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Developing Equivalence Tools to Control Quality of Transportation Infrastructure Asset Management Data

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Prepared by:
P. Hu and S. Stoffels
The Pennsylvania State University

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16. Abstract

Transportation infrastructure monitoring requires substantial investments of time and money. New technologies are frequently developed and deployed, but the serviceability lives of transportation infrastructure assets are long, and new technologies produce challenges. One promising formulation of statistical tools for informing these decisions can be found in biostatistics, in the formulation of statistical tests developed for the acceptance of generic pharmaceuticals. Unlike statistical tests formulated to seek significant differences between methods or for variables significantly affecting outcomes, these tests are formulated to assess equivalence or noninferiority between methods, thus also holding promise for assessing if new equipment or vendors are equivalent (or noninferior) to current accepted standards. Recently, these methods have also been proposed for use in the social sciences and in quality and manufacturing engineering. In this project, statistical equivalence methods are assessed as to suitability and formulated in the context of three elements of condition assessment. This report discusses the background of equivalence testing, pavement cracking data, application scenarios using pavement roughness data, traffic-speed deflection device evaluation methods, and examples with simple MATLAB computational code for supporting the calculations. The two one-sided t-test (TOST) methodology is recommended as the easiest and most practical to apply for infrastructure asset management condition data. The biggest challenges are in making informed selections of acceptable statistical risks and data tolerances. While this study provides illustrations and some suggestions, the determinations must ultimately be driven by the limits of available technologies, the sensitivity of the agency-specific decision support systems, and the costs of collecting needed data to reduce statistical uncertainty.

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CHAPTER 1

Introduction

Transportation infrastructure monitoring—the collection of data regarding infrastructure asset characteristics, condition, and performance—requires substantial investments of time and money. These data elements are used to evaluate current asset conditions, to develop and calibrate predictive models, to allocate funds for treatments, and to assess responses to changes in system parameters. Collection and processing of the desired quantity and quality of transportation infrastructure asset data can be costly, time-consuming, and sometimes dangerous. New technologies are frequently developed and deployed, often enabling more expedient data collection. But the serviceability lives of transportation infrastructure assets are long, and transitioning technologies produce challenges in the temporal assessment of data or development of prediction models. In addition, promising new techniques sometimes may not deliver the expected precision and accuracy of information, and quantification of variability is particularly challenging for condition data. Faced with a constant menu of promising new equipment and innovative vendors, how can agencies make wise investment decisions as to the timing of implementation of technology advances and choices of purchases and data collection contracts?

One promising formulation of statistical tools for informing these decisions can be found in biostatistics, in the formulation of statistical tests developed for the acceptance of generic pharmaceuticals (Hsu, Hwang, et al. 1994; Lung, Gorko, et al. 2003; Wellek 2010). Unlike statistical tests formulated to seek significant differences between methods or for variables significantly affecting outcomes, these tests are formulated to assess equivalence or noninferiority between methods, thus also holding promise for assessing if new equipment or vendors are equivalent (or noninferior) to current accepted standards. Very recently, these methods have also been proposed for use in the social sciences and in quality and manufacturing engineering (Lakens 2017, Pardo 2019).

In this project, statistical equivalence methods are assessed as to suitability and formulated in the context of three elements of condition assessment. In Chapter 2, the background of equivalence testing is presented. Chapter 3 focuses on pavement cracking data. In Chapter 4, application scenarios using pavement roughness data are presented. Traffic-speed deflection device (TSDD) evaluation methods are considered in Chapter 5. Examples are provided and simple MATLAB computational code is provided in an appendix for supporting the calculations. The appendices provide all data not easily publicly accessible.

The two one-sided t-test (TOST) methodology is recommended as the easiest and most practical to apply for infrastructure asset management condition data. The biggest challenges are in making informed selections of acceptable statistical risks and data tolerances. While this study provides illustrations and some suggestions, the determinations must ultimately be driven by the limits of available technologies, the sensitivity of the agency-specific decision support systems, and the costs of collecting the needed data to reduce statistical uncertainty.

CHAPTER 2

Background on Equivalence Statistical Methods

LITERATURE REVIEW

ANOVAs and t-tests are commonly used testing methods to demonstrate the difference between two (t-tests) or more groups (ANOVAs) by calculating test statistics or confidence intervals (Lakens 2013, Rusticus and Lovato 2014). The null hypothesis of these difference-based methods usually claims that the population means are not significantly different ($\mu_1 = \mu_2$ or $\mu_1 - \mu_2 = 0$). A p-value smaller than the predetermined significance level (usually 5%) indicates that one has enough evidence to reject the null hypothesis and conclude that the groups are significantly different. On the contrary, a p-value larger than the significance level indicates non-rejection of the null hypothesis and indicates that there is not enough evidence to conclude that the groups are not significantly different. However, the non-rejection of the null hypothesis is not the same as the acceptance of the null hypothesis. In other words, the most common hypothesis formulations for difference-based hypothesis tests are not able to claim the comparability or equivalence between groups (Schuirmann 1987).

In the National Bureau of Standards Handbook 91 (Natrella 1963), the formulation of the null hypothesis was not presumed to be that the population means are not significantly different. The intention was for flexibility in formulation of the null hypothesis to reflect the goals of the experiment. The emphasis was on correctly formulating the null hypothesis to address the question of interest. In most research applications, the test is used to look for a difference in results. But in some applications, the goal is to determine if two methods or data sources give the same results, or at least yield results close enough to not affect the outcomes from use of the methods producing the data. Equivalence tests are hypothesis tests formulated for those applications and research questions.

In clinical studies, researchers are sometimes interested in the bioequivalence of a new treatment and a standard treatment (Walker and Nowacki 2011). The two one-sided t-test (TOST) was formulated to determine if the difference that exists between groups is small enough (smaller than the equivalence bounds) to claim that the two groups can be regarded as equivalent (Blackwelder 2004, Wellek 2010, Walker and Nowacki 2011). In addition, with an equivalence test, one is able to set the equivalence limits based upon practically meaningful differences rather than comparing the mean difference to a fixed value of 0 as the traditional difference-based hypothesis tests do (Cribbie, Gruman et al. 2004). A literature review of biomedical applications of equivalence testing yields hundreds of articles. On the other hand, there are only a handful of published articles of applications in engineering. The most similar applications to infrastructure condition data were found in applications to robotic sample preparations being compared to manual methods in the pharmaceutical industry (Lung, Gorko et al. 2003) and relatively recent recommendations and methodologies for manufacturing engineering (Pardo 2019). Our literature review yielded no prior published applications in infrastructure asset management or construction. The first known recommendations for the application of equivalence testing to infrastructure management data were made by the principal investigator of this study in *Developing Guidelines for Cracking Assessment for Use in Vendor Selection Process for Pavement Crack Data Collection/Analysis Systems and/or Services* (Morian 2020). The context for that application was a key focus of that report.

In order to demonstrate the difference among t-tests formulated to test for a statistically significant difference and equivalence testing, the assumptions and basics of three types of traditional t-tests (unpaired student's t-test, Welch's t-test, and paired student's t-test) and TOST are introduced and discussed. Unpaired student's t-test and Welch's t-test are both designed for independent samples that are randomly selected from normally distributed populations. The unpaired student's t-test assumes the population variances are equal and Welch's t-test does not assume equal population variances (Bhattacharyya 2013). The paired t-test and TOST are formulated for dependent samples that are randomly selected from normally distributed populations. In traditional difference-based hypotheses testing (unpaired student's t-test, Welch's t-test, and paired student's t-test), the alternative hypothesis is the statement of what the researchers want to verify as true. So, the burden of proof rests on demonstrating that there is a difference between groups. However, when applying the TOST equivalence test, the researchers or practitioners are more interested in investigating whether the two groups are equivalent. Thus, the burden of proof rests on showing whether the mean difference of two groups lies within the preset limits (equivalence limits). To be concise, the null and alternative hypothesis of the TOST is a reversed version of the customary t-test hypotheses, as shown in Table 1 (Wellek 2010; Walker and Nowacki 2011).

Table 1. A fundamental comparison between traditional t-tests and TOST.

	Sample Assumption	Null Hypothesis	Alternative Hypothesis
Unpaired student's t-test	Independent	No difference between population means ($\mu_1 - \mu_2 = 0$)	There is a difference between population means ($\mu_1 - \mu_2 \neq 0$)
Welch's t-test	Independent	No difference between population means ($\mu_1 - \mu_2 = 0$)	There is a difference between population means ($\mu_1 - \mu_2 \neq 0$)
Paired student's t-test	Dependent	No difference between population means ($\mu_1 - \mu_2 = 0$)	There is a difference between population means ($\mu_1 - \mu_2 \neq 0$)
TOST equivalence test for paired samples	Dependent	Population means are not equivalent $\mu_1 - \mu_2 \leq -\theta_1$ $\mu_1 - \mu_2 \geq +\theta_2$	Population means are equivalent $\mu_2 - \theta_1 \leq \mu_1 \leq \mu_2 + \theta_2$

NOTE: $\theta_1$and θ_2 are equivalence limits, which can either be equal or unequal.

APPLICATIONS OF EQUIVALENCE TESTING TO INFRASTRUCTURE

Pavement cracking, roughness, and deflection are important parameters for monitoring and modeling the performance of roadway pavements and can be used to program future needs for maintenance and rehabilitation as components of an infrastructure asset management system. In the past, the pavement condition information was collected by manual and/or stationary field surveys, which are time-consuming as well as potentially hazardous. With the rapid development of sensor technology and computational power, automatic pavement condition evaluation systems have been implemented by vendors (Ouyang and Xu 2013) and are widely used by state agencies. However, the accuracy and precision of ratings using new automated technologies and analysis methods, including comparison to reference methods accepted as accurate, need to be examined. To demonstrate the most appropriate hypothesis test for this scenario among the aforementioned tests, a MATLAB simulation was conducted.

In the simulation, two normally distributed populations were generated with means of 100 and 95, respectively, as shown in Table 2. The standard deviation of population 1, representing an established method), was fixed as 10. The standard deviation of population 2, representing a new technology, was varied from 0 to 20 with increments of 5, representing infrastructure condition ratings with different levels of precision. Samples of 10 values were drawn from each of the two normal populations and the sampling was repeated 10,000 times. After each sampling, Welch's t-test, paired student's t-test, and TOST equivalence tests were conducted on the two samples; the test statistics were summarized and presented as follows:

Table 2. A basic description of the MATLAB simulation for t-tests comparison.

	Population 1	Population 2
Mean	100	95
SD	10	0, 5, 10, 15, 20
Number of samples in each comparison	10	10
Number of repeated sampling	10,000	10,000

The values in Table 3 indicate the percentage of simulations where the conclusion of not significantly different (for Welch's t-test and paired student's t-test) or equivalent (for TOST equivalence test) were drawn. For example, when standard deviation of population 2 was set as 0, the number of simulations that concludes “no difference” using paired student's t-test was 6,600, divided by the total number of simulations (10,000), a percentage of 71 was obtained.

The statistics of Welch's t-test and paired student's t-test are similar at all standard deviations. It was found that the percentage of traditional difference-based t tests increases as standard deviation (consistency) of population 2 (new technology) increases. This could present a problem for pavement condition data as it demonstrates that the methods with less consistency would have an advantage to be concluded as “not significantly different” from the established reference method. Nevertheless, this is not a problem when using the TOST equivalence test. When the standard deviation of population 2 increases from 0 to 20, the TOST percentage value drops drastically from 16% to 0% and 41% to 2% at ± 7.5 and ± 10 equivalence limits, respectively. Therefore, technologies producing less consistent data have less probability to be detected as equivalent to the reference ratings. Moreover, it could be observed from Table 3 that at the same standard deviation, the TOST percentage values increase as the equivalence limits increase. It shows that one can manipulate the threshold (equivalence limits) of the mean difference to be regarded as equivalence based on the intended uses of the data, while traditional difference-based t tests do not have the capability to do so. The limits set in equivalence testing are not based on statistical evaluation of the data itself, but on the acceptable variation for the use of the data.

Table 3. Percentage of simulations where conclusions of not significantly different or equivalent were drawn for three formulations of t-tests.

	Welch's t-test [1]	Paired Student's t-test	TOST (± 7.5) [2]	TOST (± 10) [3]
SD2=0	71%	71%	16%	41%
SD2=5	74%	75%	12%	36%
SD2=10	82%	83%	5%	21%
SD2=15	87%	87%	1%	8%
SD2=20	90%	91%	0%	2%

Significance level was set as 95% for all the tests (alpha = 5%).
[1]The degrees of freedom were rounded up to the nearest integer.
[2] Equivalence limits were set as ± 7.5.
[3] Equivalence limits were set as ± 10.

CHAPTER 3

Application to Pavement Cracking

INTRODUCTION

Most pavement asset management systems include pavement condition data, including cracking, as key decision support information. For state agencies, today's data collection is typically performed via highway-speed instrumented vehicles supplemented with automated or semi-automated analysis systems. Agencies may procure the vehicles and systems or contract for data collection and analysis services. A key challenge in that process has been the quantification of the quality of the cracking data provided by the systems or services under consideration.

Transportation Pooled Fund study TPF-5(299) included a project to develop guidelines for technical assessment protocols for automated and semi-automated pavement cracking data collection and analysis systems and services (Morian 2020). In extended discussions with Federal Highway Administration (FHWA) personnel, it was determined that none of the processes currently in use for comparison of reference cracking data and vendor systems or services were both practically and statistically viable. As pointed out in Chapter 2, statistical tests for a significant difference inherently favor more variable systems. In addition, the quantity of reliable reference data that can be feasibly collected is limited by both qualified manpower and safety concerns.

In seeking a solution, equivalence testing was explored as a possibility. As noted in Chapter 2, no prior applications of equivalence testing to construction materials or civil infrastructure were found in the literature. For the purposes of the recommendations of that project, equivalence was found to be the most promising statistical comparison. Recommendations were also made for minimum specimen size (inspected pavement length) and sample size (number of specimens). In this chapter, the assumptions and recommendations made in that study are reconsidered by more exhaustive use of the available data.

In pavement cracking verification, there are at least two major motivations for recommending equivalence testing. First, the purpose of cracking verification is not to examine if the vendor ratings are exactly the same ($\mu_1 - \mu_2 = 0$) as the reference ratings but if the ratings are similar enough to produce the same conclusions in the context of infrastructure asset management. In the TPF-5(299) study, the required equivalence was considered in the context of the FHWA Highway Performance Monitoring System (HPMS) reporting requirements (Morian 2020). However, agencies also use the collected cracking data for decision support within their own pavement asset management systems; the necessary similarity may be different in that context and may vary between agencies. In addition to the procurement process, agencies must also establish acceptance and quality assurance processes.

For example, one state agency had developed the ground reference ratings for a pavement section by manual rating, and the vendor ratings on the same pavement section were also provided by using automated pavement inspection techniques. The state agency may not expect or require the vendor ratings to be exactly the same as the reference ratings, since the automated pavement inspection is much more efficient and cost-effective than the manual inspection. Further, the ground reference ratings are typically collected with extra care and by expert raters. The state agency may be willing to accept a certain level of difference to embrace the advantages of new pavement inspection techniques, especially for network-level pavement condition inspections. More importantly, with statistical equivalence tests, the state agency is able to manipulate the equivalence limits to meet the needs of its own uses of the data, meaning that the agency can change the equivalence limits (difference between population agency ratings and vendor ratings) that can be regarded as equivalent. Secondly, as previously mentioned, the more commonly applied difference-based hypothesis tests may provide a competitive advantage for vendors with more variability in their data. A vendor's data are more likely to pass the hypothesis test and be regarded as having no significant difference by providing less consistent data. This issue is also avoided by utilizing the TOST equivalence testing method.

In order to limit the total extent of ground reference ratings required, it was recommended (at the suggestion of FHWA) that each inspected pavement section be divided into N subsections (Morian 2020). In that process, the HPMS Cracking Percent values are calculated at the subsection level. The number of subsections and the subsection length are then two key factors for statistical pavement cracking verification. A small subsection length may create more variability than a longer subsection length by emphasizing small localized distress, which could obscure the true differences between the reference and vendor ratings. In addition, more variability would mean a greater number of subsections would be needed to achieve the same statistical power, and thus that a total greater reference site length would be needed. On the other hand, while a longer subsection length might reduce variability between subsections and thus reduce the number of required subsections, the total length is also increased.

This chapter further explores and demonstrates the two one-sided paired t-test as the equivalence testing method to conduct pavement cracking verification. The number of subsections should be determined by both considering the variability of the cracking data and total required inspection length. Although the HPMS requires 0.1-mi reporting length (Federal Highway Administration 2016), that length may not be the most suitable for cracking verification, whether for vendor selection or for acceptance testing and quality assurance. In order to address the above questions, variance analysis was conducted on pavement cracking data from three state departments of transportation, referred to as XDOT, YDOT, and ZDOT. The data are included in Appendix A.

XDOT CRACKING DATA

The data from XDOT contains three years (2013, 2014, and 2015) of visible fatigue-type cracking data from 10 sites at three levels of severity: low-severity cracking, medium-severity cracking, and high-severity cracking. There is one state agency rating and one vendor rating from 2013 and 2014, while one state agency rating and four vendor ratings are available from 2015. The reporting length increment is 0.01 mi with 30 total subsections in each site, thus the total length of each site is 0.3 mi. The cracking data used from XDOT is the visible fatigue-type cracking across the entire pavement. However, according to the definition of HPMS Cracking Percent, only the fatigue cracking within the wheelpaths is considered. Based upon wheelpath width set at 39 inches, Cracking Percent is the calculated area of wheelpath cracking divided by the total wheelpath area (wheelpath width*length of the section) multiplied by 100 (Federal Highway Administration 2016). The Cracking Percent is to be reported to the nearest 1 percent. Consistent with the Transportation Pooled Fund study (Morian 2020), these assumptions were made when interpreting the XDOT data to estimate the length of cracking occurring within the wheelpaths:

- Low-severity fatigue cracking only influences a small pavement area and can be observed in either the left wheelpath or right wheelpath.
- Medium-severity and high-severity fatigue cracking extend to both wheelpaths and thus should be counted twice when calculating the visible fatigue cracking in the wheelpath.

The visible fatigue cracking in the wheelpath is estimated using the equation:

$$\text{Visible fatigue cracking in the wheelpath} = \text{low} - \text{severity fatigue cracking} + 2 * (\text{medium} - \text{severity fatigue cracking and high} - \text{severity fatigue cracking})$$

The HPMS Cracking Percent of each site was then calculated by dividing the total area exhibiting visible fatigue cracking for all severity levels in the wheelpath by the total area in each section. The interval of the provided raw data is 0.01 mi, which means that the minimum subsection length that can be evaluated with the XDOT data is 0.01 mi. In order to investigate the impact of different subsection lengths on data variability, HPMS Cracking Percent of adjacent subsections was averaged to obtain three larger subsection lengths for consideration: 0.02, 0.03, and 0.06 mi. The summary of available XDOT data for consideration using this scheme is shown in Table 4.

With similar reasoning, but to provide a more extensive comparison with the available data than presented in (Morian 2020), MATLAB was used to draw different numbers of continuous samples (N=5, 10, 15, and 30) from each site 5,000 times to examine the effect of N on data variability. The standard deviations of the paired differences between agency (ground reference) and vendor HPMS Cracking Percent were calculated for each site. The results are summarized in Table 5, Table 6, and Table 7.

Table 4. Summary of the processed XDOT data available for MATLAB sampling.

	0.01-mi Subsections	0.02-mi Subsections	0.03-mi Subsections	0.06-mi Subsections
Total subsections in each site	30	15	10	5
Total length (mi)	0.3	0.3	0.3	0.3
Number of subsections (N)	5, 10, 15, 30	5, 10, 15	5, 10	5
Subsection length (mi)	0.05, 0.1, 0.15, 0.3	0.1, 0.15, 0.3	0.15, 0.3	0.3
Number of repeated samplings	5,000	5,000	5,000	5,000

Table 5. Impact of subsection length (l, miles) and number of subsections (N) on cracking data variability (standard deviation of paired differences (in %) between vendor and agency HPMS Cracking Percent ratings) using XDOT 2013 reference site data from one agency rating and one vendor.

Site	N=5 l=0.01	N=5 l=0.02	N=5 l=0.03	N=5 l=0.06	N=10 l=0.01	N=10 l=0.02	N=10 l=0.03	N=15 l=0.01	N=15 l=0.02	N=30 l=0.01
A	2.79	2.27	1.87	1.74	3.30	2.43	1.82	3.66	2.26	3.18
B	7.47	6.10	5.21	5.25	8.08	5.98	6.02	7.84	6.75	9.46
C	11.72	8.08	8.91	12.09	12.57	10.55	12.62	13.41	12.85	15.35
D	7.60	5.36	5.76	4.90	8.36	5.46	6.16	8.37	5.82	8.30
E	9.79	9.21	7.31	3.68	11.19	8.69	6.88	10.86	8.32	11.02
F	4.45	3.48	2.90	3.11	4.14	3.80	3.99	4.28	4.65	5.37
G	6.16	7.31	5.95	5.46	7.85	8.30	6.26	8.74	7.93	8.81
H	6.43	6.13	6.96	5.62	7.90	7.24	6.57	8.13	6.42	8.24
I	10.12	9.17	6.98	7.79	10.39	9.04	9.09	10.28	11.61	13.92
J	7.47	4.99	5.19	4.16	7.50	5.17	6.06	7.51	6.62	10.90
AVG	*7.40*	*6.21*	*5.70*	*5.38*	*8.13*	*6.66*	*6.55*	*8.31*	*7.32*	*9.46*

Table 6. Impact of subsection length (l, miles) and number of subsections (N) on cracking data variability (standard deviation of paired differences (in %) between vendor and agency HPMS Cracking Percent ratings) using XDOT 2014 reference site data from one agency rating and one vendor.

