TECH**BRIEF**

Adequacy of Rut Bar Data Collection

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LTPP

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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Introduction

Pavement rutting is a critical distress in flexible pavements because rutted pavements pose a serious safety hazard. During wet weather, water tends to collect in the pavement ruts, increasing the potential for hydroplaning and associated wet-weather accidents. Pavement rutting also may have a detrimental effect on overall ride quality and, hence, user satisfaction.

The importance of timely corrective action for rutted pavements, coupled with the need for safe and efficient data collection, has led many State highway agencies to use automated survey vehicles to collect the data needed to assess and monitor the extent and severity of pavement rutting. Typically, these devices measure the distance from a reference point on the survey vehicle to the pavement surface at three or five points across the pavement width. These data are then used to compute an estimate of the depth of pavement rutting. Recent Long Term Pavement Performance (LTPP) data analysis has provided information on the repeatability and accuracy of the rut statistics obtained with these devices.

Key Findings

- The transverse location of the rut bar dramatically affects the measurements and, hence, the rut depth computation. Thus, consistent lateral placement of the survey vehicle is essential to repeatable rut depth measurements using the three- or five-point procedure.

- The three measurement systems (wire line, three point, and five point) do not provide the same rut depth values. In other words, the two rut bar measurement systems did not necessarily provide a measurement of the rut depth that is similar to the true total amount of rutting as measured by the wire line method.

- Although the five-point rut depths are more highly correlated with the wire line rut depths, they consistently underestimate the mean wire line rut depth.

- Due to the highly variable measurement of rut depth using the three- or five-point method, consistent year-to-year measurements may be difficult to achieve.

Monitoring Pavement Rutting

Rut bars are commonly used by highway agencies for collecting rut depth data for their pavement management systems. The most widely used rut bars are equipped with either three or five sensors.

The top portion of figure 1 provides the standard configuration of the five-sensor rut bars. The rut depth is obtained by drawing a line from the elevations at sensor 1 to sensor 3 and sensor 3 to sensor 5. The difference between the line and the pavement elevation at sensors 2 and 4 is the rut depth for the left and right wheelpaths, respectively. The average of the left and right wheelpath rut depths generally is recorded in the agency's pavement management system and is used for programming rehabilitation activities.

The rut bar configuration with three sensors is illustrated in the lower portion of figure 1. The rut depths for the two wheelpaths are computed by taking the difference in pavement elevation between the wheelpath sensors (sensors 1 and 3) and the mid-lane sensor (sensor 2).

The LTPP protocol for collecting rut depth data uses a photographic technology that results in a series of approximately 30 x-y points that accurately describe the transverse surface of the travel or outer lane of the pavement at a particular location. The transverse profile is measured at intervals over 15.2 m in the 152-m LTPP section. These x-y points are used to determine the rut depth, as shown in figure 2. Rut depth is the difference in elevation between the pavement surface and an imaginary wire that is stretched across the lane. Both wheelpath rut values are stored in the LTPP database. Comparisons of rutting were made using the average of the wheelpath rut depths.

Figure 1. Illustration of rut bar configuration.

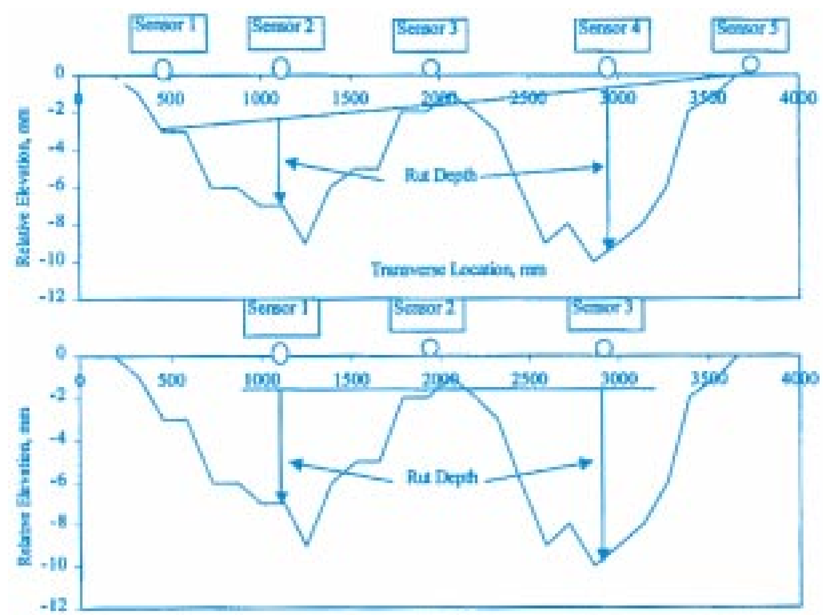
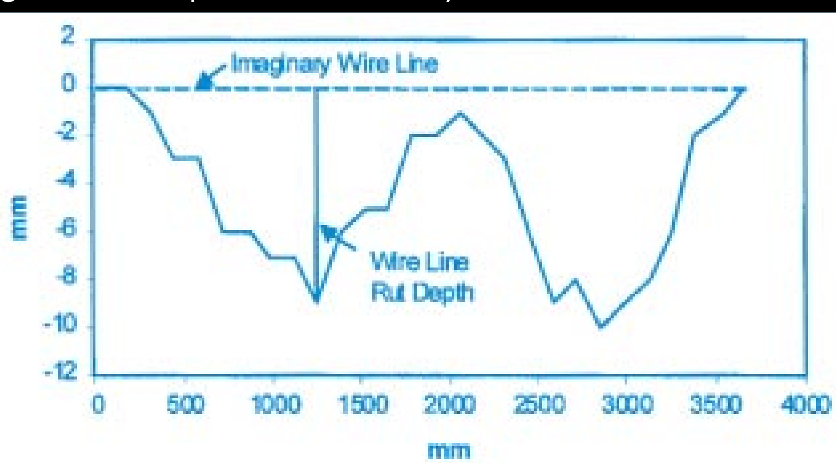


