	-0.2
Longitudinal Cracking NWP	meters	All levels (Total)	75.0	70.7	14.7	21	-4.3
Transverse Cracking	number	All Levels (Total)	26.4	24.7	3.2	13	-1.7
Transverse Cracking	meters	All Levels (Total)	44.3	44.6	4.2	9	0.3

[1]U.S. Army Corps of Engineers, Pavement Maintenance Management for Roads and Parking Lots, Technical Report M-294, October 1981.

low) for AC and PCC pavements, respectively. In these tables, the bias is the difference between the references and their corresponding group means. To overcome the often very small quantities of some distresses, the coefficient of variation (COV), in percentages, was determined by constructing plots of standard deviation versus mean for each distress type/severity level combination and fitting the best line through these data. The slope of the best-fit line (in percentages) forced through zero is a measure of the ratio of standard deviation and mean, and was taken as the COV. The following observations were derived from the COV plots and tables:

- Standard deviation seems to increase as distress quantity increases.
- The apparent bias for most distress type/severity level combinations is small, suggesting that group means may be used to represent unbiased estimates of the reference values.
- The precision of the manual distress data varies considerably; however, most of the large COVs are associated with very small magnitudes of distress. The precision seems acceptable when considering the COVs of the total distresses only. COV values ranged from 9% to 38% for AC pavements and from 8% to 22% for cracking-related PCC pavement distresses. Quantifying precision for joint spalling in PCC pavements appears to be more difficult.

A more vigorous statistical analysis was also conducted to investigate further the suggestion that the group mean may be considered as an unbiased estimate of the reference. It was concluded that there was no statistical difference between the reference and the group mean for most distresses. Therefore, assuming a normal distribution and using a 95% confidence level, one can state that the true value is bound by the measured value ±2 standard deviations. The standard deviation can be calculated using regression equations developed in this study.

Recommendations

The outcome of this study produced several specific items that

Table 2. Indicators of precision and bias for PCC pavement distresses.

Distress Type	Unit	Distress Severity	Pooled Ref.	GROUP Mean	GROUP Std. Dev.	GROUP COV (%)	GROUP Bias
Corner Breaks	number	All Levels (Total)	3.9	3.7	0.5	14	-0.2
Longitudinal Cracking	meters	All Levels (Total)	7.5	7.0	1.6	22	-0.5
Transverse Cracking	number	All levels (Total)	9.4	9.6	1.4	15	0.2
Transverse Cracking	meters	All Levels (Total)	24.8	25.0	2.1	8	0.2
Spalling of Longitudinal Jts.	meters	All Levels (Total)	6.6	7.2	4.9	68	0.5
Spalling of Transverse Jts.	number	All Levels (Total)	3.7	3.4	0.9	25	-0.3
Spalling of Transverse Jts.	meters	All Levels (Total)	1.7	2.0	1.4	71	0.3

were adopted in the training, data collection, and data review processes of the LTPP program. In addition, the bias and precision findings are a first step in quantifying distress variability for use in stochastic modeling of pavement performance. The recommendations for use in the LTPP program include:

- Enhanced rater training within the LTPP regional coordination offices and a requirement for minimum levels of data collection activity within a calendar year.
- Stricter, more uniform data quality checks for incoming distress data. These include time- series studies to ensure logic and consistency between survey events.
- Reliance on standard deviation (expressed as a percentage of an assumed maximum quantity) as a basis for determining the COV.

The authors believe that for research purposes, target levels of variability for distress of 10% are desired so that 90th percentile confidence limits are less than 30%. The difficulty is in the percentage calculation because low distress quantities create very large coefficients of variation. Sometimes this variability is not significant in absolute terms relative to the large amounts of distress that could occur. It is recommended that additional research be conducted to assess the impact of indexing these variability values to logical maximum values or assumed "typical" values.

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Distribution—This TechBrief is being distributed according to a standard distribution.

Availability—The publication linked to this TechBrief is *Study of LTPP Distress Data Variability* (Report No. FHWA-RD-99-074). It is available from the National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161. A limited number of copies will be available from the R&T Report Center, FHWA, 9701 Philadelphia Court, Unit Q, Lanham, MD 20706, telephone: (301) 577-0818, fax: (301) 577-1421.

Key Words—Variability, distress, bias and precision, manual survey, film-derived distress survey, and LTPP.