Site	N=5	N=5	N=5	N=5	N=10	N=10	N=10	N=15	N=15	N=30
	l=0.01	l=0.02	l=0.03	l=0.06	l=0.01	l=0.02	l=0.03	l=0.01	l=0.02	l=0.01
AA	1.90	1.14	0.83	0.76	1.75	1.19	1.03	1.73	1.39	2.14
BB	10.82	4.69	5.13	4.10	11.17	5.24	6.32	11.13	5.66	11.26
CC	6.99	5.73	5.81	7.25	7.51	7.36	7.15	7.78	8.36	9.73
DD	4.18	3.56	3.70	3.18	4.67	3.62	4.95	4.90	5.10	5.92
EE	8.52	8.95	6.58	9.61	9.74	8.77	9.31	9.85	10.32	11.14
FF	6.66	4.61	2.87	3.19	6.63	4.98	4.66	6.70	9.82	11.67
GG	8.14	7.49	7.09	5.35	8.60	7.97	8.77	9.18	9.24	10.37
HH	13.06	11.43	6.14	8.60	14.98	12.07	9.33	15.78	12.68	15.45
II	5.49	5.95	8.70	6.72	7.79	8.16	7.72	9.64	7.17	8.43
JJ	6.17	8.69	9.31	5.36	9.31	8.81	9.59	9.38	9.37	10.01
AVG	*7.19*	*6.22*	*5.62*	*5.41*	*8.22*	*6.82*	*6.88*	*8.61*	*7.91*	*9.61*

Table 7. Impact of subsection length (l, miles) and number of subsections (N) on cracking data variability (standard deviation of paired differences (in %) between vendor and agency HPMS Cracking Percent ratings) using XDOT 2015 reference site data from one agency rating and four vendors.

Site	N=5	N=5	N=5	N=5	N=10	N=10	N=10	N=15	N=15	N=30
	l=0.01	l=0.02	l=0.03	l=0.06	l=0.01	l=0.02	l=0.03	l=0.01	l=0.02	l=0.01
AAA	9.50	8.12	8.10	6.57	10.13	9.17	9.16	10.86	10.84	13.12
BBB	2.54	1.81	1.97	2.00	2.82	2.15	2.22	3.13	2.63	3.83
CCC	6.70	6.72	6.32	5.88	8.31	7.46	6.12	8.85	6.94	8.24
DDD	8.37	6.40	5.66	4.87	8.66	6.76	6.73	8.64	7.57	9.76
EEE	5.56	5.22	4.73	4.69	6.55	6.41	5.54	7.13	6.59	7.76
FFF	5.48	4.31	4.02	2.18	6.12	4.52	3.70	6.37	4.34	6.00
GGG	9.91	9.18	8.76	7.77	10.94	10.00	11.41	11.04	12.18	13.76
HHH	10.96	8.19	5.63	4.32	11.28	7.97	5.57	11.21	7.79	11.04
III	0.79	0.53	0.52	0.49	0.89	0.61	0.65	0.91	0.70	1.07
JJJ	8.03	6.55	6.23	6.62	8.54	7.20	7.08	8.69	7.39	9.16
AVG	*6.78*	*5.70*	*5.19*	*4.54*	*7.42*	*6.23*	*5.82*	*7.68*	*6.70*	*8.37*

As can be generalized from Table 5, Table 6, and Table 7, for the same N, the larger the subsection length, the lower the standard deviation. This indicates that with the same number of subsections, the increase of subsection length will result in a decrease of standard deviation of the paired differences between vendor and agency HPMS Cracking Percent ratings. This occurs because HPMS Cracking Percent is somewhat smoothed over a larger subsection length while smaller lengths can emphasize very localized distress occurrences. In the considered scenarios, there is one exception; in Table 6, the average standard deviation increases slightly from 6.82% to 6.88% when the subsection length is increased from 0.02 mi to 0.03 mi at N = 10. Possible explanations for this exception, which are worth considering in terms of practical applications, include:

- The difference between reference and vendor HPMS Cracking Percent ratings is not perfectly normally distributed and contains outliers. For the XDOT cracking data in 2014, the distribution of the HPMS Percent Cracking difference (reference – agency) is right-skewed and has a few outliers within the range of -27% to -21%.
- Continuous samples (subsections) rather than random samples were taken from each site to simulate field pavement data collection. For the same number of samples, larger subsection length indicates that longer continuous pavement sections were inspected. The combination of small sample size and small subsection length only reflects the pavement condition within a small range. Thus, although larger subsection length will result in less overall variability, a particular occurrence of small subsection length with less total inspected pavement length could occasionally and coincidentally exhibit even less variability.

Figure 1 and Figure 2 illustrate the HPMS Percent Cracking variability of reference HPMS Cracking Percent ratings with different subsection lengths for site EE and site AA, respectively. Both show that the larger the subsection length, the less the variability. However, the overall variability of reference HPMS Percent Cracking ratings of site AA is much less than that of site EE. The effect of this can be observed from Table 6. For Site AA with low overall variability, the standard deviation decreases as interval increases. Nevertheless, Site EE with high variability has some violations of the observation from site AA. In general, the paired difference of most sites follows an approximate normal distribution and the overall variability is low. This is similar to the findings of (Morian 2020) based on different site data.

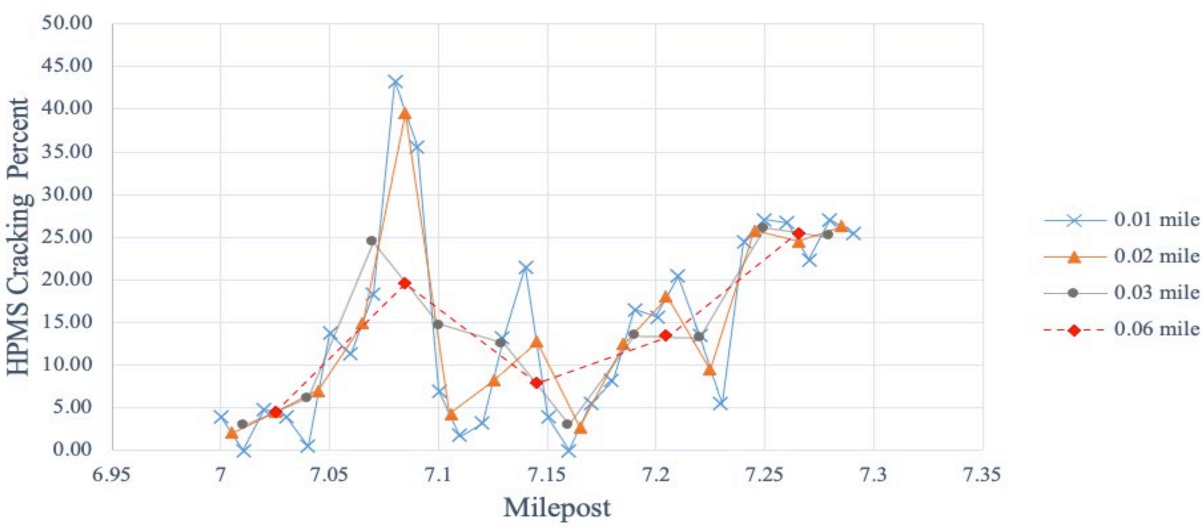


Figure 1. Impact of subsection length on HPMS Cracking Percent using XDOT reference cracking data in 2014 from site EE.

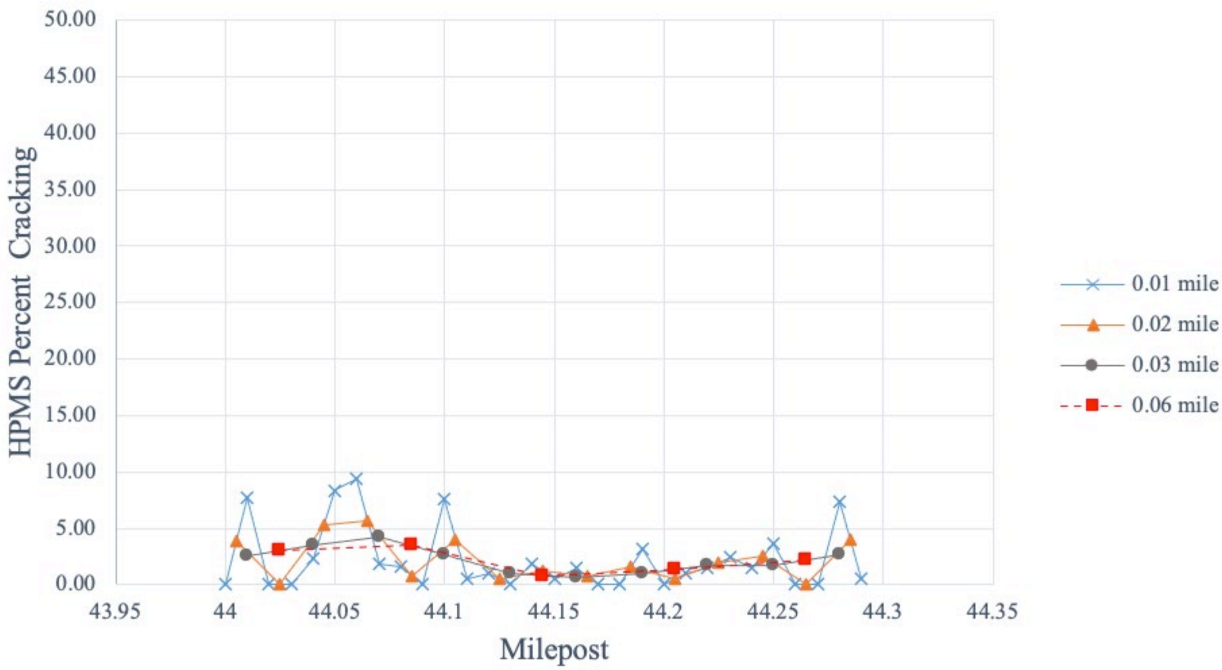


Figure 2. An illustration of impact of subsection length on percent cracking using XDOT reference cracking data in 2014 from site AA.

YDOT CRACKING DATA

The YDOT cracking data were collected from three sites and were rated by one field rater, three automated raters, and two image raters. The standard deviations of paired difference between the reference ratings and the other ratings were calculated. The cracking data from YDOT is the fatigue cracking within the wheelpaths, thus can be directly used to calculate the HPMS Cracking Percent. For each site, there are 26 subsections (N) with a subsection length of 20 ft. The HPMS Cracking Percent of adjacent subsections was averaged to obtain four larger subsection lengths: 40 ft, 60 ft, 80 ft, and 100ft.

To obtain effective subsection lengths of 60 ft, 80 ft, and 100 ft, the full inspected length could not be utilized. The redundant inspected subsections were omitted; since only 20 to 40 ft of cracking data were omitted, a significant influence on the analysis results would not be expected. The total number of subsections and total lengths are shown in Table 8.

Table 8. Summary of the processed YDOT data available for MATLAB sampling.

	20-ft Subsections	40-ft Subsections	60-ft Subsections	80-ft Subsections	100-ft Subsections
Total subsections in each site	26	13	8	6	5
Total length (ft)	520	520	480	480	500
Number of subsections (N)	5, 10, 15	5, 10	5	5	5
Subsection length (ft)	100, 200, 300	200, 400	300	400	500
Number of sampling	5,000	5,000	5,000	5,000	5,000

As for the process for the XDOT data, MATLAB was used to draw samples from each site 5000 times to examine the effect of N on data variability. The standard deviation of the paired differences between field rater, automated raters, and image raters for HPMS Cracking Percent was calculated for each site. The results are summarized in Table 9.

Table 9. Impact of subsection length (l, ft) and number of subsections (N) on cracking data variability (standard deviation of paired differences (in %) between the reference and other HPMS Crack Percent ratings) using YDOT reference site data from one field rater, three automated raters, and two image raters.

Site	N=5	N=5	N=5	N=5	N=5	N=10	N=10	N=15
	l=20 ft	l=40 ft	l=60 ft	l=80 ft	l=100 ft	l=20 ft	l=40 ft	l=20 ft
2602	10.30	10.68	8.31	10.18	8.29	11.53	10.79	11.63
2608	11.39	8.12	9.31	6.77	8.60	12.28	8.38	12.66
3401	12.47	7.39	6.87	6.22	4.20	12.00	7.28	11.88
AVG	*11.38*	*8.73*	*8.16*	*7.72*	*7.03*	*11.94*	*8.82*	*12.06*

ZDOT CRACKING DATA

The ZDOT cracking data contain six ZDOT control sites. All ratings were taken from the same sets of images. Each image was rated by three consultant raters and by one state agency rater. The HMPS Cracking Percent was estimated using only the cracking that was recorded as fatigue cracking. This may be an underestimate for some sections that also have reported low-severity longitudinal cracking, which may or may not be in the wheelpath; current ZDOT ratings do not differentiate. The number of subsections (N) varies from 8 to 10 in different sites with subsection length of 0.1 mi. Due to the limitation of the small number of subsections, only one larger subsection length was obtained. The summary of available XDOT data for consideration using this scheme is shown in Table 10.

Table 10. Summary of the processed ZDOT data available for MATLAB sampling.

	Total Subsections in Each Site	Total Length (mi)	Number of Subsections (N)	Subsection Length (mi)	Number of Samplings
0.1-mi subsections	8-10	0.8-1.0	5, 10	0.5, 1.0	5,000
0.2-mi subsections	5	1.0	5	1.0	5,000

Similar to the process for the XDOT data, MATLAB was used to draw samples from each site 5,000 times to examine the effect of N on data variability. The standard deviation of the paired differences between the agency rater and the average consultant rater HPMS Cracking Percent was calculated for each site. The results are summarized in Table 11. Sites 12, 14, and 20 have less than 10 sites at 0.1-mi subsection length, thus only 5 samples were drawn from the sites. Moreover, due to the insufficient subsections, only cracking data from sites 3, 11, and 20 were aggregated to generate 0.2-mi subsection lengths.

Table 11. Examination of the impact of subsection length (l, miles) and number of subsections (N) on cracking data variability (standard deviation of paired differences (in %) between average consultant and agency HPMS Cracking Percent ratings) using ZDOT reference site data from one state agency rater and three consultant raters using the same pavement images.

Site	N	3	11	12	14	17	20	Avg
l=0.1 mi	N=5	0.29	0.25	1.17	0.62	1.41	1.53	0.88
l=0.1 mi	N=10	0.29	0.26	-	-	1.45	-	0.67
l=0.2 mi	N=5	0.25	0.18	-	-	1.31	-	0.58

SUMMARY OF EFFECTS OF SUBSECTION LENGTH

The HPMS requires 0.1-mi reporting lengths. For reporting and asset management purposes, the use of 0.1 mi is logical and convenient. But if used as the subsection length for cracking verification for vendor selection, considering the needed sample size (N, the number of required subsections), the overall quantity of pavement required to be rated could be prohibitively laborious for both agency and vendor. In order to investigate the minimum suitable subsection length for this purpose, the results from consideration of data from XDOT, YDOT, and ZDOT are combined in Figure 3.

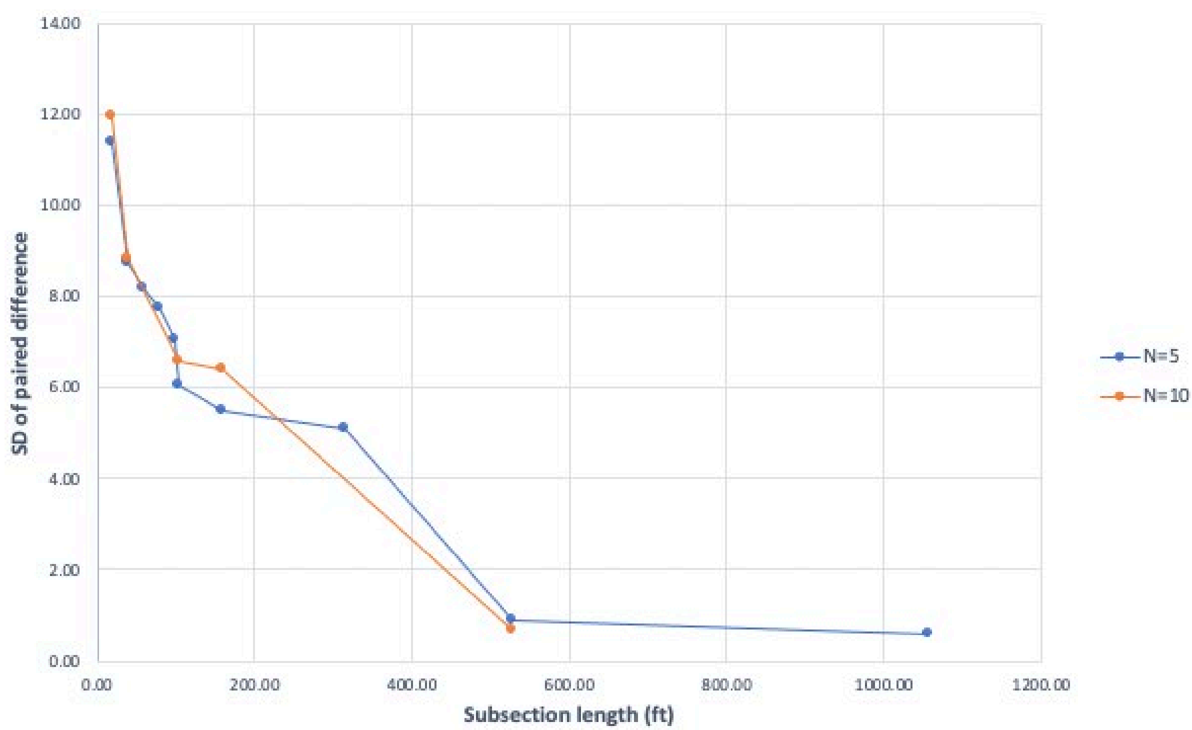


Figure 3. Impact of subsection length on standard deviation of paired difference (in %) from aggregated data.

As seen from Figure 3, the standard deviation of paired differences decreases as the subsection length increases. Based upon limited analysis of the same agency data, (Morian 2020) recommended a subsection length of 0.03 mi (158 ft). Even with the more exhaustive consideration of the data in this study, limited data were available for evaluating subsection lengths greater than 0.03 mi. However, Figure 3 does imply that there would be potential to further reduce variability in the paired differences by using longer subsections. While that may not be feasible for cracking verification reference sites, it does indicate that using the HPMS reporting length of 0.1 mi may be suitable for quality control and quality assurance comparisons during network-level data collection and analysis.

RELATIONSHIP BETWEEN ALPHA, POWER, EQUIVALENCE LIMITS, STANDARD DEVIATION, AND N

The power of the paired TOST equivalence test is a function of alpha, standard deviation of the paired difference, sample size (N), equivalence limits, and the population mean difference. In the context of pavement cracking, the population mean difference is the mean difference between the agency (ground reference) and vendor cracking ratings on the same pavement section. The sample size, N, is the number of subsections of each site. Alpha is the risk of accepting a rating as equivalent (within the equivalence limits) when it is not; alpha can be regarded as the agency's risk. Beta represents the vendor's risk; it is the risk of determining the vendor rating is not equivalent to the reference rating when it is in fact equivalent. The power of the test is defined as 1-beta (1-β). There is an interaction among these statistical parameters. For example, a higher value of alpha would increase the agency's risk while reducing the vendor's risk. The wider the equivalence limits, the higher the probability of concluding equivalence and the less the agency's risk at the same level of power.

The selection of the appropriate equivalence limits for the HPMS Cracking Percent reporting is discussed in (Morian 2020); power curves showing the relationships between sample size, standard deviation, and power were provided for the selected equivalence limits. However, an agency may require tighter equivalence limits (less difference between the vendor values and reference values) for their pavement asset management system. As shown in Figure 4, the higher the number of subsections (sample size, N), the higher the power. The standard deviation of paired difference and mean difference are closely related with the number of subsections (N) and subsection length.

Alpha and the width of equivalence limits are both positively correlated with power as shown in Figure 5. Moreover, the higher the population mean difference, the lower the power achieved. The standard deviation of paired difference was set at 6 in Figure 5, which was used to represent the data variability when N=10 and subsection length of 0.03 mi are adopted as recommended in (Morian 2020). For a site with agency HPMS Cracking Percent ratings below 30%, thus the equivalence limits of 4% applied (Morian 2020). If that conceptual site had a population mean difference of 2, the relationship between equivalence, alpha, and power limits is represented by the green surface in Figure 5. With the assumption that vendors wouldn't accept a risk of more than 20% when deciding whether to undertake the expense for the verification testing, a minimum power of 0.8 was considered. It was found that, even though the ratings of the conceptual site are within the equivalence limits, the power would be far from sufficient (0.8) at all levels of alpha (0 to 0.2). Theoretically, reducing the standard deviation of paired difference would yield in higher power, as shown in Figure 6.

As illustrated in Figure 6, the power increases as equivalence limits increase and standard deviation decreases. In this case, the equivalence limits were preset and fixed for a specific range of agency HPMS Cracking Percent ratings. Assuming the equivalence limits were set as $\pm$ 4, the standard deviation of paired difference should be approximately below 1 at given population mean difference of 2 and alpha of 0.05. It is shown that even though the mean difference is within the equivalence limits, a power of 0.8 won't be guaranteed. Alpha (agency's acceptable risk) is the only remaining factor that affects the power when N and subsection length are determined.