Figure 2. Rut depth as determined by the wire line method.



Rut Depth Calculation

The LTPP transverse profile data were used to simulate three-point and five-point rut bar data for 1,387 test sections, using two approaches to rut bar measurement, as illustrated in figure 3. In the "best case" scenario, the transverse placement of the rut bar is identical for all stations along the test section at which transverse profile data are collected (no lateral vehicle movement in the lane within the section). In the "worst case" scenario, the transverse placement of the rut bar is random for all stations (variable lateral vehicle movement in lane within section).

For each scenario, rut depth calculations are made at each station along the highway at a randomly selected transverse location (from a normal distribution) for 30 data collection "runs." The lateral standard deviation or "wander" of the survey vehicle used in the computations was 127 mm. This value for the vehicle wander was determined from field data collected at a limited number of sites.

The variability of the section average between simulated runs was examined using both the best case and the worst case scenario. The coefficients of variation (COVs) for the best case scenario were nearly identical to those for the worst case scenario (103.6 vs. 104.4). For the three-point rut bars, the average COV was 104 percent, while the average COV for the five-point rut bars was 239 percent. These values indicate that the transverse placement of the rut bar dramatically influences the measurement and, hence, the rut depth calculation. For example, for the profile shown in figure 4, if the transverse placement of the sensors for a five-point rut bar is varied by 127 mm (5 in), as indicated by the data points and error bars at the top of figure 4, the mean rut depth varies from -0.5 mm (a slight "hump") to 10 mm, as indicated in table 1.

Analysis of Rut Depth Data

Two statistical parameters were used to examine the relationship between the three-point, the five-point, and the wire line rut depths. Results from the paired t-test were used to determine the probability that the three-point rut depth is equal to the wire line rut depth or the probability that the five-point rut depth is equal to the wire line rut depth. Similarly, the correlation coefficients indicate the strength of the relationship between the three-point or five-point and wire line rut depths. In other words, the correlation coefficient provides a quantitative index of the degree to which the three-point or five-point rut bars correlate with the wire line rut depth. A correlation coefficient of 0 indicates no relationship and a coefficient of 1 indicates a perfect one-to-one relationship.

The data were examined as a whole and in four subsets based on the shape of the profile. Based on the paired t-test, there is zero probability that either the three-point or the five-point rut depth measured is equivalent to the wire line rut depth, regardless of cross-profile shape category. The data set was then arbitrarily divided into three groups based on the magnitude of the rutting. A third of the data, with a mean rut depth greater than 7.25 mm, was classified as high; the next third was classified as moderate; and the final third of the data set, with an average rut depth of less than 4.32 mm, was classified as low. Results from these t-tests indicate that there is zero probability that either the three-point or five-point rut depth is equivalent to the wire line rut depth.

The correlation coefficients for the entire data set are shown in table 2.

Figure 3. Rut bar calculation scenarios (best case: same lateral locations at each station, worst case: random lateral locations at each station).

