TECH**BRIEF**

Validation of Pavement Performance Measures Using Long-Term Pavement Performance Data

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This document is a technical summary of the Federal Highway Administration report *Validation of Pavement Performance Measures Using LTPP Data*, Publication No. FHWA-HRT-17-089.

Background

The Moving Ahead for Progress in the 21st Century (MAP-21) Act requires performance measures to be established for the Interstate Highway System (IHS).[1] Consequently, in January 2015, the Federal Highway Administration (FHWA) issued a Notice of Proposed Rulemaking (NPRM) to establish performance measures to assess the condition of the pavements on the National Highway System (NHS) and IHS.[2] And, in January 2017, FHWA issued the Final Rule to implement the performance management requirements of MAP-21 and the Fixing America's Surface Transportation Act.[3] The performance measures established to assess pavement condition are the percentage of pavements on the IHS in good condition, IHS in poor condition, NHS (excluding IHS) in good condition, and NHS (excluding IHS) in poor condition.[4] The condition of the pavements is to be determined based on the following condition metrics contained in the Highway Performance Monitoring System (HPMS): the International Roughness Index (IRI), cracking percent, rutting, and faulting.[4]

An important first step toward implementation of the performance measures by highway agencies is to demonstrate the measures are valid and effective. Due to the wealth of data contained in its Pavement Performance Database, the Long-Term Pavement Performance (LTPP) program was poised to

The Long-Term Pavement Performance (LTPP) Program is a large research project for the 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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assist in implementation of the performance measures. Accordingly, FHWA undertook a study to validate the pavement performance measures and to demonstrate their use within the pavement decisionmaking process.[5,6] Accomplishing these objectives required translation of LTPP pavement condition data to condition metrics in accordance with the NPRM. For asphalt concrete (AC) percent cracking, the translation was done based on the NPRM and Final Rule. A database containing the translated data and other supporting information was created; it is available via LTPP InfoPave™ (https://infopave.fhwa.dot.gov/). This database supported all analyses for the study in question, and highlights from those analyses are presented in this TechBrief.

Initial Validation

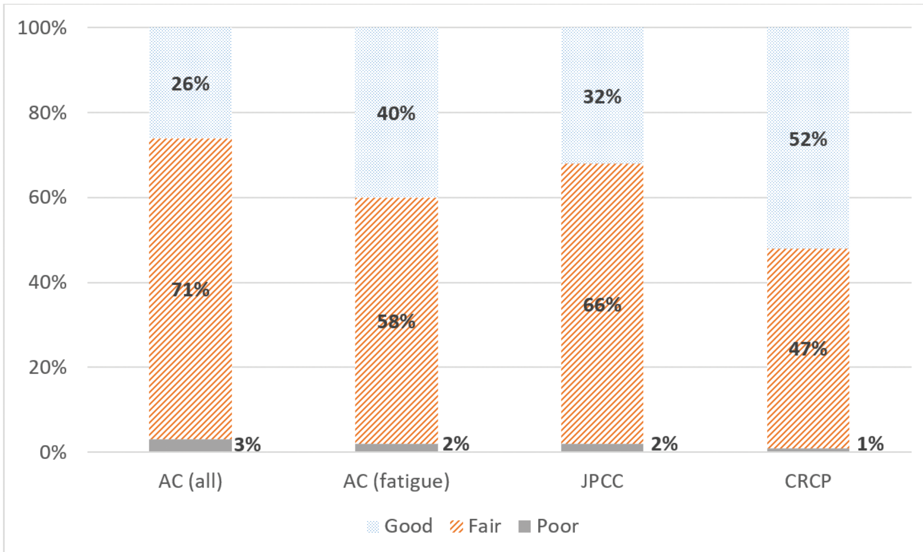
A summary aggregate statistical approach was used to get a grasp on general data trends to make sure the data were suitable for the planned analyses as well as for more indepth analyses. The initial analysis entailed a review of condition metrics over time. As part of the review, the numeric values from surveys within two consecutive construction events were plotted versus time, and a linear trend line was defined for each section. The trend was then classified as increasing (worsening), decreasing (improving), or no change, based on the slope. The results appeared logical, in that conditions generally worsen with time in the absence of maintenance and rehabilitation (M&R). An increasing slope was found for 70 percent or more of the cases. For those cases in which the slope did not increase, there was generally an explanation; for example, it is expected that rutting will increase with time, but the rate of change is generally less than the measurement error, and as a result, it is possible for pavements to show a decreasing slope.