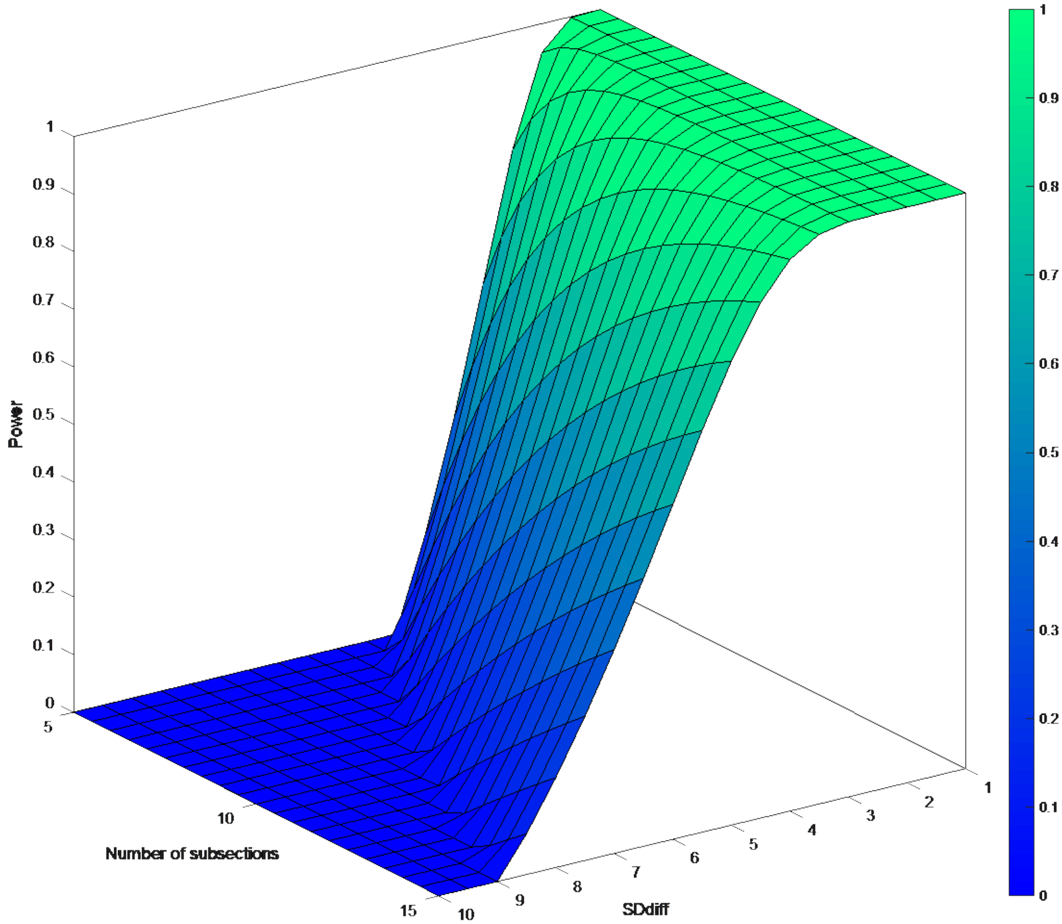


Figure 4. Relationship between number of subsections, standard deviation of paired difference (in %), and power (represented by color scale) when alpha=0.05, equivalence limits = +/- 4%, and mean difference = 0%.

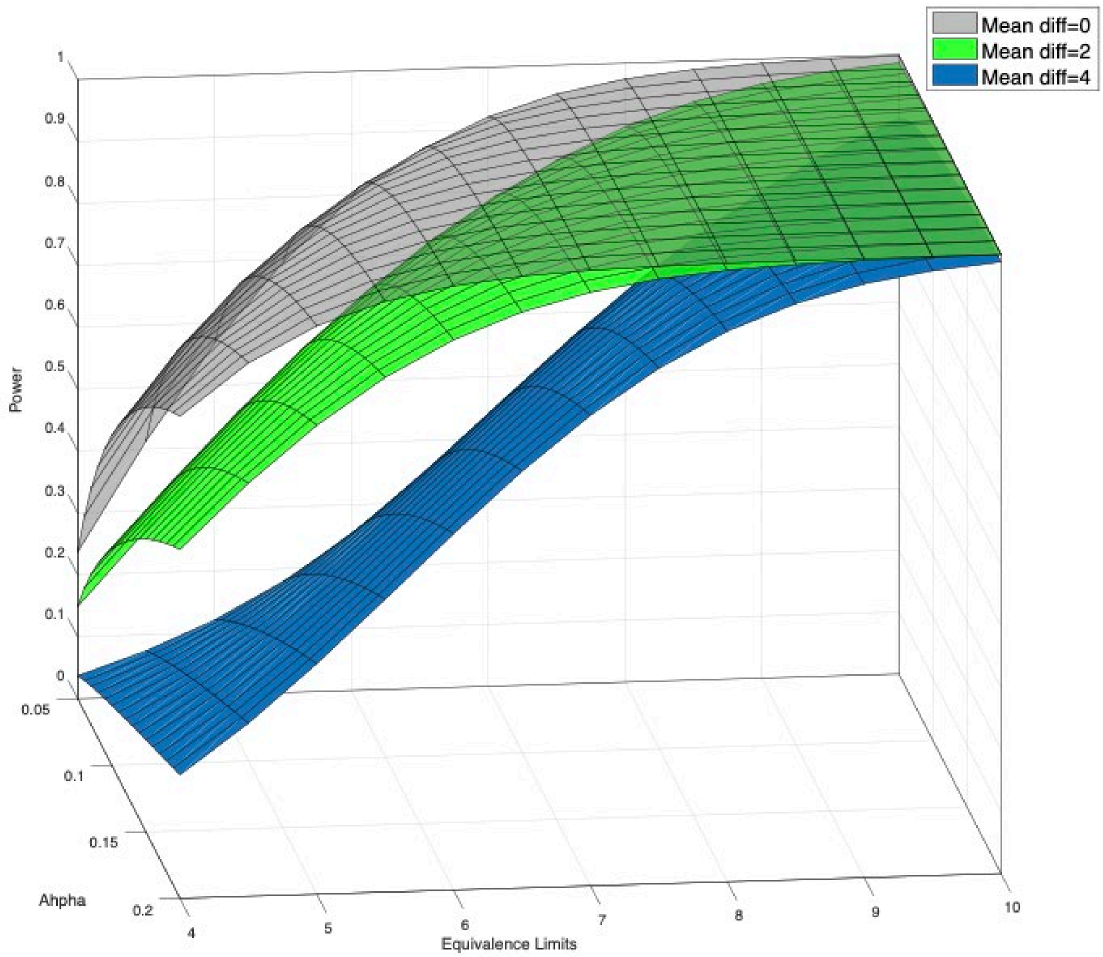


Figure 5. Relationship between equivalence limits (in %), alpha, and power at population mean difference of 0, 2, and 4%, when SDdiff = 6% and N=10.

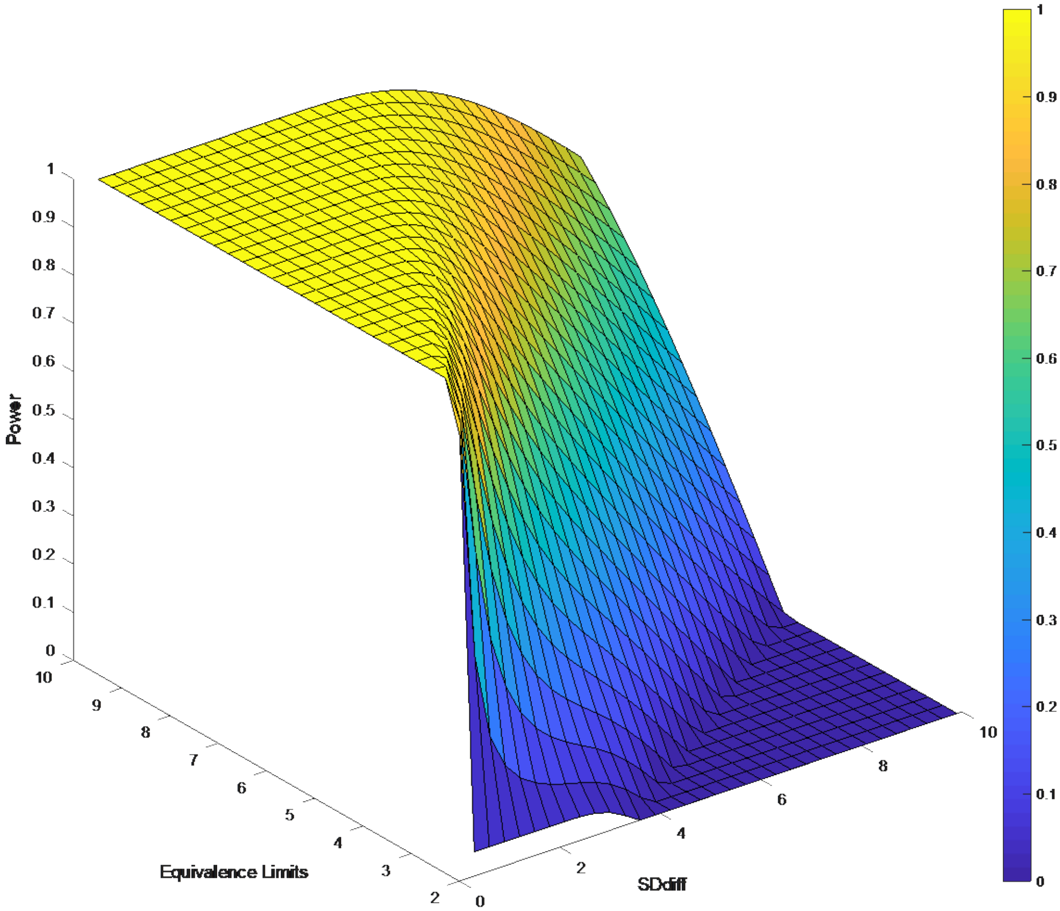


Figure 6. Relationship between standard deviation of paired difference (in %), equivalence limits (in %), and power (represented by color scale) when alpha=0.05, N=10, and population mean difference=2%.

CHAPTER 3 ANALYSIS SUMMARY AND FINDINGS

In this chapter, the use of equivalence testing for cracking assessment in the vendor selection process, as recommended by Stoffels in (Morian 2020), was further explored through more exhaustive analysis of asphalt pavement cracking data provided by XDOT, YDOT, and ZDOT. The effect of subsection length and number of subsections on the standard deviation of paired difference was examined to inform agency selection and design of cracking verification sites. In addition, the relationship between the standard deviation of paired difference, equivalence limits, alpha, mean difference, and power was investigated and illustrated using MATLAB. An example calculation of TOST test and power can be found in Appendix B, and the MATLAB code for TOST power analysis can be found in Appendix C. Findings in this chapter include:

- The larger the subsection length, the less the standard deviation of paired differences. Based upon the limited data available for greater subsection lengths, this decrease seems to level off at approximately

0.1-mi subsection length. This finding would be specific to the asphalt concrete pavement surface type and HPMS Cracking Percent.

- A high value of alpha, a small standard deviation of paired difference, a large sample size, a small mean difference, and wider equivalence limits will result in a higher power (less risk for the vendor). For the sites that have a predetermined number of subsections, subsection length, and equivalence limits, one way to increase power would be to increase the alpha (agency risk). To shift this balance, a greater length of pavement ratings would be required.

To further support the use of equivalence testing in pavement cracking assessment, a case study example using real data is presented in Appendix D, demonstrating the selection of alpha (agency risk) for asphalt concrete pavement cracking verification using power analysis. The alpha value is considered as the agency's risk of accepting an unqualified vendor. Increasing the alpha value will yield a higher statistical power for the same dataset, however, it will introduce more risks to the state agency. A low power will increase the probability of rejecting a qualified vendor and thus could discourage vendors from competing or increase contract costs. Power analysis was conducted on all the sites from XDOT, with different combinations of alpha and equivalence limits. The findings from the example, which are specific to the data provided by XDOT, are:

- For the sites with agency HPMS Cracking Percent ratings less than or equal to 30%, number of subsections equal to 10, subsection length of 0.03 mi, and equivalence limits of ±4, an alpha of 0.05 is recommended for equivalence testing.
- For the sites with agency HPMS Cracking Percent ratings greater than 30%, number of subsections equal to 10, subsection length of 0.03 mi, and equivalence limits of ±10, an alpha of 0.05 is also recommended for equivalence testing.

CHAPTER 4

Application to IRI

INTRODUCTION

As one component of the Long-Term Pavement Performance (LTPP) program, pavement distress surface characteristics (IRI, rut, and texture) and deflection information have been collected on pavement test sections across the United States since 1987. The LTPP database is accessible at infopave.fhwa.dot.gov. The LTPP database records IRI (m/km) measurements of both left and right wheelpaths for each test section.

As part of an LTPP data analysis project, Using LTPP Distress Data to Support MAP-21 (DTFH61-14-C-00019)(Morian 2018), vendor data independently collected for state agencies (by a single vendor) were paired with the LTPP IRI measurements of the same site that occurred within approximately 1 year. The IRI data from that project were used for this study and are included in Appendix E. In this chapter, equivalence testing is demonstrated to determine whether the state agency IRI data (collected under single pass conditions for pavement asset management) are equivalent to the LTPP IRI ratings (collected under controlled research protocols with multiple passes).

Average IRI measurements on the right and left wheelpaths for each test section from LTPP were paired with the measurements provided by the vendor. After extensive data combing, there were 5 paired data groups for both left and right wheelpaths. For asphalt concrete (AC) pavement, there were 25 paired records in 2011, 12 paired records in 2012, 11 paired records in 2013, and 28 paired records in 2014 for AC pavement. For portland cement concrete (PCC) pavement, there were 14 paired records in 2013. These records came from multiple states.

Equivalence testing was carried out addressing the following questions:

- Question 1: Could the LTPP and vendor-collected agency pavement asset management measurements be used interchangeably in the Virginia DOT (VDOT) pavement management system (PMS) enhanced maintenance decision tree? The VDOT decision tree was chosen for the demonstration of addressing this question as a typical decision process example.
- Question 2: Could the LTPP and vendor-collected agency pavement asset management data be combined, using one source of data on some pavement sections and the other source on other pavement sections, and produce overall consistent results in the VDOT PMS enhanced maintenance decision tree? This scenario could be considered relevant to an agency using different equipment or vendors in different areas of a state, to an agency owning and operating multiple brands of equipment, or to an agency upgrading/changing equipment over time.
- Question 3: Could the data sources be used interchangeably for reporting HPMS pavement condition rating?

The determination of equivalence limits is question-specific; for the first two questions, the equivalence limits should consider the IRI thresholds for maintenance and rehabilitation decision support in the VDOT PMS decision trees. The IRI thresholds for the VDOT decision tree are presented in Table 12. VDOT developed enhanced decision trees for Bituminous (BIT), Bituminous over Jointed Concrete (BOJ), and Bituminous over Continuously Reinforced Concrete (BOC) pavements by considering the IRI and rut depth thresholds in addition to the load-related (LDR) and non-load-related (NDR) performance indices.

The decision-making thresholds for BOJ and BOC pavements are similar to the BIT pavement in Table 12. The introduction of IRI and rutting depth further help specify the appropriate pavement conditions for each maintenance action. The equivalence limits for the first two questions will be established based on Table 12.

Table 12. The enhanced index-based maintenance and rehabilitation decision-making thresholds for bituminous pavement (IRI in inches/mile).

LDR ≤ 30 or NDR ≤ 30	LDR ≤ 50 or NDR ≤ 50	LDR ≤ 50 or NDR ≤ 50	LDR ≤ 70 or NDR ≤ 70	LDR ≤ 70 or NDR ≤ 70	LDR ≤ 70 or NDR ≤ 70	LDR ≤ 85 or NDR ≤ 85	LDR ≤ 85 or NDR ≤ 85	LDR ≤ 85 or NDR ≤ 85	LDR ≤ 85 or NDR ≤ 85
Corrective Maintenance	IRI ≥ 250 or Rut Depth ≥ 1 in.	Else	IRI ≥ 250 or Rut Depth ≥ 1 in.	IRI > 200 or Rut Depth > 0.75 in.	Else	IRI ≥ 250 or Rut Depth ≥ 1 in.	IRI > 200 or Rut Depth > 0.75 in.	IRI > 140 or Rut Depth > 0.5 in.	Else
Corrective Maintenance	Restorative Maintenance	Rehabilitation / Reconstruction	Rehabilitation / Reconstruction	Restorative Maintenance	Corrective Maintenance	Rehabilitation / Reconstruction	Restorative Maintenance	Corrective Maintenance	Preventive Maintenance

Source: Stantec Consulting Services Inc. and H.W. Lochner (2007).

For the third question, the HPMS IRI thresholds for pavement condition classification should be considered when determining the equivalence limits. HPMS uses IRI to classify pavement section conditions as presented in Table 13. The equivalence limits for the third question will be established based on Table 13.

Table 13. HPMS criteria for qualitative section IRI rating.

Pavement Type	Good	Fair	Poor
IRI (in./mi)	Less than 95	Greater than or equal to 95 and less than or equal to 170	Greater than 170

Source: Legal Information Institute.

QUESTION 1: COULD THE LTPP AND VENDOR-COLLECTED STATE AGENCY MEASUREMENTS BE USED INTERCHANGEABLY IN THE VDOT PMS ENHANCED MAINTENANCE DECISION TREE?

The selection of equivalence limits would be based on the differences that would change the maintenance decision results (Table 12). For the VDOT enhanced maintenance decision tree, the equivalence limits were recommended as shown in Table 14.

Table 14. Equivalence limits for IRI ratings in VDOT enhanced maintenance decision tree.

LTPP IRI (in/mi)	IRI ≤140	140<IRI≤200	200<IRI≤250	IRI ≥ 250
Equivalence limits (+/-)	20	30	40	50

Equivalence testing using TOST was performed on all paired data groups. In each paired data group, the LTPP IRI measurements were considered as the ground reference; the equivalence limits were determined based on the reference IRI measurements. The testing results are presented in Table 15.

Table 15. TOST results of five paired IRI data groups from LTPP and vendor-collected state data considering the VDOT maintenance decision tree.

Year	2011	2011	2012	2012	2013	2013	2014	2014	2013	2013
Pavement Type	AC	AC	AC	AC	AC	AC	AC	AC	PCC	PCC
Number of Pairs	25	25	12	12	11	11	28	28	14	14
Wheelpath	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right
LTPP Mean IRI (in./mi)	65.369	63.851	49.495	47.684	88.936	68.272	58.681	62.151	103.496	115.399
EQ Limits (+/-)	20	20	20	20	20	20	20	20	20	20
TOST p-value	0.152	0.015	0.010	0.011	0.001	0.000	0.000	0.000	0.000	0.092

Table 15 indicates that 8 out of 10 groups had a TOST p-value below 0.05, which indicates that the LTPP and vendor-collected state agency IRI measurements are equivalent at the significance level of 0.05. However, the AC pavement IRI measurements of the left wheelpath in 2011 and PCC pavement IRI measurements of the right wheelpath had p-values of 0.152 and 0.092, respectively, indicating that the LTPP- and vendor-collected state agency IRI measurements are not significantly equivalent at the significance level of 0.05. If these 10 groups were reasonably representative of the distribution of pavement conditions, an agency might broadly generalize that vendor-collected state agency IRI measurements have an 80% probability of equivalently representing the reference LTPP IRI measurements.

QUESTION 2: COULD ONE SOURCE OF DATA BE USED ON SOME PAVEMENTS AND THE OTHER SOURCE ON OTHER PAVEMENTS IN THE VDOT PMS ENHANCED MAINTENANCE DECISION TREE?

In order to examine the feasibility of using mixed IRI data from the two data sources, Monte Carlo simulation was performed to randomly non-repeatedly mix the LTPP and vendor-collected state agency measurements in each paired group. Then, the mixed data were compared to the LTPP measurements to examine if the mixed measurements can be regarded as equivalent to the reference (LTPP data without mixing). To perform this, let N be a randomly generated index array that denotes which rows of the LTPP measurements (in a column vector) will be replaced by the vendor-collected state agency measurements. N should contain a set of repeating numbers ranging from 0 to the number of paired records in each group. The number of indices in N denotes the degree of utilization of the vendor-collected state agency data. An empty index array means no mixing and only using LTPP measurements, while the number of indices equal to the number of paired records indicating that only vendor-collected state agency measurements were used. After data mixing, the mixed data were compared to the reference (LTPP measurements) to see if they can be regarded as equivalent at a certain significance level (0.05 in this case).

In order to have meaningful results, only two paired data groups with relatively large sample size were selected to perform the equivalence test: AC IRI measurements in 2011 and AC IRI measurements in 2013, with 25 and 28 paired records for both left and right wheelpaths.

As shown in Table 16, based on the 2011 data, with only 5 records from the vendor-collected state agency data and 20 records from LTPP, the TOST p-value was 0, indicating that the mixed measurements are equivalent to the LTPP measurements at the significance level of 0.05. However, with more records from the vendor-collected state agency data included in the mixed dataset, the TOST p-value increases. When the number of indices in N reaches 25, meaning that only vendor-collected state agency data were used in the mixed dataset, the p-values are the same as the results in Table 15. In order to have an equivalent result between the LTPP (without mixing) and mixed data, the maximum allowable number of vendor-collected state agency data records in the mixed data is around 20 in this case, with the significance level of 0.05.

Table 16. TOST results of IRI mixed data from LTPP and vendor-collected state data in 2011 (AC pavement, 25 paired records).

Number of Indices in N	5	5	10	10	15	15	20	20	25	25
Wheelpath	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right
LTPP Mean IRI	65.369	63.851	65.369	63.851	65.369	63.851	65.369	63.851	65.369	63.851
EQ Limits (+/-)	20	20	20	20	20	20	20	20	20	20
TOST p-value	0.000	0.000	0.000	0.000	0.017	0.001	0.049	0.001	0.152	0.015

As shown in Table 17, based on 2014 data, all test results were concluded as equivalent at the significance level of 0.05 for all numbers of indices in N. This result would be expected because the full vendor-collected state agency data were equivalent to the LTPP data indicated in Table 15. Therefore, when a partial vendor-collected state agency data is included in the mixed dataset and compared to the LTPP data, the test results will be equivalent as well.