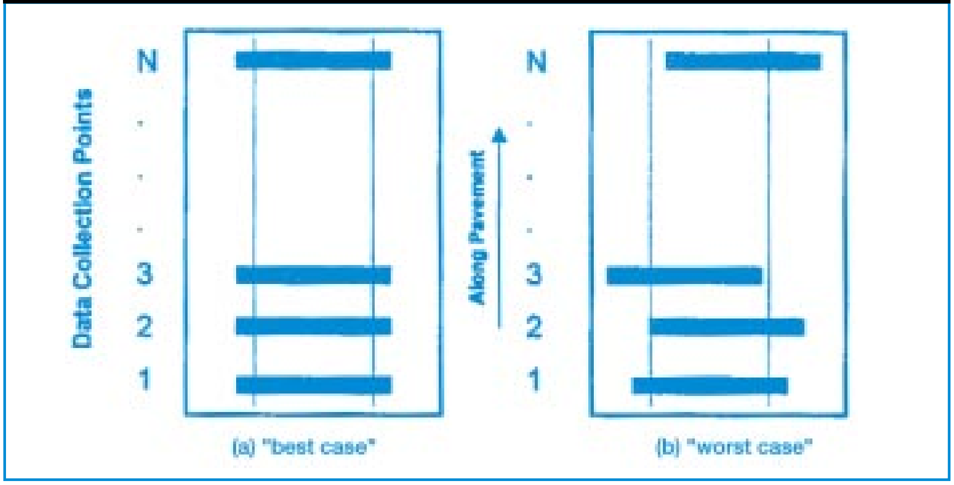


Figure 4. Sample transverse profile with varying rut bar sensor positions.

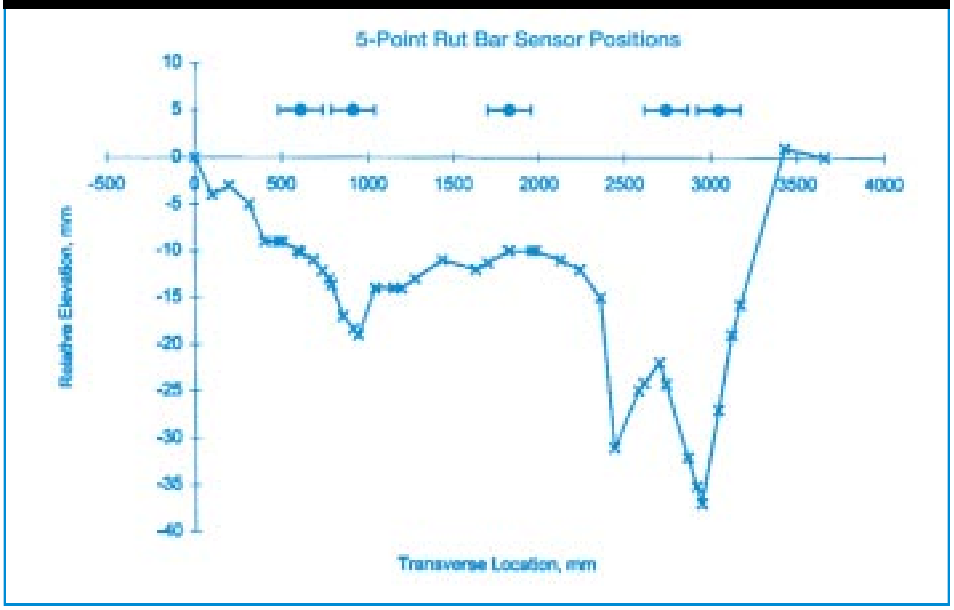


Table 1. Variation in five-point rut depth with transverse position for profile shown in figure 4.

Transverse Position of Left Wheelpath Sensor	Left	Right	Average
787 mm	4	-5	-0.5
914 mm	8	2	5
989 mm	2	18	10

Table 2. Correlation coefficients (r) for the entire data set.

Correlation Coefficients	Wire Line Rut Depth	Three-Point Rut Depth	Five-Point Rut Depth
Wire Line Rut Depth	1.0000	0.4108	0.7940
Three-Point Rut Depth	0.4108	1.0000	0.3772
Five-Point Rut Depth	0.7940	0.3772	1.0000

Figure 5. Example from section 21001 of the average rut depth and standard deviation measured over time (the bars represent ±1 standard deviation).