The next analysis looked at changes in overall condition over time, with condition established by grouping the individual condition metrics; each group required that surveys of the different condition metrics were taken within 1 year. Figure 1 presents the overall condition ratings for AC (NPRM) pavements, AC (Final Rule) pavements, jointed portland cement concrete (JPCC) pavements, and continuously reinforced concrete pavements (CRCPs). As shown, there are few groupings in poor condition (less than 3 percent), and, except for CRCP, the majority of groupings are in fair condition.

The overall condition trends over time were then reviewed to determine if they followed a logical (good to fair to poor) trend. The results showed that they performed as expected in 83 percent or more of the cases. A more indepth review of those cases not following the expected trend was conducted. For AC pavements, for example, the main cause was rutting values fluctuating between 0.15 and 0.2 inch (i.e., between good and fair), while for JPCC pavements, it was faulting values fluctuating between 0 and 0.05 inch (i.e., between good and fair).

Next, a comparison was made of the condition metrics and overall condition time-series against documented M&R applications. Treatments were first grouped based on similarity; for example, skin patching and pothole patching were grouped under patching. Next, the trend of the individual metrics was classified as increasing, decreasing, or no change, and the change in the metric resulting from the M&R application was quantified in percentage and magnitude terms. For the IRI metric, for example, the results showed that treatments such as mill and overlay and overlay had the most significant effect (i.e., reduction) on IRI. Finally, the M&R effect on overall condition was investigated. Table 1, for example, shows how JPCC pavement overall

Figure 1. Overall condition rating.



Source: FHWA.

Table 1. JPCC overall pavement condition between construction events.

Treatment Type	No Change (%)	Improve (%)	Reduce (%)
Crack seal	86	0	14
Grinding	72	17	11
Joint seal	88	5	7
Patch	90	0	10
Slab replacement	50	17	33

condition was affected by M&R, with the effect classified as improved, reduced, or no change. As shown, the overall condition is largely unaffected based on the large percentage of no change.

The results also showed that the largest "No Change" percentage is a result of a "before" condition of fair and, to a lesser degree, a "before" condition of good. Table 2 illustrates the M&R impact on performance measures after treatment. For AC pavements and CRCPs the percent good increases, while for JPCC pavements, the percent good slightly decreases (only grinding was shown to improve overall condition, and that was minimal in comparison to the amounts associated with other treatments).

The final analysis entailed the review of overall condition against thresholds. First, the composition of the overall condition rating to the metric conditions was compared; in other words, how was overall condition affected by individual condition metrics? As an example, table 3 shows the breakdown of metrics for AC pavements. As shown, the overall condition rating for fair is driven by rutting, with 75 percent having rutting in fair or poor condition. The poor rating is driven by cracking and rutting.

Next, a review was conducted to identify the number of metrics in a given condition that makes up the overall condition. It was determined that the overall condition rating of

Table 2. Effect of treatments on performance measures.

Pavement	Before Good (%)	Before Poor (%)	After Good (%)	After Poor (%)
AC (NPRM)	3.6	2.2	6.1	1.4
AC (Final Rule)	6.2	1.2	11.1	1.0
JPCC	4.2	2.5	4.0	3.0
CRCP	9.5	0	13.8	0.5

Table 3. AC (Final Rule) percentage metrics.

Condition Rating	IRI	IRI	IRI	Cracking	Cracking	Cracking	Rutting	Rutting	Rutting
Condition Rating	G	F	P	G	F	P	G	F	P
Good	100%	0%	0%	100%	0%	0%	100%	0%	0%
Fair	65%	32%	2%	56%	15%	29%	25%	68%	7%
Poor	19%	29%	52%	7%	1%	91%	8%	30%	62%

G = good; F = fair; P = poor.

fair was largely affected by one or no metric in fair condition; that is, two metrics are good and one metric is fair or poor, or one metric is each good, fair, and poor. Similarly, the overall condition rating of poor is largely a result of two, not all three, metrics being poor. These findings also support the overall condition rating not being affected as much by M&R, as it does not require many metrics to be classified as fair for the overall condition to be fair.