Table 17. TOST results of IRI mixed data from LTPP and vendor-collected data in 2014 (AC pavement, 25 paired records).

Number of Indices in N	5	5	10	10	15	15	20	20	25	25
Wheelpath	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right
LTPP Mean IRI	58.681	62.151	58.681	62.151	58.681	62.151	58.681	62.151	58.681	62.151
EQ Limits (+/-)	20	20	20	20	20	20	20	20	20	20
TOST p-value	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

In conclusion, for paired groups that were originally concluded as equivalent, the mixed data from vendor-collected state agency data and LTPP will also be concluded as equivalent for all degrees of mixing. For paired groups that were originally concluded as not significantly equivalent, equivalence tests need to be carried out to determine how much vendor-collected state agency data can be mixed into the LTPP data to be regarded as equivalent to the reference (LTPP data without mixing). This analysis scenario could be considered relevant to an agency using different equipment or vendors in different areas of a state, to an agency owning and operating multiple brands of equipment, or to an agency upgrading/changing equipment over time. That agency would face the question: can we mix the data from different sources in our analyses?

QUESTION 3: COULD THE DATA SOURCES BE USED INTERCHANGEABLY FOR REPORTING HPMS PAVEMENT CONDITION RATING?

The selection of equivalence limits would be based on the differences that would change the qualitative ratings (Table 13). The equivalence limits were recommended as shown in Table 18.

Table 18. Equivalence limits for HPMS qualitative categories using IRI.

LTPP IRI (in./mi)	IRI ≤ 95	95 < IRI < 170	IRI ≥ 170
Equivalence limits (+/-)	10	20	30

Equivalence tests were conducted on both left and right wheelpath IRI for paired measurements of five groups. The equivalence limits were determined based on the reference (LTPP) mean IRI values. The test results are presented in Table 19.

Table 19. TOST results of five paired IRI data groups from LTPP and vendor-collected state agency data for pavement roughness rating using IRI.

Year	2011	2011	2012	2012	2013	2013	2014	2014	2013	2013
Pavement Type	AC	AC	AC	AC	AC	AC	AC	AC	PCC	PCC
Number of Pairs	25	25	12	12	11	11	28	28	14	14
Wheelpath	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right
LTPP Mean IRI	65.369	63.851	49.495	47.684	88.936	68.272	58.681	62.151	103.496	115.399
EQ Limits (+/-)	10	10	10	10	10	10	10	10	20	20
TOST p-value	0.984	0.783	0.795	0.695	0.431	0.936	0.053	0.001	0.000	0.092

By comparing the applied equivalence limits in Table 15 and Table 19, the HPMS IRI pavement condition rating has overall narrower equivalence limits than that of the VDOT maintenance decision tree. As a result, 8 out of 10 groups were concluded as not significantly equivalent at the significance level of 0.05. It indicates that, with current equivalence limits, the LTPP data and vendor-collected state agency data are not interchangeable for HPMS condition rating using IRI. For other criteria, an agency might find that their asset management system requires tighter equivalence limits than the HPMS reporting requirements.

CHAPTER 4 ANALYSIS SUMMARY AND FINDINGS

In this chapter, two sets of IRI data from an LTPP project report (Morian 2018) were utilized—one set was downloaded from LTPP InfoPave and the other obtained from data collected for state agencies by a vendor. The paired and unpaired equivalence tests were applied to the two IRI data sources to examine if the vendor-provided IRI ratings are equivalent to the LTPP IRI ratings in certain applications. The findings include:

- Eight out of 10 sites were tested to be equivalent for the LTPP and vender IRI data, such that it will not affect the maintenance decisions. Thus, the data sources are interchangeable in the context of the specific VDOT maintenance decision tree used for this demonstration.
- It was found that a certain degree of mixing of the two sources of data can still be regarded as equivalent to the LTPP IRI data. However, the acceptable degree of mixing varies from site to site and needs to be carefully determined. This scenario is relevant to agencies with multiple sources of data over space or time.
- For HPMS pavement condition classification, only 2 out of 10 sites were tested to be equivalent for the LTPP IRI data and state-agency vendor IRI data. Thus, the sources are considered as not equivalent in the context of reporting HPMS qualitative roughness rating, based only on the limited amount of available data.

The major purpose of this chapter is to demonstrate the situations in which an agency might meaningfully utilize equivalence testing for the pavement roughness data that have been collected for their pavement asset management system. Similar situations could also be relevant to other pavement condition data and to the condition data for other infrastructure assets.

CHAPTER 5

Application to TSDD

INTRODUCTION

The network-level assessment of pavement structural condition can also play an important role in maintenance and rehabilitation decision-making. In the same way as for other pavement monitoring data, automated assessment technologies such as the Traffic Speed Deflection Device (TSDD) are being considered by transportation agencies due to their efficiency. However, there are several types of TSDD equipment produced by different manufacturers and different deflection calculation models used for interpreting the TSDD raw data to the deflections. The raw data collected by different TSDD equipment and the deflection results from different deflection calculation models may vary. Thus, it is important to examine the similarity between different TSDD equipment and deflection calculation models. In this section, three conceptual agency scenarios will be discussed based on TSDD data from the LTPP InfoPave InfoMaterials database. The potential applications of one-sided significance tests (TOST) and power analysis on the TSDD data are investigated.

DATA ACQUISITION AND DESCRIPTION

The LTPP InfoMaterials database includes 4,944 TSDD data records (segments) collected from 57 road sections in 2019 with a fixed reporting interval of 0.01 mi (16.09 m). The LTPP InfoMaterials database is accessible at https://infopave.fhwa.dot.gov/InfoMaterials. The reported TSDD data in the LTPP InfoMaterials database have already been processed. The sampling frequency of a TSDD is usually about 1 kHz, which means the sampling interval can be as fine as 0.066 ft (0.02 m) (Zofka, Sudyka et al. 2014). The deflections at different locations relative to the load were calculated and provided in the database. Two different models were used to calculate the deflection basins, the AUTC model (numerically integrated model) and the Greenwood Beam model.

The Federal Highway Administration conducted an investigation of using TSDD for network-level pavement structural evaluation. In the project report (Katicha, Flintsch et al. 2017), the FHWA stated thresholds of Structural Curvature Index 300 (SCI300) and Deflection Slope Index (DSI) for differentiating pavement structural condition from Good vs. Fair and Fair vs. Poor, as shown in Table 20.

Table 20. SCI300 thresholds for pavement structural condition classification.

Road Category	AC Layer Thickness, in.	Annual Traffic, million ESAL	Threshold for Poor, mil	Threshold for Fair, mil
Interstate	> 9	1.4	3.7	2.7
Primary	6 – 9	0.2	6.2	4.9
Secondary	3 – 6	0.07	9.7	7.3

Source: Katicha, Flintsch et al. (2017)

Since the Greenwood Beam model only calculates deflections at 0, 200, 300, and 450 mm from the load, SCI300 was used for pavement structural condition classification in this case. Note that the deflections of the AUTC model at 300 mm from the load were replaced by the deflection at 12 in. (305 mm) from load, because the data records from the AUTC model were in empirical units and interpolation may bring more errors to the data. Considering the Greenwood Beam model gives direct measurements at 0 mm and 300 mm from the load, the SCI300 of the Greenwood Beam model was considered as the ground reference when conducting equivalence tests between the AUTC model and the Greenwood Beam model. The equivalence limits are defined as:

- For Greenwood Beam (reference) SCI300 between 0-9 mil (type I segment), upper and lower equivalence limits between the testing and reference SCI300 are ±1 mil.
- For Greenwood Beam (reference) SCI300 greater than 9 mil (type II segment), upper and lower equivalence limits between the testing and reference SCI300 are ±3 mil.

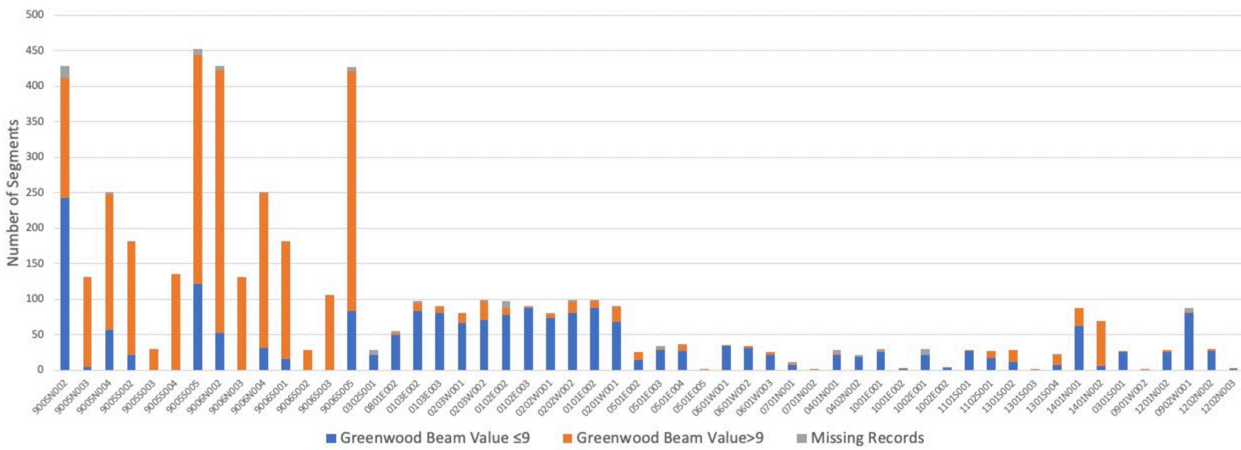
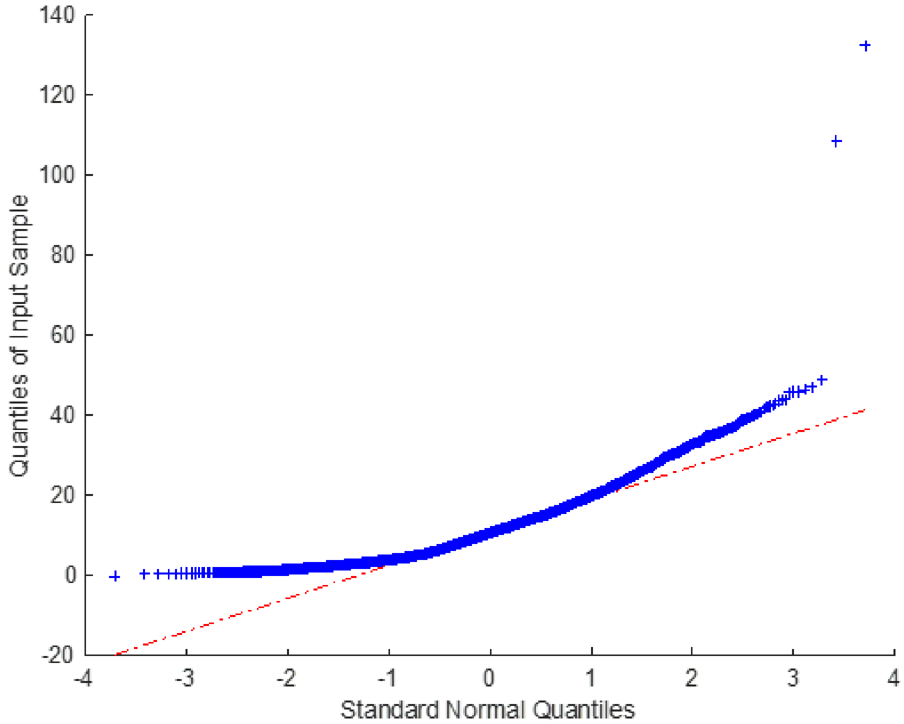
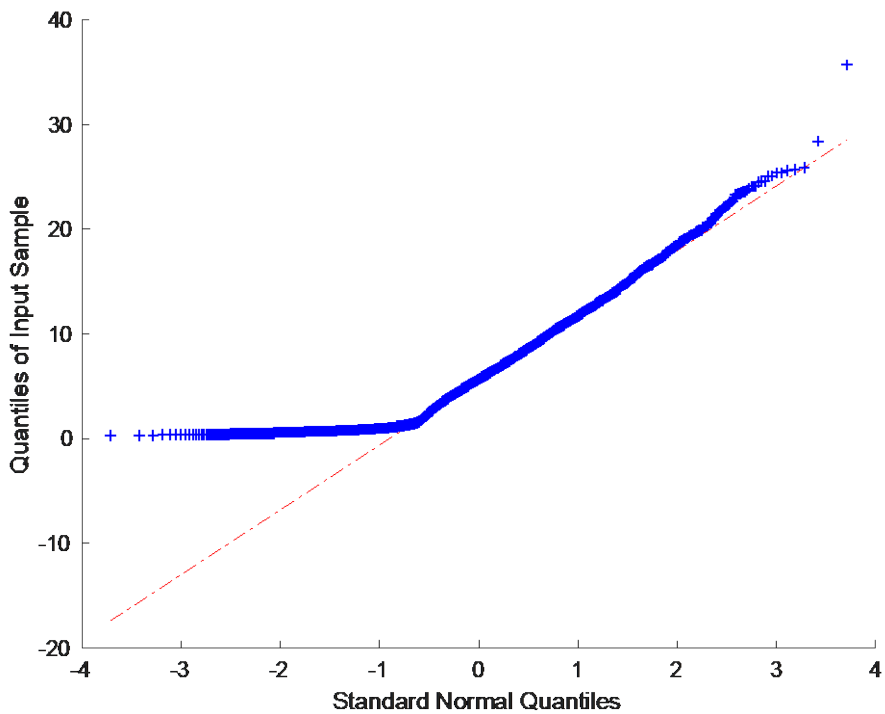


Figure 7. Number of segments that have SCI300 below and above threshold (9 mil) in each road section.

As seen from Figure 7, from section 900SN002 to section 90065005, most of the segments have Greenwood Beam value (reference) SCI300 value above 9 mil (type II segment), while from section 03025001 to section 1202N003, the reference SCI300 values were most likely to be smaller or equal to 9 mil (type I segment). The grey bars in Figure 7 indicate the number of segments that have either missing Greenwood Beam values or missing AUTC values and thus were removed. After cleaning, 4,828 pairs of data records remained; the results of QQ plot normality check are presented in Figure 8. As seen from Figure 8, both Greenwood Beam SCI300 values and AUTC SCI300 values follow a near normal distribution, but both are heavily right-skewed and with some outliers.



(a)



(b)

Figure 8. QQ Plot of Greenwood Beam SCI300 data (a) and AUTC SCI300 data (b) versus standard normal quantiles.

APPLICATION 1: DETERMINATION OF SOFT BOUNDARIES OF TSDD DATA FOR EQUIVALENCE TESTING USING POWER ANALYSIS

The TSDD directly measures pavement surface deflection velocity as the load passes. The LTPP InfoMaterials database applied different calculation models to convert the surface deflection velocity to deflections. This example considers the hypothetical scenario that a state agency has been using one calculation model, while researchers proposed another calculation model that might have more merits in terms of implementation (higher calculation speed, easier to understand). The state agency may want to conduct statistical tests to examine if the deflection results from the new proposed model are different or similar enough to the existing model. The state agency usually manages a large road network; different road sections may have different deflection conditions. Thus, it is critical to specify the hard and soft boundaries to appropriately divide the road network into groups for statistical testing. Or perhaps the state agency is comparing TSDD results of equipment from two manufacturers. Some of the equipment may perform well on large sections, but that good performance is an average result over the whole section. If the state agency breaks the large section into small groups, the statistical results will be more meaningful and will help the state agency to better evaluate the performance of equipment from different manufacturers.

If the road network is not appropriately divided, the statistical results may lose meaning. For example, statistical tests usually assume the testing data groups came from corresponding normally distributed populations. If the testing TSDD data contain data from two or more different sections, then the testing results will be pointless because the material, traffic volume, climate, and other factors may vary for different pavement sections. Moreover, even within the same pavement section, the mechanical response under load may be different as caused by different distress and historical M&R treatments. Thus, it is important to find boundaries that appropriately divide the road network into testing groups.

The TSD data in the LTPP InfoMaterials database is reported on a segment basis with segment length of 0.01 mi. Each road has a unique road section ID and includes a different number of segments depending on the total length of the road. The following are two road sections that have high and low variability. Power analysis was used to determine the soft boundaries of the road sections to divide the sections into groups. TOST and paired-sample t-test were applied to the divided groups and to the sections as a whole, respectively.

Table 21 indicates that section 9005N002 contains 412 available segments, which include 242 type I segments and 170 type II segments. The SCI300 fluctuates a lot even within the same section, as shown in Figure 9. The different historical M&R treatments may have made the segments in section 9005N002 deteriorate differently and respond differently to the load. Thus, boundaries are needed to divide these segments into groups for testing. The one straightforward hard boundary will be the section ID. Since each section ID represents a unique road, SCI300 might be significantly different for different section IDs. However, the soft boundaries within each section will be the main interest for this case demonstration. Since each section may have a different number of segments and the SCI300 profile differs, the soft boundaries are section dependent.

Table 21. Basic description of section 9005N002.

	Greenwood Beam Value ≤ 9	Greenwood Beam Value > 9	Missing Records	Total Available Segments
Number of segments	242	170	17	412

Section 9005N002

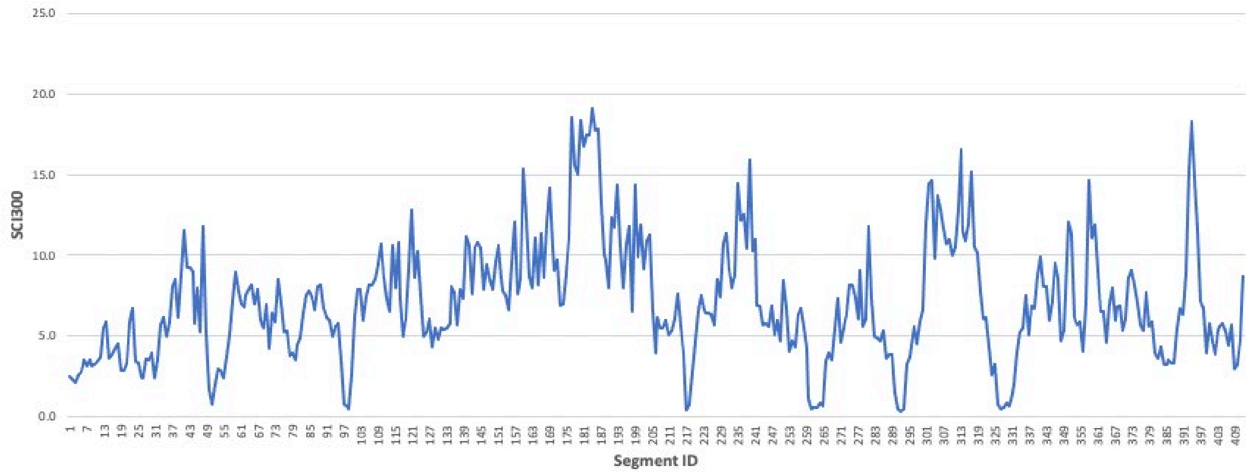


Figure 9. Greenwood Beam (reference) SCI300 of all segments in section 9005N002.

As shown in Figure 10, the mean standard deviation increases rapidly when the number of segments (N) increases from 0 to 30. This is because if N is small, the group doesn't capture too much variability of the road section; each group only focuses on a short length of the road. To further explain the concept of number of segments in testing group, consider that the illustrated section 9005N002 contains 412 segments. If the optimal number of segments in each testing group is determined to be 135, the section 9005N002 will be divided into 3 groups that contain segments 1-135, 136-270, and 271-412, respectively. Statistical tests will be applied to the first and second groups; the last group will be discarded due to insufficient segments in the group. There are several sudden drops in Figure 10. These drops happen at N=83, 138, and 207, respectively, where the last 80, 136, and 205 segments were discarded. It indicates that the last 80, 136, and 205 segments have significantly higher variability than the first two groups. Thus, section 9005N002 needs to be divided into different groups for meaningful statistical testing.

Power analysis is an effective approach to evaluate if the divided results have sufficient probability of correctly rejecting the null hypothesis (which will mean the results are equivalent). For equivalence testing, the power value is dependent on the equivalence limits.

- For Greenwood Beam (reference) SCI300 between 0 - 9 mil (type I segment), upper and lower equivalence limits between the testing and reference SCI300 are ±1 mil.
- For Greenwood Beam (reference) SCI300 greater than 9 mil (type II segment), upper and lower equivalence limits between the testing and reference SCI300 are ±3 mil.