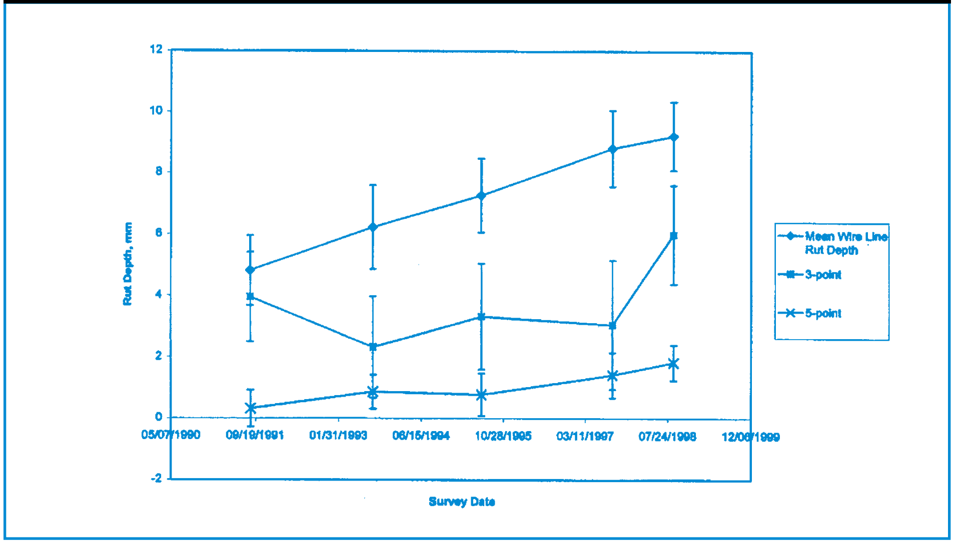
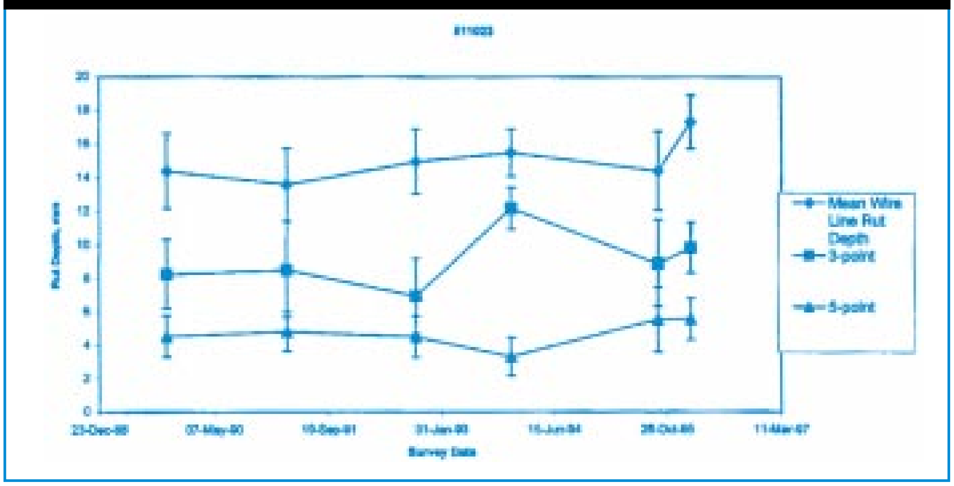


Figure 6. Example from section 511023 of the average rut depth and standard deviation measured over time (the bars represent ±1 standard deviation).



Although the five-point rut depth is more highly correlated with the wire line rut depth, it still greatly underpredicts rut depth. Figures 5 and 6 show typical examples of the average rut depth and standard deviation measured over time for two of the LTPP test sections using the three-point and five-point rut bars as compared to the average rut depth and standard deviation measured from the wire line.

Recommendations

The following recommendations are made based on these results:

- The three-sensor rut bar does not provide repeatable and accurate rut depth measurements and, therefore, would not provide adequate network-level rut depths for pavement management systems. Inconsistent rut depth measurements obtained over time from the highway network would be problematic for determining rehabilitation needs.

- If a five-sensor rut bar is used for network-level data collection, care should be taken to ensure that the transverse location of the rut bar is consistent from year to year and that the mean values are adjusted to reflect more realistic rut depth values.

Researcher—This study was performed by Fugro-BRE, Inc., 8240 MoPac, Suite 220, Austin, TX 78759, Contract No. DTFH61-96-C-00003.

Distribution—This TechBrief is being distributed according to a standard distribution. Direct distribution is being made to the Resource Centers and Divisions.

Availability—The publication from which this TechBrief was developed—*Characterization of Transverse Profile* (Report No. FHWA-RD-01-024)—will be 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, HRD-11, FHWA, 9701 Philadelphia Court, Unit Q, Lanham, MD 20706, telephone: (301) 577-0818, fax: (301) 577-1421.

Key Words—Rutting, permanent deformation, transverse profile.