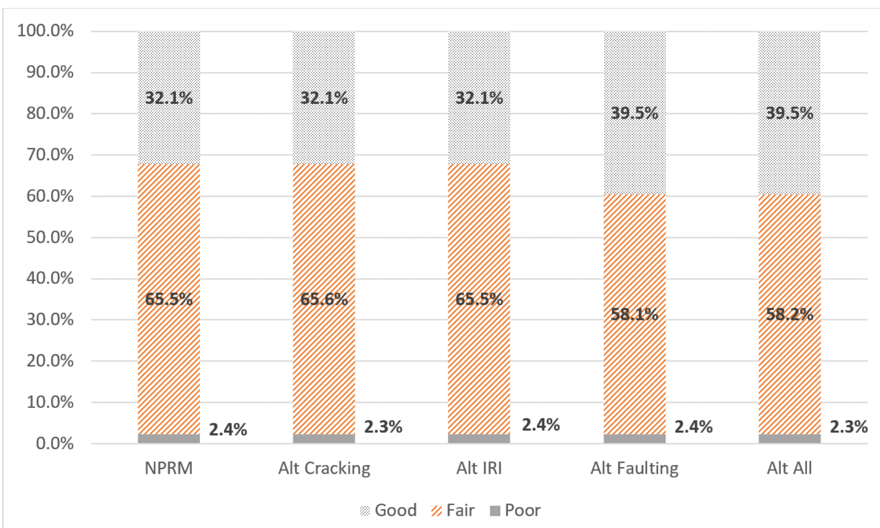
Finally, the average time for the overall condition to change over time was investigated using LTPP AC and JPCC Seasonal Monitoring Program and selected LTPP CRCP test sections that had at least four survey groupings within a construction event. The results showed that overall condition is largely static as it remained constant for more than 60 percent of the test sections investigated. The average timespan over which the condition remained constant ranged by pavement type from 3.8 to 15.8 years. For those cases where the condition changed, the average time for the condition to change varied from 4.1 to 12.0 years depending on pavement type.

Additional Validations

In light of the findings from the initial validations, additional analyses were done to assess the performance measures. The first analysis considered alternate pavement condition threshold values to those proposed in the NPRM. These values correspond with those in the Final Rule. Both sets of threshold values are presented in table 4. The alternate values were first used to evaluate the condition for each metric. The condition metrics were then combined to establish overall condition, and the results were compared to those based on the NPRM values. Figure 2, for example, presents the JPCC overall condition comparison results. As shown, the alternate (Final Rule)

Table 4. NPRM and Final Rule threshold values.			
Condition Metric	**Performance Level**	**NPRM Threshold**	**Final Rule Threshold**
IRI	Good	<95	<95
IRI	Poor	>170: population < 1,000,000 >220: population > 1,000,000	>170
Percent cracking, AC	Good	<5%	<5%
Percent cracking, AC	Poor	>10%	>20%
Percent cracking, JPCC	Good	<5%	<5%
Percent cracking, JPCC	Poor	>10%	>15%
Faulting	Good	<0.05	<0.10
Faulting	Poor	>0.15	>0.15

Figure 2. Overall condition comparison for JPCC.



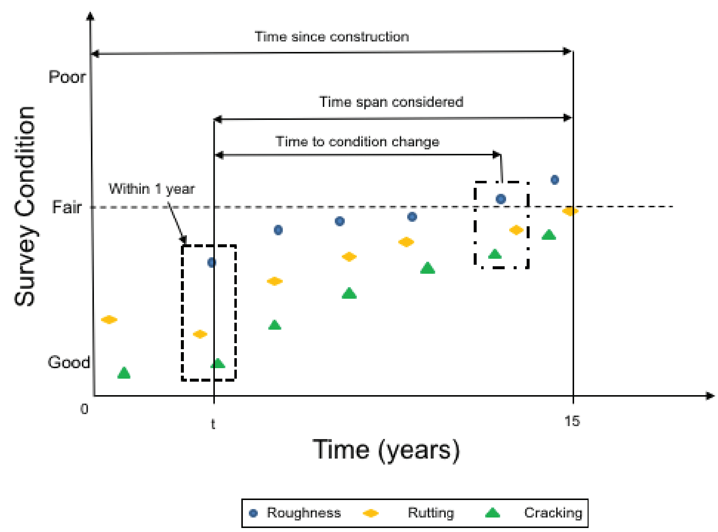
Source: FHWA.

cracking threshold reduces percent poor for the overall condition by 0.1 percent (from 2.4 to 2.3 percent). The largest effect on overall condition is a result of the alternate faulting threshold, which increases percent good by 7.4 percent (from 32.1 to 39.5 percent).

Next, a follow-up temporal analysis was conducted using LTPP test sections located on the IHS. Figure 3 depicts the timespans referenced in this analysis. A survey grouping was formed only if the individual metric measurements were taken within 1 year, which often created a time lag between the time of construction (designated by time equal to zero) and the time the first grouping was considered (designated as time "*t*"), on average 1.5 years for AC pavements and longer for other pavements. The overall timespan considered was from the time of the first to the last survey grouping (or "15 – *t*" years). The time to change was calculated as the time between the first survey grouping and the first grouping at a different condition (i.e., the fifth grouping in figure 3), which does not consider the time from construction to the first survey.

Table 5 summarizes the temporal analysis results. There were, for example, 130 AC test sections that remained fair for an average span of 5.5 years, while there were 135 AC test sections that changed from good to fair over an average span of 4.8 years. The percentage of test sections that remained constant over the entire analysis period ranged from 63 percent for AC to 86 percent for CRCP. Again,

Figure 3. Temporal groupings.