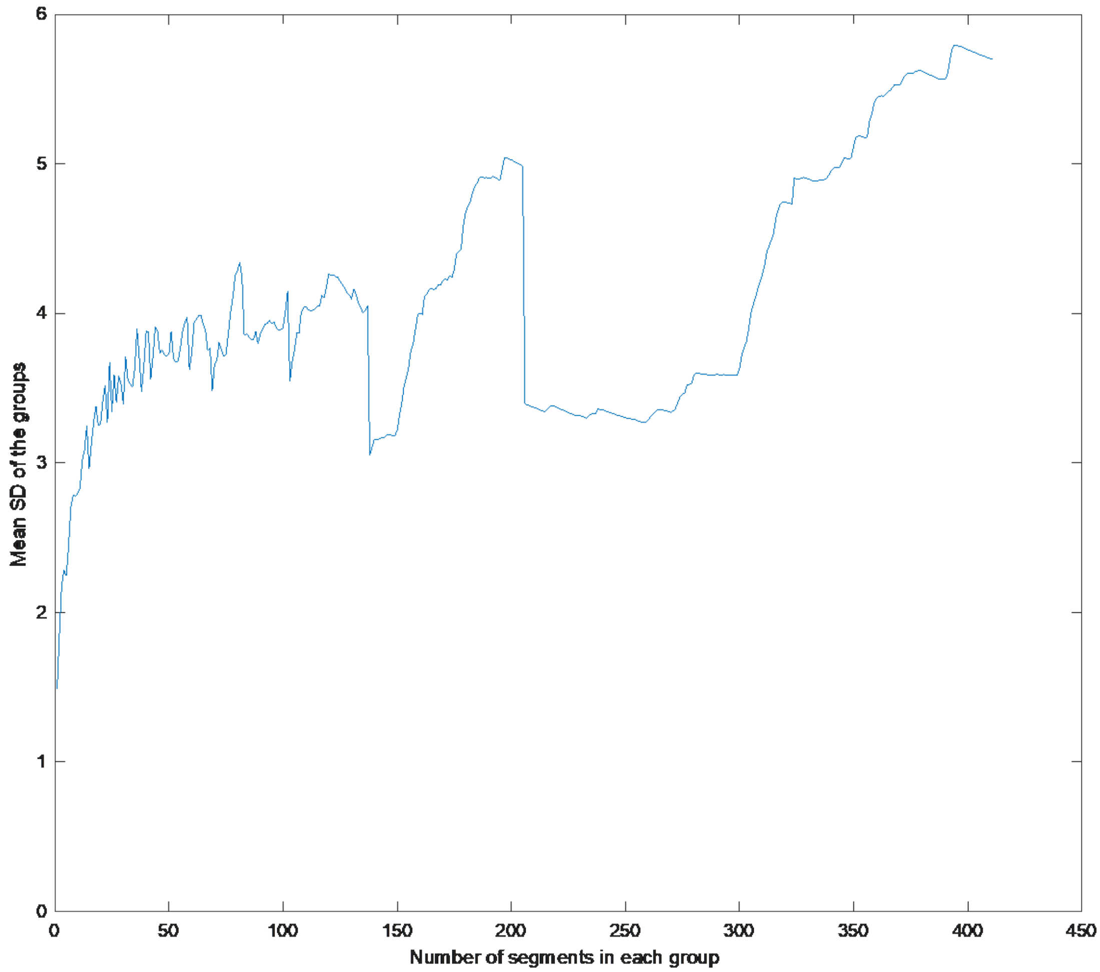


Figure 10. The effect of different numbers of segments (N) in each group on the mean standard deviation of groups in section 9005N002.

In the context of the previously described hypothetical agency-concerned problem, the power will first be evaluated on the data (SCI300 values) from the currently existing model (Greenwood Beam). The standard deviation of paired difference was replaced by the standard deviation of the Greenwood Beam SCI300 values; the mean difference between the testing group and the reference group was set as 0. The mean power of the groups in section 9005N002 with different number of segments (N) in each group is shown in Figure 11.

As illustrated in Figure 11, the mean power increases from 0.62 to 0.91 when the number of segments (N) increases from 61 to 62. Nevertheless, there isn't a significant change in mean standard deviation from N=61 to N=62. The cause of the change in mean power is the mean SCI300. When looking at the data, it was found that, with N=61, the section 9005N002 can be classified into 7 groups, where 6 groups were used for power calculation (the last group was discarded due to insufficient segments). Only 1 out of 6 groups has mean SCI300 greater than 9 mil, which means only 1 group has equivalence limits of ± 3 mil. However, for N=62, 3 out of 6 groups have equivalence limits of ± 3 mil and thus the mean power of the 6 groups increased. The result is that the mean power increases from N=61 to N=62 while the mean standard deviation isn't changed substantially.

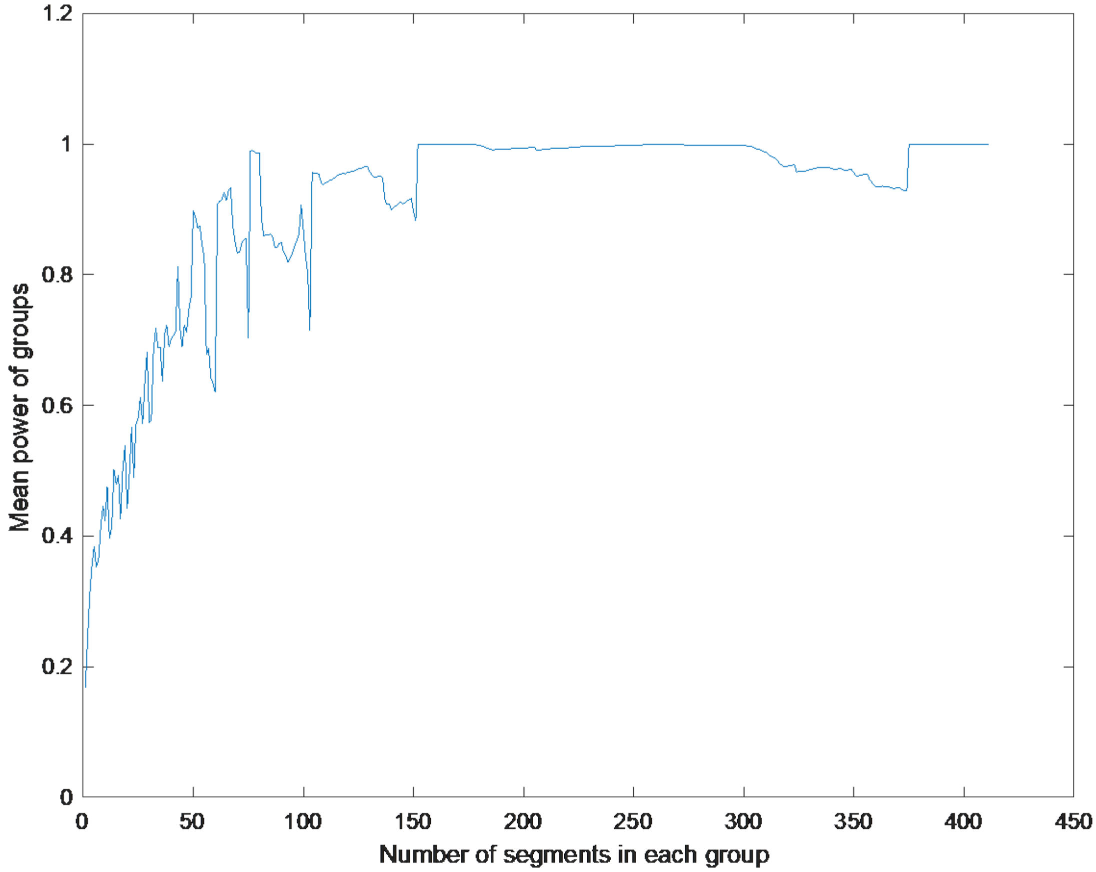


Figure 11. The effect of different numbers of segments in each group on the mean power of groups in section 9005N002.

To further validate the reasoning above, three types of equivalence limits were applied to section 9005N002; the mean power results are presented in Figure 12. In the first scenario (blue line), equivalence limits of ± 1 were applied to all the groups. It can be observed that the power line has the same pattern as the mean standard deviation line in Figure 10. This is because the power was mainly determined by the mean standard deviation of Greenwood Beam SCI300, since equivalence limits were fixed. In the second scenario (red line), equivalence limits of ± 3 were applied to all the groups. However, the power quickly went up and reached 1 at approximately N=70. This is because the effect of mean standard deviation was overshadowed by the large sample size (N greater than 70 in this case) and large equivalence limit of ± 3, especially when we have assumed a small population mean difference of 0. Thus, the power remains near 1 even if there was fluctuation in mean standard deviation after N=70.

For the problem of the aforementioned state agency, the mix equivalence limit scenario (yellow line) is what the agency might be interested in. Where equivalence limits of ± 3 mil were applied to groups that have mean Greenwood Beam SCI300 greater than 9 mil, equivalence limits of ± 1 were applied to the rest of groups. For section 9005N002, the first mean power reached above 0.8 corresponds to N=44. Thus, section 9005N002 was divided into groups that contain 44 continuous segments with 44 pairs of SCI300 values from the Greenwood Beam model and AUTC model. The TOST and paired-sample t-test were applied to each group and the test results are presented in Figure 12.

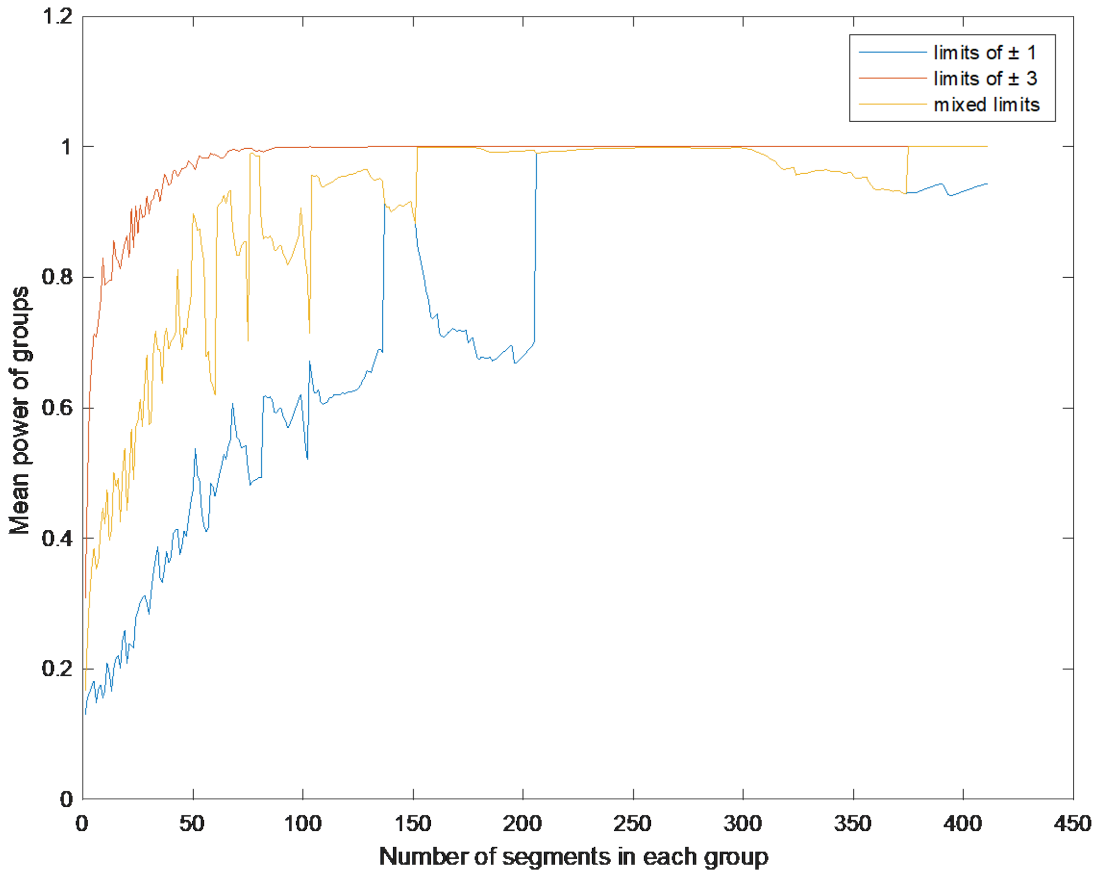


Figure 12. The effect of different equivalence limits on the mean power of groups in section 9005N002.

To clarify, the power analysis in Table 22 is different from that in Figure 12. In Table 22, N has been determined based in Greenwood Beam SCI300 (reference) and the AUTC SCI300 has been divided according to the determined mean. The standard deviation of paired difference and the mean difference are calculated based on the Greenwood Beam SCI300 and AUTC SCI300.

As seen from Table 22, regarding segments 1 through 396 as a whole, the TOST test indicated that the SCI300 values from the Greenwood Beam model and the AUTC model are equivalent; the paired-sample t-test indicated they are significantly different. However, when dividing 396 segments into 9 groups, all groups were concluded to be significantly different, while 6 out of 9 groups were concluded to be equivalent. It can be observed that with dividing, the last three groups were found to be not equivalent; those groups have high variability. The powers of the last three groups were not available because the mean differences between the Greenwood Beam SCI300 and AUTC SCI300 lie out of the corresponding equivalence limits. Thus, dividing the section into smaller groups will help the agency better examine the statistical equivalence of the data from the two models, rather than not discerning that three groups are not statistically equivalent and concluding that the populations are equivalent when assessing all 396 segments together as a whole.

Table 22. TOST and paired-sample t-test on segments 1 through 396 in section 9005N002.

Segment Range	TOST p-value	TOST Result	Paired-sample t-test p-value	Paired-sample t-test Results	Power
[1,44]	0	EQ	0	significantly different	1
[45,88]	0	EQ	0	significantly different	1
[89,132]	0	EQ	0	significantly different	1
[133,176]	0	EQ	0	significantly different	1
[177,220]	0	EQ	0	significantly different	1
[221,264]	0	EQ	0	significantly different	1
[265,308]	1	Not EQ	0	significantly different	not available
[309,352]	1	Not EQ	0	significantly different	not available
[353,396]	1	Not EQ	0	significantly different	not available
[1-396]	0	EQ	0	significantly different	0.9903

Section 0902W001

For sections with high variability, the value has been shown of dividing sections into groups for equivalence testing. However, for the sections with relatively low variability, the necessity might not remain. As seen from Figure 13 and Table 23, 81 out of 82 segments in section 0902W001 have Greenwood Beam SCI300 below 9 mil and have low variability compared to that of section 9005N002.

Table 23. Basic description of section 0902W001.

	Greenwood Beam Value ≤9	Greenwood Beam Value>9	Missing Records	Total Available Segments
Number of segments	81	1	5	82

As shown in Figure 14, the mean standard deviation does not change substantially as N changes. This means that the deflection conditions in section 9006N004 are relatively similar. This is in accordance with the basic description of section 0902W001 where 81 out of 82 segments have SCI300 less than or equal to 9 mil.

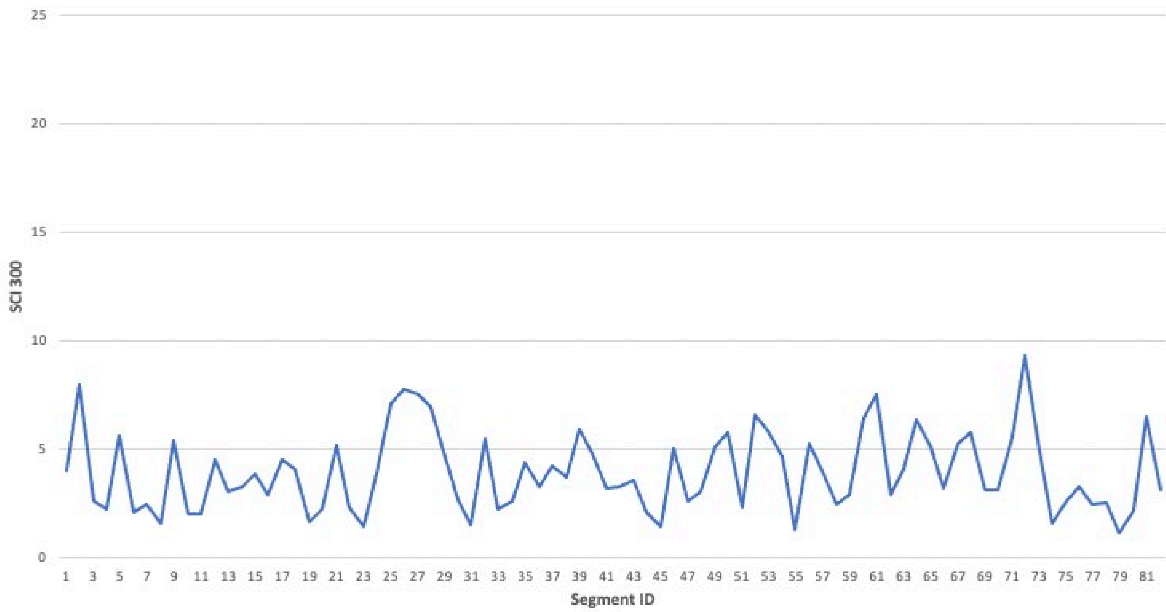


Figure 13. The effect of different numbers of segments (N) in each group on the mean standard deviation of groups in section 0902W001.

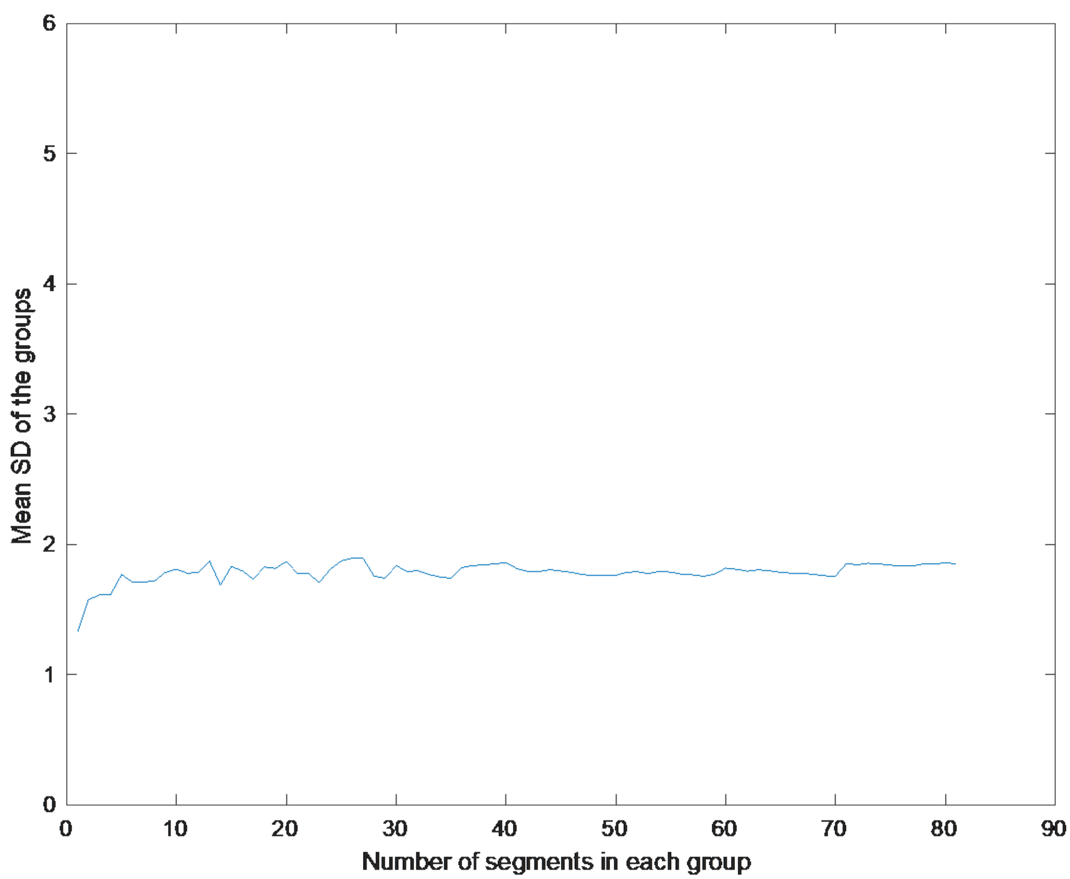


Figure 14. Greenwood Beam (reference) SCI300 of all segments in road section 0902W001.

From Figure 15, it can be seen that, unlike for section 9005N002, the power increases steadily as N increases. This occurs because the segments in sections 0902W001 have comparatively low variability and the equivalence limits don't change among groups. It was found that the first power above 0.8 corresponds to N of 29. Thus, section 0902W001 was divided into three groups that contain segments 1-29, 30-58, and 59-82, respectively. The Greenwood Beam SCI300 and AUTC SCI300 in the first two groups will be used for statistical testing.

As indicated in Table 24, for sections with low variability in SCI300, the soft boundaries don't have significant effect on either the TOST or paired-sample t-test results. This is primarily because the section itself doesn't have high variability in SCI values, potentially indicating that the segments in the section may have the same M&R history, pavement structure and material, or other sets of conditions causing similar structural responses.

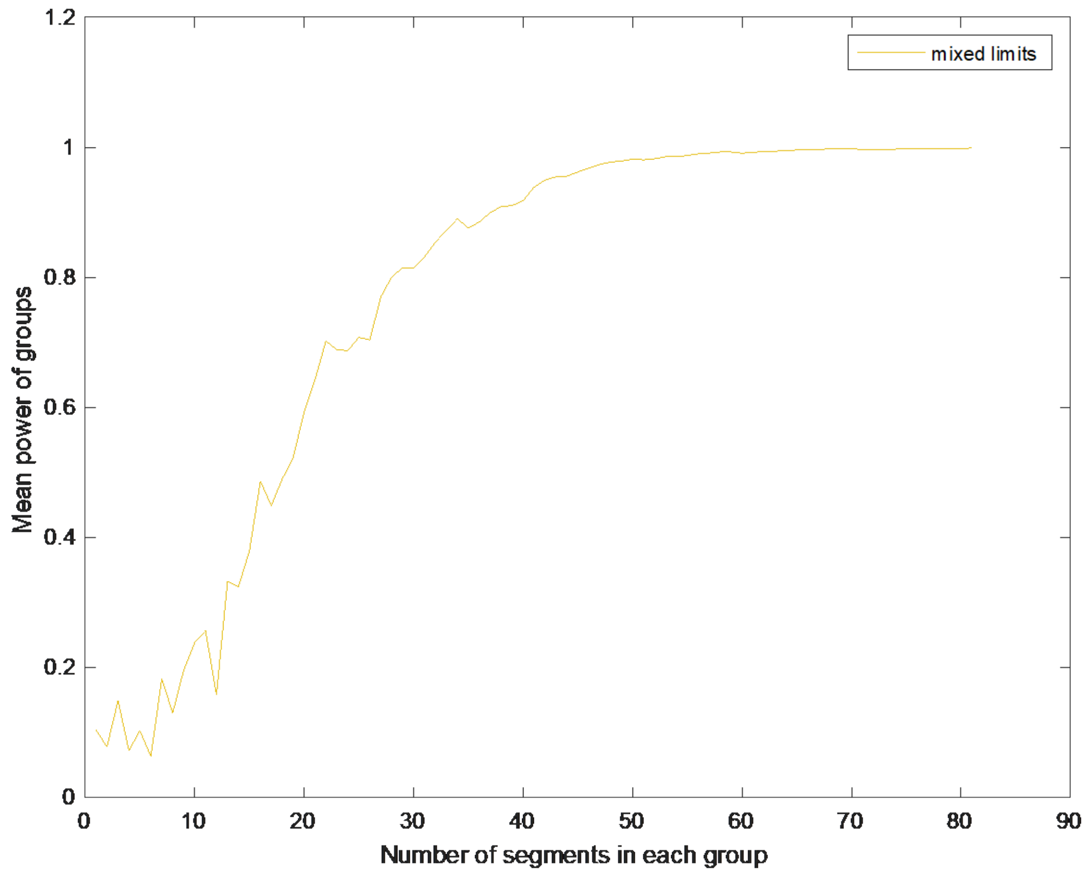


Figure 15. The effect of different numbers of segments in each group on the mean power of groups in section 0902W001.

Table 24. TOST and paired-sample t-test on segments 1 through 58 in section 0902W001.

Segment Range	TOST p-value	TOST Result	Paired-sample t-test p-value	Paired-sample t-test Results	Power
[1,29]	1	NOT EQ	0	significantly different	Not available
[30,58]	1	NOT EQ	0	significantly different	Not available
[1,58]	1	NOT EQ	0	significantly different	Not available

APPLICATION 2: A SIMULATED POWER APPROACH FOR DETERMINING THE REQUIRED LENGTH FOR TSDD DATA VERIFICATION USING EQUIVALENCE TESTING

Assume one state agency wants to compare the similarity of deflection results from one deflection calculation model to a new model or to compare the deflection results from two TSD devices from different manufacturers. The sample size required to keep the type II error below a certain level can be determined using power analysis. In this example, the sampling interval of the TSDD data is fixed as 0.01 mi. Thus, the different number of sample size indicates the different inspection lengths of the roadway using TSDD. A small inspection length might cause the statistical test to have insufficient power (1- probability of type II error), while a high inspection length will require redundant work. The formular power approach for sample size calculation has been be widely studied in clinical research (Chow, Shao et al. 2002; Chow, Shao et al. 2017). Due to the sampling process of the TSDD data, the formular power approach was considered as an inaccurate method of estimating the sample size. Thus, a simulated power approach was proposed in this case. The results from the formular power approach and the proposed simulated power approach were compared.

The Formular Power Approach

The formular power approach calculates power using an equation that is based on assumptions of a t-test (Schuirmann 1987; Chow, Shao et al. 2002; Shieh 2016). This approach assumes that the data are normally distributed and that the samples are independent and identically distributed (i.i.d.). For paired samples, the formular power approach uses the following equation to calculate power (Chow, Shao et al. 2002):

$$Power = \mathcal{T}_{n-1}\left(-t_{\alpha}, n-1 \middle| \frac{\sqrt{n}\,(\delta - |\epsilon|)}{\sigma}\right) - \mathcal{T}_{n-1}\left(t_{\alpha}, n-1 \middle| \frac{\sqrt{n}\,(\delta + |\epsilon|)}{\sigma}\right)$$

Where $\mathcal{T}_{n-1}(.\,|\theta)$ is the cumulative distribution function of the noncentral t-distribution with n-1 degrees of freedom and the noncentrality parameter θ; n is number of data pairs; ϵ is the true mean difference between the test and reference populations; δ is the upper limit of a symmetric equivalence limits; σ is the standard deviation of paired difference.

There are two issues with adopting the formular power approach when examining the TSDD data. First, it can be seen from Figure 8 that the TSDD data follow a near normal distribution with skewness. Second, due to the sampling process of the TSDD, the samples are always from consecutive locations and are not randomly distributed in the road network.

Simulation Power Approach

For equivalence testing of two populations, the simulation power approach first simulates two sets of normally distributed data that contain a certain number of random samples based on given means and standard deviations. The given mean difference should not exceed the equivalence limits ($\pm\delta$) in this case. Secondly, statistical testing is conducted at a pre-determined significance level (α) on the two simulated data sets and the test results are recorded (equivalent or not equivalent). After that, the first and second steps are repeated N times. Power is the ratio between total simulation times N divided by the total number of simulations where the conclusion of equivalent was drawn (Rusticus and Lovato 2014). The simulation power approach has also been used to examine if the new proposed formular power approach is reasonable. It is done by comparing the closeness of the results from simulated power and formula-calculated power (Shieh 2016).

A case study demonstration was conducted on section 9005N002. The mean of the Greenwood Beam SCI300 is 9.32 mil and equivalence limits of ± 3 should apply. The mean difference between the Greenwood Beam SCI300 and AUTC SCI300 of the section is 2.26 mil, which is within the range of the equivalence limits. Since we want to examine the power using existing data from LTPP InfoMaterials, the samples (segments) were not generated using simulation. Instead, consecutive segments were sampled from the section with sample size ranging from 10 to 400 at an increment of 10. For each sample size, the sampling was repeated for 1,000 times. For each sampling and each sample size, TOST was applied to the Greenwood Beam and AUTC model. Power is the probability of correctly concluding equivalence when the data sets are truly equivalent. In this simulation, the power is obtained by calculating the percentage of 1,000 simulations where equivalence was concluded.

It can be observed from Table 25 that both simulated and exact power increase as number of segments increases, regardless of increasing standard deviation of paired samples. According to the results of formular power, at segment length of 0.01 mi, the required sample size to achieve a power above 0.8 is 20, while at least 360 subsections were required based on the simulated power results. The exact power approach uses formulations that are based on several assumptions about the data, while the simulated power approach is based on the original definition of the power and considering both the inherent distribution of the data and the characteristics of the sampling process (consecutive samples). In this case, the TSDD data violate some of the assumptions of the formular power approach, thus the simulated power approach is more appropriate.

Table 25. Simulated and exact power of section 9005N002.

Segment Length	Number of Segments	SD of Greenwood Beam Model (%)	SD of AUTC Model (%)	Mean SD of Greenwood Beam Model (%)	Mean of AUTC Model (%)	Mean diff (%)	SD of Paired diff (%)	Simulated Power	Formular Power
0.01	10	2.74	2.18	9.35	7.17	2.18	1.05	0.66	0.66
0.01	20	3.39	2.73	9.42	7.21	2.21	1.25	0.64	0.81
0.01	30	3.65	2.96	9.44	7.23	2.22	1.36	0.64	0.90
0.01	40	3.83	3.11	9.51	7.30	2.21	1.45	0.63	0.93
0.01	50	3.91	3.19	9.51	7.32	2.19	1.52	0.62	0.96
0.01	60	3.95	3.24	9.41	7.35	2.06	1.57	0.62	0.97
0.01	70	4.05	3.31	9.44	7.37	2.07	1.64	0.61	0.98
0.01	80	4.09	3.37	9.34	7.43	1.91	1.67	0.61	0.99
0.01	90	4.17	3.43	9.32	7.45	1.87	1.75	0.60	0.99
0.01	100	4.22	3.48	9.30	7.47	1.83	1.80	0.59	0.99
0.01	110	4.27	3.53	9.29	7.55	1.75	1.83	0.60	0.99
0.01	120	4.36	3.58	9.27	7.54	1.73	1.94	0.60	0.99
0.01	130	4.41	3.62	9.20	7.57	1.63	2.02	0.63	0.99
0.01	140	4.45	3.65	9.15	7.60	1.55	2.08	0.64	0.99
0.01	150	4.50	3.69	9.11	7.64	1.48	2.16	0.66	0.99
0.01	160	4.52	3.74	9.09	7.69	1.40	2.23	0.68	0.99
0.01	170	4.59	3.77	9.11	7.70	1.41	2.35	0.68	0.99
0.01	180	4.62	3.82	9.12	7.74	1.38	2.45	0.69	0.99
0.01	190	4.62	3.82	9.08	7.75	1.33	2.49	0.69	0.99
0.01	200	4.63	3.83	9.07	7.75	1.33	2.58	0.69	0.99
0.01	210	4.65	3.84	9.08	7.74	1.34	2.68	0.70	0.99
0.01	220	4.67	3.85	9.10	7.74	1.36	2.78	0.68	0.99
0.01	230	4.70	3.86	9.11	7.75	1.37	2.89	0.67	0.99
0.01	240	4.73	3.84	9.11	7.72	1.39	2.98	0.66	0.99
0.01	250	4.77	3.82	9.10	7.69	1.42	3.09	0.63	0.98
0.01	260	4.82	3.81	9.09	7.64	1.45	3.22	0.57	0.98
0.01	270	4.89	3.79	9.12	7.61	1.51	3.38	0.57	0.97
0.01	280	5.00	3.78	9.18	7.58	1.60	3.54	0.53	0.97
0.01	290	5.09	3.77	9.22	7.55	1.67	3.67	0.50	0.96
0.01	300	5.18	3.76	9.24	7.52	1.72	3.76	0.46	0.96
0.01	310	5.31	3.75	9.31	7.50	1.81	3.89	0.45	0.95
0.01	320	5.38	3.74	9.34	7.46	1.88	3.99	0.42	0.95
0.01	330	5.43	3.72	9.35	7.41	1.94	4.06	0.42	0.95
0.01	340	5.49	3.69	9.39	7.39	2.00	4.13	0.53	0.95
0.01	350	5.55	3.68	9.42	7.36	2.06	4.19	0.64	0.95
0.01	360	5.62	3.67	9.46	7.33	2.13	4.26	0.81	0.95
0.01	370	5.64	3.65	9.47	7.30	2.18	4.29	0.91	0.95
0.01	380	5.66	3.65	9.45	7.24	2.21	4.30	1.00	0.95
0.01	390	5.70	3.66	9.44	7.20	2.24	4.30	1.00	0.96
0.01	400	5.72	3.65	9.40	7.15	2.25	4.28	1.00	0.96
0.01	410	5.70	3.65	9.33	7.07	2.26	4.25	1.00	0.97

APPLICATION 3: STATISTICAL TESTING FOR TSDD DATA SAMPLED UNDER DIFFERENT FREQUENCIES

The SCI300 values from the Greenwood Beam model were selected for statistical testing with different sampling frequencies. The raw reported deflection data in the LTPP InfoMaterials database has an interval of 0.01 mi and a sampling speed of approximately 37 mph; the reported sampling frequency is approximately 1 Hz. The reported data in the LTPP InfoMaterials database was already processed; the common TSDD sampling frequency is approximately 1 kHz, but different TSDD equipment may have different sampling frequencies. Even for the same equipment, the reporting interval might change depending on the storage capacity of the disk. Thus, it is necessary to examine if the data sampled using TSDD with relatively low frequency are significantly equivalent to or significantly different from the data sampled using TSDD with high frequency.

In this case, the SCI300 values from the Greenwood Beam model were selected for statistical testing with different sampling frequencies. The raw data from the Greenwood Beam model at 0.01 mi are considered as a reference (high frequency). Then one data record (segment) was selected for every two data records (segments) from the Greenwood Beam model to mimic a lower sampling frequency of 0.5 Hz (0.02 mi). Since the sample size of the high-frequency dataset (0.01-mi interval) and the low-frequency dataset (0.02-mi interval) are not the same, the TOST procedure was formulated to test the equivalency of the unpaired groups. Also, the difference-based Welch's t-test was adopted to examine the difference between the independent (unpaired) datasets.

In Figure 16, three sections were removed due to insufficient segments in each section. A p-value of the TOST smaller than or equal to the significance level (0.05 in this study) indicates that the two groups are significantly equivalent, while it states that the two groups are significantly different for a difference-based Welch's t-test. It can be summarized from Figure 16 that 20 out of 54 sections were found to be significantly equivalent using TOST, while all sections were concluded as not significantly different using Welch's t-test. This re-emphasizes that the formulation and testing of the correct hypothesis is essential.

From the preceding analysis, it can be concluded that if the sampling frequency increased from 0.5 Hz to 1 Hz (or reduced from 1 Hz to 0.5 Hz), the difference-based Welch's t-test would conclude that the SCI300 from the Greenwood Beam model of all sections are not significantly different. But a conclusion of "not significantly different" is not a finding of equivalence. If interpreted incorrectly in that way, it might be concluded that the agency would not need to repeat data collection, re-analysis, or some method of data correction. However, only 20 sections were concluded as significantly equivalent using TOST, meaning that the data sets are not equivalent within the given equivalence limits and assumptions for 34 sections.

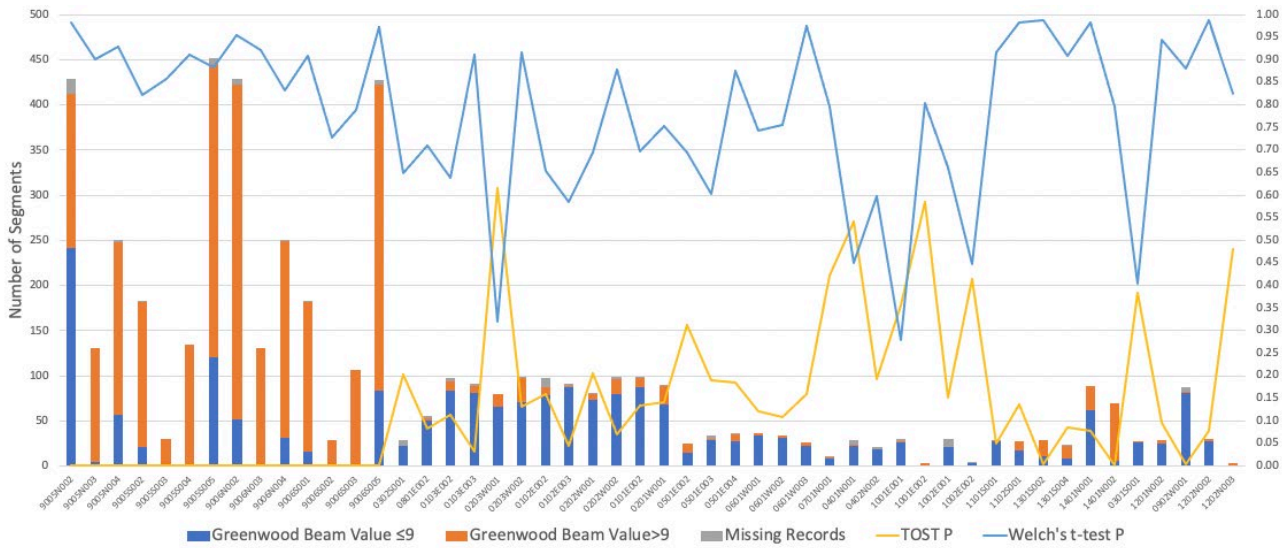


Figure 16. Number of segments below and above the threshold in each section and the statistical p-values from TOST and Welch's t-test.

Chapter 5 Analysis Summary and Findings

In Chapter 5, the TSDD SCI300 values were downloaded from the LTPP InfoMaterial database. Two models (the Greenwood Beam model and AUTC model) were used to interpret the raw data to the deflection results in the LTPP InfoMaterial database. The equivalence tests and power analyses were applied to the deflection results from the two models. The main findings are as follows:

- When conducting the equivalence tests on two sources of TSDD data, the soft boundaries should be carefully determined, as they will affect the power of the equivalence tests as well as the equivalence test results.
- For a dataset that violates the normality assumptions, the simulation approach would be recommended to calculate the power as opposed to the formular approach that doesn't consider the violation of the assumptions.
- It was also demonstrated that the equivalence tests could be used to investigate if TSDD data sampled under different frequencies can be regarded as equivalent or not. This application provided an opportunity to demonstrate and re-emphasize the fundamental importance of formulating the correct null hypothesis for significance testing. If determining whether the data sets are equivalent for a given purpose, equivalence testing with meaningful equivalence limits is the more appropriate formulation. Finding that there is not a statistically significant difference at the 95% confidence level does not mean that the data sets are equivalent for the intended purpose.

CHAPTER 6

Summary and Recommendations

Transportation agencies make a significant investment in the equipment, data collection, and data interpretation required for condition monitoring of infrastructure assets. That condition data is essential for multiple components of their infrastructure asset management decision support system. Due to the long life and tremendous extent of transportation infrastructure assets, the equipment, systems, and personnel used to collect the condition data change over the life of an asset (temporal variability) and may also vary over the physical extent of the system (spatial variability). Promising new technologies may not initially deliver the anticipated precision and accuracy of information. The statistical evaluation, precision and accuracy quantification, and quality control of condition data have been an enduring challenge.

In this study, applications of statistical equivalence testing to three categories of pavement condition data were demonstrated. While equivalence methods have been used in the pharmaceutical industry and related fields for decades, they have been seemingly slow to be adopted for engineering and construction applications. Equivalence tests are formulated to assess equivalence or noninferiority between methods, thus also holding promise for assessing if new equipment or vendors are equivalent (or noninferior) to current accepted standards.

In Chapter 3, the use of equivalence testing for cracking assessment in the vendor selection process, as recommended by Stoffels in (Morian 2020), was further demonstrated. The effect of subsection length and number of subsections on the standard deviation of paired differences for cracking verification was examined. It was found that the larger the subsection length, the less the standard deviation of paired differences. The relationship between the standard deviation of paired difference, equivalence limits, alpha, mean difference, and power was investigated and illustrated for values typical for assessing pavement cracking. A high value of alpha, a small standard deviation of paired difference, a large sample size, a small mean difference, and wider equivalence limits will result in a higher power (less risk for the vendor). A case study example using real data is presented in Appendix D demonstrating the selection of agency risk for asphalt concrete pavement cracking verification using power analysis. This chapter demonstrated how an agency might utilize equivalence testing in its vendor selection process.

In Chapter 4, pavement roughness values (IRI) from two sources on the same sites were compared—research quality data from the FHWA LTPP program and network-level asset management data collected by several state agencies via an experienced vendor. Both paired and unpaired equivalence tests were demonstrated for potential application for use of the data in a state agency's pavement maintenance and rehabilitation decision tree. Equivalence testing of the data in the context of the Highway Performance Monitoring System was also demonstrated. This chapter demonstrated how an agency might utilize equivalence testing for the pavement condition data that have been collected for the agency's pavement asset management system.

In Chapter 5, pavement deflection data (TSDD) that had been collected at highway speeds were utilized. Two different models had been used to convert the raw instrumentation data to interpreted deflection results. Equivalence tests and power analysis were applied to the deflection results from the two models. Contexts for application that were explored included determining the soft or dynamic boundaries used for grouping the data for testing and equivalence testing for data that violates normality assumptions. Both equivalence and significant difference testing were conducted on TSDD data sampled under different frequencies to emphasize that determining that there is not a statistically significant difference at the 95% confidence level does not mean that the data sets are equivalent for the intended purpose.

The two one-sided t-test (TOST) methodology is recommended as the easiest and most practical to apply for most cases of infrastructure asset management condition data. However, the examples and data types demonstrate that while equivalence testing may often be the statistical technique that answers the right questions, its unfamiliarity to most engineers will require the careful consideration of the data to be compared and informed selection of input assumptions and calculation techniques.

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APPENDIX A

Cracking Data from XDOT, YDOT, and ZDOT

Table 26 contains 2018 data from six ZDOT control sites. All ratings were taken from the same sets of images. Each image was rated by three reference raters and by a vendor that has performed ZDOT ratings for many years, and is experienced with the ZDOT ratings and with meeting the QA process conducted by ZDOT's consultant raters. For the purposes of this exercise, the HMPS Cracking Percent was estimated using only the Fatigue Cracking that was recorded. This may be an underestimate for some sections that also have low-severity longitudinal cracking, which may or may not be in the wheelpath.

Table 26. HPMS cracking ratings from 6 ZDOT control sites.