Source: FHWA.

Table 5. Average time to change for sections on the IHS.

Pavement	AC (Final Rule)	AC (Final Rule)	JPCC	JPCC	CRCP	CRCP
Condition	Number of Sections	Average Time (years)	Number of Sections	Average Time (years)	Number of Sections	Average Time (years)
Good–constant	115	6.3	19	7.9	18	11.3
Fair–constant	130	5.5	103	7.7	12	11.5
Poor–constant	1	4.7	3	7.3	0	No data
Good to fair	135	4.8	45	6.7	5	8.5
Fair to poor	9	4.4	15	6.3	0	No data
Total sections and span of time	390	6.3	185	9.0	35	11.7

the implication is that condition ratings are stable; they do not change rapidly.

The final analysis investigated which metrics drive the overall condition and performance measures for both fair and poor condition using the alternate thresholds. Table 6, for example, presents the drivers for fair condition when only one of three metrics is causing the overall pavement condition to be fair. The G-G-P and the G-G-F groupings represent 12 and 45 percent of the total number of groupings in fair condition, respectively. The table shows that cracking is the driving metric for the G-G-P grouping, while rutting is the driving metric for the G-G-F grouping, and roughness is rarely the driver of either the G-G-P or G-G-F groupings.

Guidelines to Affect Measures

The findings from the validation study enabled the development of guidelines for informing decisionmaking to affect the performance measures. The guidelines are provided as a stand-alone report, and their goal is to illustrate potential strategies to move the overall condition of pavements from poor to fair to good.[6] Toward achieving this goal, the guidelines enable agencies to address critical questions, such as what are the performance measure drivers and what are the effects of M&R treatments on condition metrics and overall condition?

The approach in the guidelines begins with development of performance measure drivers for metric conditions and overall condition using agency data. The drivers are then combined with the effects of M&R treatments, and the findings are used to develop a list of potential M&R treatments that affect the condition. The final step is the integration of the results within the pavement management system (PMS). Challenges that agencies need to consider when implementing the performance measures are also provided at the end of the guidelines. They include different data sources (HPMS versus PMS), changes in optimization goals (how measures affect decisionmaking), and updating of models within PMS. Ultimately, agencies are required to meet the performance measures or face loss of flexibility for spending National Highway Performance Program funds until the minimum required condition levels are exceeded.

Conclusions

The results of this validation study showed that the performance measures are comprehensive with respect to the state of the practice—they address functional and structural (albeit using cracking as a surrogate) performance. They are balanced as they comprise several individual types of metrics (IRI, cracking, rutting, and faulting), and they show the expected performance trend over time. A parallel study detailed in the FHWA *Interstate Pavement Condition Sampling* report addresses these and other criteria, including appropriateness or measures at the national level.[7] Although improvements are possible, the performance measures are considered appropriate and valid for their intended purposes.

Table 6. AC fair driver, single metric.

Overall Condition	Metrics	Rutting	Roughness	Cracking	Number of Groupings
Fair	G-G-P	29%	4%	67%	652
Fair	G-G-F	75%	14%	11%	2,413

G-G-P = good–good–poor; G-G-F = good–good–fair.

References

1. Moving Ahead for Progress in the 21st Century Act. (2012). Public Law No. 112–141, 126 Stat. 405.

2. Federal Register. (2015). *National Performance Management Measures; Assessing Pavement Condition for the National Highway Performance Program and Bridge Condition for the National Highway Performance Program, 80*(2), 80 FR 325.

3. Fixing America's Surface Transportation Act. (2015). Public Law No. 114–94, 129 Stat. 1312.

4. Federal Register (2017). *National Performance Management Measures; Assessing Pavement Condition for the National Highway Performance Program and Bridge Condition for the National Highway Performance Program, 82*(11), 23 CFR, Part 490.

5. Visintine, B.A., Simpson, A.L., and Rada, G.R. (2017). *Validation of Pavement Performance Measures Using LTPP Data: Final Report*, Report No. FHWA-HRT-17-089. Federal Highway Administration, Washington, DC.

6. Visintine, B.A., Rada, G.R., and Simpson, A.L. (2017). *Guidelines for Informing Decision-Making to Affect Pavement Performance Measures: Final Report*, Report No. FHWA-HRT-17-090. Federal Highway Administration, Washington, DC.

7. Rada, G.R., Simpson, A.L., Visintine, B.A., and Groeger, J.L. (2016). *Interstate Pavement Condition Sampling*, Report No. FHWA-HIF-17-022. Federal Highway Administration, Washington, DC.

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