Site	Segment Length (mi)	HPMS Cracking % Reference Rater 1	HPMS Cracking % Reference Rater 2	HPMS Cracking % Reference Rater 3	HPMS Cracking % Reference Average	HPMS Cracking % Vendor Rating
3	0.1	1.69%	0.17%	0.00%	0.62%	0.00%
3	0.1	1.80%	0.14%	0.09%	0.68%	0.00%
3	0.1	0.00%	0.08%	0.00%	0.03%	0.00%
3	0.1	0.00%	0.00%	0.11%	0.04%	0.00%
3	0.1	0.00%	0.02%	0.03%	0.02%	0.00%
3	0.1	0.79%	0.03%	0.00%	0.27%	0.00%
3	0.1	1.85%	0.11%	0.00%	0.65%	0.00%
3	0.1	0.38%	0.00%	0.11%	0.16%	0.00%
3	0.1	1.50%	0.35%	0.24%	0.69%	0.00%
3	0.1	0.44%	0.00%	0.03%	0.16%	0.00%
11	0.1	0.73%	0.00%	0.49%	0.41%	0.00%
11	0.1	2.27%	0.00%	0.21%	0.83%	0.00%
11	0.1	1.34%	0.05%	0.00%	0.46%	0.00%
11	0.1	2.51%	0.05%	0.28%	0.95%	0.00%
11	0.1	1.17%	0.05%	0.14%	0.45%	0.00%
11	0.1	0.54%	0.00%	0.09%	0.21%	0.00%
11	0.1	1.29%	0.00%	0.13%	0.47%	0.00%
11	0.1	0.33%	0.00%	0.11%	0.15%	0.00%
11	0.1	0.82%	0.05%	0.74%	0.54%	0.00%
11	0.1	0.00%	0.00%	0.68%	0.23%	0.00%
12	0.1	0.00%	0.02%	0.17%	0.06%	0.95%
12	0.1	6.17%	0.08%	0.96%	2.40%	1.20%
12	0.1	8.02%	0.03%	8.32%	5.46%	0.65%
12	0.1	6.90%	0.05%	3.36%	3.44%	1.42%
12	0.1	2.86%	0.03%	1.75%	1.55%	0.03%
12	0.1	4.07%	0.00%	0.00%	1.36%	0.06%

Site	Segment Length (mi)	HPMS Cracking % Reference Rater 1	HPMS Cracking % Reference Rater 2	HPMS Cracking % Reference Rater 3	HPMS Cracking % Reference Average	HPMS Cracking % Vendor Rating
12	0.1	3.35%	0.03%	0.19%	1.19%	0.00%
12	0.1	3.80%	0.14%	0.09%	1.35%	0.00%
12	0.1	6.88%	0.19%	0.09%	2.39%	0.17%
14	0.1	0.00%	0.21%	0.22%	0.14%	0.51%
14	0.1	0.00%	0.03%	0.17%	0.07%	2.23%
14	0.1	0.00%	0.06%	0.00%	0.02%	0.24%
14	0.1	0.00%	0.00%	0.00%	0.00%	0.22%
14	0.1	0.00%	0.24%	0.02%	0.08%	0.16%
14	0.1	0.41%	0.84%	0.33%	0.53%	0.03%
14	0.1	0.00%	0.00%	0.13%	0.04%	0.00%
14	0.1	0.66%	0.30%	0.17%	0.38%	0.58%
17	0.1	15.85%	9.77%	10.09%	11.90%	9.82%
17	0.1	18.56%	6.17%	6.01%	10.25%	5.57%
17	0.1	18.62%	12.86%	12.64%	14.71%	13.43%
17	0.1	15.03%	8.54%	9.52%	11.03%	8.60%
17	0.1	12.74%	3.09%	4.12%	6.65%	2.18%
17	0.1	12.20%	3.11%	5.29%	6.87%	2.56%
17	0.1	13.54%	1.63%	3.08%	6.08%	1.78%
17	0.1	8.19%	0.46%	0.47%	3.04%	0.19%
17	0.1	2.70%	0.32%	0.52%	1.18%	0.16%
17	0.1	3.85%	0.11%	0.17%	1.38%	0.00%
20	0.1	3.05%	0.43%	0.13%	1.20%	0.00%
20	0.1	2.65%	0.65%	0.57%	1.29%	0.00%
20	0.1	2.81%	0.66%	1.37%	1.62%	0.33%
20	0.1	4.59%	0.73%	1.72%	2.35%	0.69%
20	0.1	2.94%	0.49%	0.65%	1.36%	0.02%
20	0.1	2.62%	0.33%	0.22%	1.06%	0.00%
20	0.1	5.82%	2.56%	2.81%	3.73%	1.40%
20	0.1	3.69%	1.59%	1.97%	2.42%	0.28%
20	0.1	5.22%	2.56%	3.00%	3.59%	1.64%

The YDOT cracking data in Table 27, Table 28, and Table 29 was collected from three sites and was rated by one field rater (reference), three automated raters, and two image raters. The automated ratings and image ratings were compared to the field ratings, respectively.

Table 27. HPMS cracking ratings from YDOT control site 26020000.

Distance (ft)	Field	Auto1	Auto2	Auto3	Image1	Image2
20	4.06%	0.00%	4.74%	3.93%	13.54%	13.54%
40	0.00%	6.36%	13.00%	2.03%	13.54%	17.60%
60	13.54%	0.00%	0.00%	3.11%	0.00%	8.13%
80	8.13%	0.00%	0.00%	0.00%	0.00%	2.71%
100	8.13%	2.44%	0.00%	0.00%	6.77%	6.77%
120	17.60%	0.00%	1.08%	0.81%	8.13%	9.48%
140	16.25%	12.32%	17.74%	7.18%	21.67%	27.08%
160	16.25%	4.60%	1.08%	13.54%	10.83%	20.31%
180	37.92%	0.27%	0.00%	4.33%	5.42%	13.54%
200	35.21%	5.15%	4.88%	4.47%	17.60%	28.44%
220	27.08%	0.00%	0.00%	0.00%	20.31%	12.19%
240	33.85%	0.00%	0.00%	0.00%	0.00%	1.35%
260	13.54%	2.30%	1.08%	2.44%	10.83%	14.90%
280	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
300	12.19%	0.00%	0.00%	0.00%	0.00%	0.00%
320	9.48%	0.00%	0.00%	0.00%	0.00%	0.00%
340	18.96%	0.00%	0.00%	0.00%	0.00%	0.00%
360	32.50%	0.00%	4.47%	3.79%	17.60%	18.96%
380	23.02%	2.98%	0.68%	2.17%	9.48%	6.77%
400	32.50%	6.77%	1.08%	8.94%	31.15%	32.50%
420	8.13%	0.00%	0.00%	0.00%	2.71%	4.06%
440	31.15%	1.08%	3.39%	7.04%	21.67%	20.31%
460	27.08%	1.22%	0.00%	3.52%	0.00%	1.35%
480	27.08%	0.00%	0.00%	0.00%	0.00%	0.00%
500	51.46%	3.66%	0.00%	2.17%	20.31%	16.25%
520	47.40%	2.57%	2.84%	2.17%	12.19%	27.08%

Table 28. HPMS cracking ratings from YDOT control site 2608000.

Distance (ft)	Field	Auto1	Auto2	Auto3	Image1	Image2
20	24.38%	12.32%	0.00%	2.71%	8.13%	0.00%
40	32.50%	17.20%	23.43%	19.23%	18.96%	21.67%
60	29.79%	20.72%	18.01%	18.28%	47.40%	17.60%
80	48.75%	37.38%	28.71%	33.99%	40.63%	37.92%
100	54.17%	29.93%	40.35%	32.91%	40.63%	47.40%
120	27.08%	26.00%	27.35%	28.84%	33.85%	36.56%
140	27.08%	28.03%	22.34%	21.53%	23.02%	27.08%
160	27.08%	28.98%	28.17%	22.34%	29.79%	23.02%
180	40.63%	29.25%	25.46%	27.63%	32.50%	39.27%
200	54.17%	33.18%	29.11%	33.85%	36.56%	28.44%
220	48.75%	28.98%	35.34%	28.57%	40.63%	51.46%
240	54.17%	36.56%	32.50%	30.60%	36.56%	29.79%
260	40.63%	32.36%	38.05%	32.23%	27.08%	31.15%
280	54.17%	38.46%	33.31%	35.61%	40.63%	23.02%
300	52.81%	36.83%	38.46%	37.51%	37.92%	40.63%
320	17.60%	36.29%	39.81%	36.97%	40.63%	37.92%
340	21.67%	22.89%	24.65%	24.24%	21.67%	24.38%
360	32.50%	33.04%	28.03%	30.88%	28.44%	28.44%
380	27.08%	31.55%	35.75%	40.90%	33.85%	36.56%
400	48.75%	36.43%	25.86%	32.50%	29.79%	21.67%
420	48.75%	42.25%	39.14%	41.71%	41.98%	41.98%
440	54.17%	45.91%	46.72%	45.64%	50.10%	47.40%
460	27.08%	49.83%	44.28%	44.96%	50.10%	51.46%
480	32.50%	32.64%	45.91%	40.90%	29.79%	44.69%
500	21.67%	25.05%	30.33%	25.05%	21.67%	27.08%
520	24.38%	12.32%	0.00%	2.71%	8.13%	0.00%

Table 29. HPMS cracking ratings from YDOT control site 34010000.

Distance (ft)	Field	Auto1	Auto2	Auto3	Image1	Image2
20	20.31%	0.00%	9.34%	12.19%	0.00%	9.48%
40	6.77%	22.48%	37.78%	34.67%	27.08%	51.46%
60	0.00%	27.90%	6.50%	6.09%	23.02%	2.71%
80	6.77%	5.69%	1.76%	1.63%	5.42%	5.42%
100	18.96%	0.41%	9.07%	10.56%	1.35%	21.67%
120	12.19%	20.99%	19.91%	13.27%	25.73%	33.85%
140	24.38%	9.34%	9.34%	11.38%	24.38%	14.90%
160	8.13%	5.15%	18.55%	19.77%	14.90%	18.96%
180	8.13%	15.71%	2.17%	0.00%	14.90%	1.35%
200	10.83%	0.81%	8.13%	19.23%	0.00%	13.54%
220	24.38%	15.98%	7.04%	10.70%	20.31%	12.19%
240	27.08%	19.09%	27.49%	24.38%	20.31%	27.08%
260	13.54%	26.81%	15.44%	13.41%	27.08%	16.25%
280	20.31%	16.11%	21.40%	24.38%	9.48%	27.08%
300	5.42%	23.83%	18.42%	11.78%	27.08%	24.38%
320	0.00%	12.86%	6.77%	9.21%	12.19%	5.42%
340	4.06%	10.83%	4.60%	8.94%	13.54%	10.83%
360	29.79%	5.69%	10.56%	19.77%	4.06%	14.90%
380	0.00%	14.22%	3.79%	2.57%	21.67%	2.71%
400	13.54%	1.49%	1.76%	8.40%	0.00%	2.71%
420	28.44%	7.18%	11.92%	17.47%	14.90%	8.13%
440	13.54%	7.58%	19.23%	25.59%	10.83%	27.08%
460	5.42%	22.61%	25.19%	24.24%	23.02%	28.44%
480	13.54%	16.79%	0.68%	0.27%	16.25%	0.00%
500	16.25%	3.25%	6.91%	6.23%	1.35%	2.71%
520	29.79%	5.28%	1.08%	10.83%	2.71%	13.54%

The cracking data used from XDOT is the visible fatigue-type cracking across the entire pavement. However, according to the definition of HPMS Cracking Percent, only the fatigue cracking within the wheelpaths is considered. Based upon wheelpath width set at 39 inches, Percent Cracking is the calculated area of wheelpath cracking divided by the total wheelpath area (wheelpath width*length of the section) multiplied by 100 (Federal Highway Administration 2016). The Cracking Percent is to be reported to the nearest 1 percent. Consistent with the Transportation Pooled Fund study (Morian 2020), these assumptions were made when interpreting the XDOT data to estimate the length of cracking occurring within the wheelpaths:

- Low-severity fatigue cracking only influences a small pavement area and can be observed in either the left wheelpath or right wheelpath.
- Medium-severity and high-severity fatigue cracking extend to both wheelpaths and thus should be counted twice when calculating the visible fatigue cracking in the wheelpath.

The visible fatigue cracking in the wheelpath is estimated using the equation:

$$\text{Visible fatigue cracking in the wheelpath} = \text{low} - \text{severity fatigue cracking} + 2 * (\text{medium} - \text{severity fatigue cracking and high} - \text{severity fatigue cracking})$$

The HPMS Cracking Percent of each site was then calculated by dividing the total area exhibiting visible fatigue cracking for all severity levels in the wheelpath by the total area in each section.

Table 35 contains data from research-level data collection by XDOT, matched with vendor data collection at the same using the vendor's 2D semi-automated system. The HPMS Cracking Percent was estimated using only the fatigue cracking that was recorded. For Table 30 and Table 31 (data collected in 2013 and 2014), PW1, PW2, and PW3 denote low-severity, medium-severity, and high-severity fatigue cracking rated by venders, respectively. However, in Table 32 through Table 35 (data collected in 2015), the corresponding fatigue cracking types were represented by VW1, VW2, and VW3, respectively, and include data collected by four vendors. For Table 32 through Table 35 (all data), AW1, AW2, and AW3 denote low-severity, medium-severity, and high-severity fatigue cracking, respectively, as collected by the agency.

Table 30. HPMS cracking ratings from 10 XDOT control sites in 2013.

Site	Route	MP	AW1	AW2	AW3	Agency HPMS	PW1	PW2	PW3	Vendor HPMS
A	AL0003	141.00	51.50	0.00	0.00	26%	0.00	0.00	0.00	0%
A	AL0003	141.01	45.20	0.00	0.00	23%	0.00	0.00	0.00	0%
A	AL0003	141.02	52.80	0.00	0.00	27%	12.20	0.00	0.00	6%
A	AL0003	141.03	52.80	0.00	0.00	27%	6.90	0.00	0.00	4%
A	AL0003	141.04	52.80	0.00	0.00	27%	0.00	0.00	0.00	0%
A	AL0003	141.05	46.50	0.00	0.00	24%	0.00	0.00	0.00	0%
A	AL0003	141.06	52.80	0.00	0.00	27%	0.00	0.00	0.00	0%
A	AL0003	141.07	50.70	0.00	0.00	26%	0.00	0.00	0.00	0%
A	AL0003	141.08	52.60	0.00	0.00	27%	0.00	0.00	0.00	0%
A	AL0003	141.09	52.80	0.00	0.00	27%	2.40	0.00	0.00	1%
A	AL0003	141.10	52.50	0.00	0.00	27%	7.20	0.00	0.00	4%
A	AL0003	141.11	52.80	0.00	0.00	27%	0.00	0.00	0.00	0%
A	AL0003	141.12	46.10	0.00	0.00	24%	0.00	0.00	0.00	0%
A	AL0003	141.13	49.20	0.00	0.00	25%	22.70	0.00	0.00	12%
A	AL0003	141.14	50.60	0.00	0.00	26%	0.00	0.00	0.00	0%
A	AL0003	141.15	52.80	0.00	0.00	27%	17.30	0.00	0.00	9%
A	AL0003	141.16	48.40	0.00	0.00	25%	0.00	0.00	0.00	0%
A	AL0003	141.17	46.80	0.00	0.00	24%	0.00	0.00	0.00	0%
A	AL0003	141.18	51.50	0.00	0.00	26%	0.00	0.00	0.00	0%
A	AL0003	141.19	48.10	0.00	0.00	25%	4.30	0.00	0.00	2%
A	AL0003	141.20	42.30	0.00	0.00	22%	0.00	0.00	0.00	0%
A	AL0003	141.21	48.70	0.00	0.00	25%	0.00	0.00	0.00	0%
A	AL0003	141.22	41.10	0.00	0.00	21%	0.00	0.00	0.00	0%
A	AL0003	141.23	45.30	0.00	0.00	23%	0.00	0.00	0.00	0%
A	AL0003	141.24	38.20	0.00	0.00	20%	0.00	0.00	0.00	0%
A	AL0003	141.25	52.50	0.00	0.00	27%	0.00	0.00	0.00	0%
A	AL0003	141.26	50.00	0.00	0.00	26%	0.00	0.00	0.00	0%
A	AL0003	141.27	52.20	0.00	0.00	27%	0.00	0.00	0.00	0%
A	AL0003	141.28	52.80	0.00	0.00	27%	0.00	0.00	0.00	0%
A	AL0003	141.29	50.80	0.00	0.00	26%	0.00	0.00	0.00	0%
B	AL0003	171.00	41.10	0.00	0.00	21%	24.30	0.00	0.00	12%
B	AL0003	171.01	2.00	0.00	0.00	1%	33.00	0.00	0.00	17%
B	AL0003	171.02	1.00	0.00	0.00	1%	0.00	0.00	0.00	0%
B	AL0003	171.03	1.00	0.00	0.00	1%	0.00	0.00	0.00	0%
B	AL0003	171.04	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
B	AL0003	171.05	1.00	0.00	0.00	1%	0.00	0.00	0.00	0%
B	AL0003	171.06	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
B	AL0003	171.07	6.30	0.00	0.00	3%	0.00	0.00	0.00	0%
B	AL0003	171.08	14.60	0.00	0.00	7%	0.00	0.00	0.00	0%

Site	Route	MP	AW1	AW2	AW3	Agency HPMS	PW1	PW2	PW3	Vendor HPMS
B	AL0003	171.09	29.80	0.00	0.00	15%	0.00	0.00	0.00	0%
B	AL0003	171.10	26.10	0.00	0.00	13%	0.00	0.00	0.00	0%
B	AL0003	171.11	6.10	0.00	0.00	3%	0.00	0.00	0.00	0%
B	AL0003	171.12	14.70	0.00	0.00	8%	0.00	0.00	0.00	0%
B	AL0003	171.13	8.50	0.00	0.00	4%	0.00	0.00	0.00	0%
B	AL0003	171.14	5.70	0.00	0.00	3%	0.00	0.00	0.00	0%
B	AL0003	171.15	20.50	0.00	0.00	11%	0.00	0.00	0.00	0%
B	AL0003	171.16	14.00	0.00	0.00	7%	14.80	0.00	0.00	8%
B	AL0003	171.17	1.00	0.00	0.00	1%	0.00	0.00	0.00	0%
B	AL0003	171.18	5.20	0.00	0.00	3%	22.60	0.00	0.00	12%
B	AL0003	171.19	17.80	0.00	0.00	9%	6.90	0.00	0.00	4%
B	AL0003	171.20	20.40	0.00	0.00	10%	0.00	0.00	0.00	0%
B	AL0003	171.21	38.90	0.00	0.00	20%	0.00	0.00	0.00	0%
B	AL0003	171.22	1.00	0.00	0.00	1%	0.00	0.00	0.00	0%
B	AL0003	171.23	42.70	0.00	0.00	22%	0.00	0.00	0.00	0%
B	AL0003	171.24	18.40	0.00	0.00	9%	0.00	0.00	0.00	0%
B	AL0003	171.25	1.00	0.00	0.00	1%	27.80	0.00	0.00	14%
B	AL0003	171.26	10.20	0.00	0.00	5%	29.60	0.00	0.00	15%
B	AL0003	171.27	17.70	0.00	0.00	9%	0.00	0.00	0.00	0%
B	AL0003	171.28	3.50	0.00	0.00	2%	37.30	0.00	0.00	19%
B	AL0003	171.29	18.80	0.00	0.00	10%	27.80	0.00	0.00	14%
C	AL0005	60.00	46.70	6.10	0.00	30%	34.80	0.00	0.00	18%
C	AL0005	60.01	52.80	0.00	0.00	27%	24.30	4.30	0.00	17%
C	AL0005	60.02	52.80	0.00	0.00	27%	35.40	17.40	0.00	36%
C	AL0005	60.03	52.80	0.00	0.00	27%	52.80	0.00	0.00	27%
C	AL0005	60.04	52.80	0.00	0.00	27%	12.80	40.00	0.00	48%
C	AL0005	60.05	52.80	0.00	0.00	27%	30.40	17.40	0.00	33%
C	AL0005	60.06	52.80	0.00	0.00	27%	25.30	0.00	0.00	13%
C	AL0005	60.07	52.80	0.00	0.00	27%	52.80	0.00	0.00	27%
C	AL0005	60.08	50.40	0.00	0.00	26%	52.80	0.00	0.00	27%
C	AL0005	60.09	47.80	0.00	0.00	25%	52.80	0.00	0.00	27%
C	AL0005	60.10	52.80	0.00	0.00	27%	46.90	0.00	0.00	24%
C	AL0005	60.11	52.80	0.00	0.00	27%	25.30	0.00	0.00	13%
C	AL0005	60.12	49.70	3.10	0.00	29%	20.00	17.40	0.00	28%
C	AL0005	60.13	51.20	1.60	0.00	28%	42.60	7.80	0.00	30%
C	AL0005	60.14	52.80	0.00	0.00	27%	52.80	0.00	0.00	27%
C	AL0005	60.15	52.80	0.00	0.00	27%	0.00	52.80	0.00	54%
C	AL0005	60.16	52.80	0.00	0.00	27%	0.00	52.80	0.00	54%
C	AL0005	60.17	51.40	0.00	0.00	26%	48.50	4.30	0.00	29%
C	AL0005	60.18	47.10	0.00	0.00	24%	5.00	47.80	0.00	52%
C	AL0005	60.19	38.80	0.00	0.00	20%	30.30	0.00	0.00	16%
C	AL0005	60.20	47.40	0.00	0.00	24%	28.40	24.40	0.00	40%
C	AL0005	60.21	48.60	0.00	0.00	25%	0.00	26.90	0.00	28%
C	AL0005	60.22	38.00	0.00	0.00	19%	0.00	52.20	0.00	54%
C	AL0005	60.23	38.70	0.00	0.00	20%	40.10	5.20	0.00	26%
C	AL0005	60.24	33.70	0.00	0.00	17%	0.00	52.80	0.00	54%
C	AL0005	60.25	48.30	0.00	0.00	25%	25.00	27.80	0.00	41%
C	AL0005	60.26	52.80	0.00	0.00	27%	0.00	52.80	0.00	54%
C	AL0005	60.27	52.80	0.00	0.00	27%	0.00	52.80	0.00	54%
C	AL0005	60.28	52.80	0.00	0.00	27%	0.00	52.80	0.00	54%
C	AL0005	60.29	49.60	0.00	0.00	25%	0.00	52.80	0.00	54%

Site	Route	MP	AW1	AW2	AW3	Agency HPMS	PW1	PW2	PW3	Vendor HPMS
D	AL0009	129.00	39.00	0.00	0.00	20%	2.40	0.00	0.00	1%
D	AL0009	129.01	43.80	0.00	0.00	22%	33.90	0.00	0.00	17%
D	AL0009	129.02	52.80	0.00	0.00	27%	27.80	0.00	0.00	14%
D	AL0009	129.03	52.80	0.00	0.00	27%	47.00	0.00	0.00	24%
D	AL0009	129.04	41.90	10.90	0.00	33%	52.80	0.00	0.00	27%
D	AL0009	129.05	28.00	22.80	0.00	38%	42.60	6.90	0.00	29%
D	AL0009	129.06	49.90	0.00	0.00	26%	40.60	12.20	0.00	33%
D	AL0009	129.07	49.30	0.00	0.00	25%	50.20	2.60	0.00	28%
D	AL0009	129.08	37.40	0.00	0.00	19%	17.40	26.90	0.00	37%
D	AL0009	129.09	12.90	0.00	10.50	17%	45.30	0.00	0.00	23%
D	AL0009	129.10	51.90	0.00	0.00	27%	34.80	0.00	0.00	18%
D	AL0009	129.11	39.00	0.00	0.00	20%	0.00	21.80	0.00	22%
D	AL0009	129.12	38.60	0.00	0.00	20%	47.50	5.30	0.00	30%
D	AL0009	129.13	30.10	10.70	0.00	26%	14.80	0.00	0.00	8%
D	AL0009	129.14	25.80	9.40	0.00	23%	35.70	0.00	0.00	18%
D	AL0009	129.15	17.70	9.40	0.00	19%	40.00	0.00	0.00	21%
D	AL0009	129.16	20.40	0.00	0.00	10%	27.80	0.00	0.00	14%
D	AL0009	129.17	8.80	0.00	0.00	5%	7.00	0.00	0.00	4%
D	AL0009	129.18	16.40	0.00	0.00	8%	10.20	0.00	0.00	5%
D	AL0009	129.19	36.20	0.00	0.00	19%	14.10	0.00	0.00	7%
D	AL0009	129.20	52.80	0.00	0.00	27%	29.50	0.00	0.00	15%
D	AL0009	129.21	27.40	8.00	0.00	22%	52.80	0.00	0.00	27%
D	AL0009	129.22	16.20	0.00	0.00	8%	7.00	0.00	0.00	4%
D	AL0009	129.23	6.00	0.00	0.00	3%	14.80	0.00	0.00	8%
D	AL0009	129.24	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
D	AL0009	129.25	5.00	0.00	0.00	3%	0.00	0.00	0.00	0%
D	AL0009	129.26	36.20	0.00	0.00	19%	25.30	0.00	0.00	13%
D	AL0009	129.27	41.50	0.00	0.00	21%	52.80	0.00	0.00	27%
D	AL0009	129.28	19.50	0.00	0.00	10%	5.20	0.00	0.00	3%
D	AL0009	129.29	29.20	10.10	0.00	25%	48.00	0.00	0.00	25%
E	AL0014	81.00	30.00	14.90	0.00	31%	0.00	49.50	0.00	51%
E	AL0014	81.01	3.90	42.10	0.00	45%	0.00	52.80	0.00	54%
E	AL0014	81.02	30.10	17.80	0.00	34%	0.00	52.80	0.00	54%
E	AL0014	81.03	16.50	34.00	0.00	43%	19.80	33.00	0.00	44%
E	AL0014	81.04	34.50	0.00	0.00	18%	12.30	22.60	0.00	29%
E	AL0014	81.05	29.60	13.40	0.00	29%	20.60	32.20	0.00	44%
E	AL0014	81.06	0.00	50.80	0.00	52%	23.40	22.60	0.00	35%
E	AL0014	81.07	17.40	35.34	0.00	45%	0.00	52.80	0.00	54%
E	AL0014	81.08	40.10	12.70	0.00	34%	0.00	52.80	0.00	54%
E	AL0014	81.09	52.80	0.00	0.00	27%	0.00	52.80	0.00	54%
E	AL0014	81.10	52.80	0.00	0.00	27%	13.00	29.60	0.00	37%
E	AL0014	81.11	52.80	0.00	0.00	27%	0.00	52.80	0.00	54%
E	AL0014	81.12	52.80	0.00	0.00	27%	0.00	52.80	0.00	54%
E	AL0014	81.13	11.10	41.70	0.00	48%	0.00	52.80	0.00	54%
E	AL0014	81.14	25.00	24.10	0.00	38%	0.00	52.80	0.00	54%
E	AL0014	81.15	0.00	51.40	0.00	53%	0.00	52.80	0.00	54%
E	AL0014	81.16	15.20	37.60	0.00	46%	0.00	52.80	0.00	54%
E	AL0014	81.17	0.00	52.80	0.00	54%	0.00	52.80	0.00	54%
E	AL0014	81.18	41.60	11.20	0.00	33%	0.00	52.80	0.00	54%
E	AL0014	81.19	6.10	42.70	0.00	47%	0.00	52.80	0.00	54%
E	AL0014	81.20	42.10	10.70	0.00	33%	0.00	52.80	0.00	54%

Site	Route	MP	AW1	AW2	AW3	Agency HPMS	PW1	PW2	PW3	Vendor HPMS
E	AL0014	81.21	51.70	0.00	0.00	27%	0.00	52.80	0.00	54%
E	AL0014	81.22	0.00	44.50	0.00	46%	0.00	52.80	0.00	54%
E	AL0014	81.23	0.00	52.80	0.00	54%	0.00	52.80	0.00	54%
E	AL0014	81.24	2.00	50.80	0.00	53%	0.00	52.80	0.00	54%
E	AL0014	81.25	0.00	52.80	0.00	54%	0.00	52.80	0.00	54%
E	AL0014	81.26	0.00	52.80	0.00	54%	0.00	52.80	0.00	54%
E	AL0014	81.27	0.00	50.00	0.00	51%	0.00	52.80	0.00	54%
E	AL0014	81.28	0.00	52.80	0.00	54%	0.00	52.80	0.00	54%
E	AL0014	81.29	40.50	0.00	0.00	21%	0.00	45.30	0.00	46%
F	AL0022	39.00	10.20	0.00	0.00	5%	4.20	0.00	0.00	2%
F	AL0022	39.01	3.00	1.90	0.00	3%	24.30	0.00	0.00	12%
F	AL0022	39.02	1.00	0.00	0.00	1%	5.00	0.00	0.00	3%
F	AL0022	39.03	4.20	5.10	0.00	7%	5.20	0.00	0.00	3%
F	AL0022	39.04	2.80	0.00	0.00	1%	5.30	0.00	0.00	3%
F	AL0022	39.05	2.90	0.00	0.00	1%	0.00	0.00	0.00	0%
F	AL0022	39.06	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
F	AL0022	39.07	1.00	0.00	0.00	1%	0.00	0.00	0.00	0%
F	AL0022	39.08	9.20	0.00	0.00	5%	12.20	0.00	0.00	6%
F	AL0022	39.09	3.90	0.00	0.00	2%	7.80	0.00	0.00	4%
F	AL0022	39.10	1.00	0.00	0.00	1%	0.00	0.00	0.00	0%
F	AL0022	39.11	0.00	0.00	0.00	0%	16.50	0.00	0.00	8%
F	AL0022	39.12	2.30	0.00	0.00	1%	0.00	0.00	0.00	0%
F	AL0022	39.13	1.00	0.00	0.00	1%	0.00	0.00	0.00	0%
F	AL0022	39.14	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
F	AL0022	39.15	5.10	0.00	0.00	3%	2.60	0.00	0.00	1%
F	AL0022	39.16	2.00	0.00	0.00	1%	12.80	0.00	0.00	7%
F	AL0022	39.17	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
F	AL0022	39.18	11.60	0.00	0.00	6%	20.00	0.00	0.00	10%
F	AL0022	39.19	1.00	0.00	0.00	1%	12.00	0.00	0.00	6%
F	AL0022	39.20	0.00	0.00	0.00	0%	2.10	0.00	0.00	1%
F	AL0022	39.21	11.10	0.00	0.00	6%	14.80	0.00	0.00	8%
F	AL0022	39.22	20.60	0.00	0.00	11%	27.00	0.00	0.00	14%
F	AL0022	39.23	8.00	0.00	0.00	4%	4.00	0.00	0.00	2%
F	AL0022	39.24	15.10	0.00	0.00	8%	40.00	0.00	0.00	21%
F	AL0022	39.25	35.00	0.00	0.00	18%	25.30	26.90	0.00	41%
F	AL0022	39.26	40.00	0.00	0.00	21%	47.00	0.00	0.00	24%
F	AL0022	39.27	34.10	0.00	0.00	17%	40.00	0.00	0.00	21%
F	AL0022	39.28	8.40	0.00	0.00	4%	7.80	0.00	0.00	4%
F	AL0022	39.29	9.80	0.00	0.00	5%	19.00	0.00	0.00	10%
G	AL0041	111.00	5.00	0.00	0.00	3%	0.00	0.00	0.00	0%
G	AL0041	111.01	5.10	0.00	0.00	3%	10.50	0.00	0.00	5%
G	AL0041	111.02	21.50	0.00	0.00	11%	0.00	0.00	0.00	0%
G	AL0041	111.03	25.40	0.00	0.00	13%	0.00	0.00	0.00	0%
G	AL0041	111.04	17.70	0.00	0.00	9%	22.60	0.00	0.00	12%
G	AL0041	111.05	14.00	0.00	0.00	7%	0.00	0.00	0.00	0%
G	AL0041	111.06	23.40	0.00	0.00	12%	24.30	0.00	0.00	12%
G	AL0041	111.07	34.70	0.00	0.00	18%	27.80	0.00	0.00	14%
G	AL0041	111.08	37.60	0.00	0.00	19%	0.00	0.00	0.00	0%
G	AL0041	111.09	40.70	0.00	0.00	21%	17.40	0.00	0.00	9%
G	AL0041	111.10	17.40	0.00	0.00	9%	12.20	0.00	0.00	6%
G	AL0041	111.11	22.70	0.00	0.00	12%	0.00	0.00	0.00	0%

Site	Route	MP	AW1	AW2	AW3	Agency HPMS	PW1	PW2	PW3	Vendor HPMS
G	AL0041	111.12	27.30	0.00	0.00	14%	6.90	0.00	0.00	4%
G	AL0041	111.13	31.00	0.00	0.00	16%	5.20	7.80	0.00	11%
G	AL0041	111.14	8.60	0.00	0.00	4%	6.90	12.20	0.00	16%
G	AL0041	111.15	11.30	0.00	0.00	6%	28.40	0.00	0.00	15%
G	AL0041	111.16	10.10	0.00	0.00	5%	18.70	0.00	0.00	10%
G	AL0041	111.17	8.50	0.00	0.00	4%	39.90	0.00	0.00	20%
G	AL0041	111.18	8.30	0.00	0.00	4%	27.80	0.00	0.00	14%
G	AL0041	111.19	18.60	0.00	0.00	10%	19.10	0.00	0.00	10%
G	AL0041	111.20	15.30	0.00	0.00	8%	2.00	0.00	0.00	1%
G	AL0041	111.21	3.00	0.00	0.00	2%	0.00	0.00	0.00	0%
G	AL0041	111.22	3.70	0.00	0.00	2%	0.00	0.00	0.00	0%
G	AL0041	111.23	4.70	0.00	0.00	2%	0.00	0.00	0.00	0%
G	AL0041	111.24	6.30	0.00	0.00	3%	0.00	0.00	0.00	0%
G	AL0041	111.25	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
G	AL0041	111.26	2.00	0.00	0.00	1%	0.00	0.00	0.00	0%
G	AL0041	111.27	8.10	0.00	0.00	4%	12.70	0.00	0.00	7%
G	AL0041	111.28	35.70	0.00	0.00	18%	37.40	0.00	0.00	19%
G	AL0041	111.29	52.80	0.00	0.00	27%	11.80	41.00	0.00	48%
H	AL0081	7.00	44.50	0.00	0.00	23%	20.00	0.00	0.00	10%
H	AL0081	7.01	23.50	0.00	0.00	12%	26.90	0.00	0.00	14%
H	AL0081	7.02	22.10	21.70	0.00	34%	30.40	0.00	0.00	16%
H	AL0081	7.03	22.60	10.90	0.00	23%	49.50	0.00	0.00	25%
H	AL0081	7.04	8.50	6.20	0.00	11%	7.80	0.00	0.00	4%
H	AL0081	7.05	1.40	0.00	0.00	1%	0.00	0.00	0.00	0%
H	AL0081	7.06	24.00	0.00	0.00	12%	0.00	0.00	0.00	0%
H	AL0081	7.07	32.20	0.00	0.00	17%	26.90	0.00	0.00	14%
H	AL0081	7.08	24.30	13.40	0.00	26%	30.40	0.00	0.00	16%
H	AL0081	7.09	9.80	0.00	0.00	5%	22.70	0.00	0.00	12%
H	AL0081	7.10	7.90	0.00	0.00	4%	2.70	0.00	0.00	1%
H	AL0081	7.11	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
H	AL0081	7.12	3.40	0.00	0.00	2%	0.00	0.00	0.00	0%
H	AL0081	7.13	12.00	0.00	0.00	6%	17.30	0.00	0.00	9%
H	AL0081	7.14	15.10	0.00	0.00	8%	0.00	0.00	0.00	0%
H	AL0081	7.15	25.20	0.00	0.00	13%	13.10	0.00	0.00	7%
H	AL0081	7.16	46.60	0.00	0.00	24%	32.20	0.00	0.00	17%
H	AL0081	7.17	52.80	0.00	0.00	27%	40.00	0.00	0.00	21%
H	AL0081	7.18	37.70	10.70	0.00	30%	39.90	0.00	0.00	20%
H	AL0081	7.19	52.70	0.00	0.00	27%	0.00	0.00	0.00	0%
H	AL0081	7.20	52.80	0.00	0.00	27%	0.00	0.00	0.00	0%
H	AL0081	7.21	35.60	0.00	0.00	18%	0.00	0.00	0.00	0%
H	AL0081	7.22	9.00	0.00	0.00	5%	0.00	0.00	0.00	0%
H	AL0081	7.23	22.50	0.00	0.00	12%	0.00	0.00	0.00	0%
H	AL0081	7.24	5.50	0.00	0.00	3%	0.00	0.00	0.00	0%
H	AL0081	7.25	1.00	0.00	0.00	1%	0.00	0.00	0.00	0%
H	AL0081	7.26	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
H	AL0081	7.27	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
H	AL0081	7.28	1.10	0.00	0.00	1%	0.00	0.00	0.00	0%
H	AL0081	7.29	24.90	0.00	0.00	13%	0.00	0.00	0.00	0%
I	AL0093	7.00	26.80	0.00	0.00	14%	0.00	0.00	0.00	0%
I	AL0093	7.01	48.90	0.00	0.00	25%	12.30	25.20	0.00	32%
I	AL0093	7.02	12.50	0.00	0.00	6%	14.80	0.00	0.00	8%

Site	Route	MP	AW1	AW2	AW3	Agency HPMS	PW1	PW2	PW3	Vendor HPMS
I	AL0093	7.03	30.00	0.00	0.00	15%	30.40	0.00	0.00	16%
I	AL0093	7.04	26.70	0.00	0.00	14%	22.60	0.00	0.00	12%
I	AL0093	7.05	17.20	0.00	0.00	9%	0.00	0.00	0.00	0%
I	AL0093	7.06	43.40	0.00	0.00	22%	27.00	0.00	0.00	14%
I	AL0093	7.07	47.70	0.00	0.00	24%	52.80	0.00	0.00	27%
I	AL0093	7.08	46.50	0.00	0.00	24%	23.20	29.60	0.00	42%
I	AL0093	7.09	42.30	0.00	0.00	22%	26.90	25.30	0.00	40%
I	AL0093	7.10	46.50	0.00	0.00	24%	32.80	20.00	0.00	37%
I	AL0093	7.11	15.30	26.30	0.00	35%	20.60	32.20	0.00	44%
I	AL0093	7.12	24.10	13.90	0.00	27%	27.80	22.70	0.00	38%
I	AL0093	7.13	19.00	35.30	0.00	46%	20.50	32.30	0.00	44%
I	AL0093	7.14	30.80	18.30	0.00	35%	45.20	4.30	0.00	28%
I	AL0093	7.15	8.60	44.20	0.00	50%	0.00	52.80	0.00	54%
I	AL0093	7.16	8.80	44.00	0.00	50%	0.00	52.80	0.00	54%
I	AL0093	7.17	7.80	44.60	0.00	50%	0.00	52.80	0.00	54%
I	AL0093	7.18	15.50	37.30	0.00	46%	0.00	52.80	0.00	54%
I	AL0093	7.19	0.00	52.10	0.00	53%	0.00	52.80	0.00	54%
I	AL0093	7.20	36.20	13.80	0.00	33%	20.00	29.50	0.00	41%
I	AL0093	7.21	0.00	40.90	0.00	42%	14.80	34.80	0.00	43%
I	AL0093	7.22	0.00	15.50	0.00	16%	17.00	0.00	0.00	9%
I	AL0093	7.23	0.00	15.20	0.00	16%	5.00	0.00	0.00	3%
I	AL0093	7.24	0.00	28.30	0.00	29%	15.60	22.60	0.00	31%
I	AL0093	7.25	0.00	0.00	10.90	11%	0.00	52.80	0.00	54%
I	AL0093	7.26	0.00	11.80	28.40	41%	11.90	14.80	0.00	21%
I	AL0093	7.27	0.00	30.00	12.70	44%	0.00	52.80	0.00	54%
I	AL0093	7.28	0.00	24.40	0.00	25%	0.00	52.80	0.00	54%
I	AL0093	7.29	0.00	17.60	0.00	18%	0.00	52.80	0.00	54%
J	AL0183	30.00	43.50	0.00	0.00	22%	44.30	0.00	0.00	23%
J	AL0183	30.01	26.70	0.00	0.00	14%	41.80	0.00	0.00	21%
J	AL0183	30.02	46.70	0.00	0.00	24%	45.30	0.00	0.00	23%
J	AL0183	30.03	44.90	0.00	0.00	23%	52.80	0.00	0.00	27%
J	AL0183	30.04	30.30	0.00	0.00	16%	52.30	0.00	0.00	27%
J	AL0183	30.05	21.30	0.00	0.00	11%	40.00	0.00	0.00	21%
J	AL0183	30.06	4.80	0.00	0.00	2%	0.00	0.00	0.00	0%
J	AL0183	30.07	2.00	0.00	0.00	1%	0.00	0.00	0.00	0%
J	AL0183	30.08	4.70	0.00	0.00	2%	7.80	0.00	0.00	4%
J	AL0183	30.09	7.20	0.00	0.00	4%	27.80	0.00	0.00	14%
J	AL0183	30.10	13.70	0.00	0.00	7%	41.80	0.00	0.00	21%
J	AL0183	30.11	42.00	0.00	0.00	22%	29.60	0.00	0.00	15%
J	AL0183	30.12	11.00	0.00	0.00	6%	7.80	0.00	0.00	4%
J	AL0183	30.13	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
J	AL0183	30.14	5.00	0.00	0.00	3%	0.00	0.00	0.00	0%
J	AL0183	30.15	14.90	0.00	0.00	8%	14.80	0.00	0.00	8%
J	AL0183	30.16	43.90	0.00	0.00	23%	52.80	0.00	0.00	27%
J	AL0183	30.17	19.20	0.00	0.00	10%	7.80	0.00	0.00	4%
J	AL0183	30.18	4.30	0.00	0.00	2%	12.20	0.00	0.00	6%
J	AL0183	30.19	12.50	0.00	0.00	6%	27.00	0.00	0.00	14%
J	AL0183	30.20	14.30	0.00	0.00	7%	42.60	0.00	0.00	22%
J	AL0183	30.21	26.60	0.00	0.00	14%	41.70	0.00	0.00	21%
J	AL0183	30.22	13.90	0.00	0.00	7%	17.40	0.00	0.00	9%
J	AL0183	30.23	20.80	0.00	0.00	11%	52.20	0.00	0.00	27%

Site	Route	MP	AW1	AW2	AW3	Agency HPMS	PW1	PW2	PW3	Vendor HPMS
J	AL0183	30.24	41.10	0.00	0.00	21%	49.60	0.00	0.00	25%
J	AL0183	30.25	22.20	0.00	0.00	11%	12.20	0.00	0.00	6%
J	AL0183	30.26	11.50	0.00	0.00	6%	12.20	0.00	0.00	6%
J	AL0183	30.27	7.10	0.00	0.00	4%	0.00	9.60	0.00	10%
J	AL0183	30.28	2.80	0.00	0.00	1%	3.20	49.60	0.00	53%
J	AL0183	30.29	52.80	0.00	0.00	27%	40.00	0.00	0.00	21%

Table 31. HPMS cracking ratings from 10 XDOT DOT control sites in 2014.

Site	Route	MP	AW1	AW2	AW3	Agency HPMS %	PW1	PW2	PW3	Vendor HPMS %
AA	AL0005	44.00	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
AA	AL0005	44.01	15.00	0.00	0.00	8%	0.00	0.00	0.00	0%
AA	AL0005	44.02	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
AA	AL0005	44.03	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
AA	AL0005	44.04	4.50	0.00	0.00	2%	0.00	0.00	0.00	0%
AA	AL0005	44.05	16.30	0.00	0.00	8%	14.80	0.00	0.00	8%
AA	AL0005	44.06	18.40	0.00	0.00	9%	2.70	0.00	0.00	1%
AA	AL0005	44.07	3.50	0.00	0.00	2%	0.00	0.00	0.00	0%
AA	AL0005	44.08	3.10	0.00	0.00	2%	0.00	0.00	0.00	0%
AA	AL0005	44.09	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
AA	AL0005	44.10	14.70	0.00	0.00	8%	6.90	0.00	0.00	4%
AA	AL0005	44.11	1.00	0.00	0.00	1%	0.00	0.00	0.00	0%
AA	AL0005	44.12	2.00	0.00	0.00	1%	0.00	0.00	0.00	0%
AA	AL0005	44.13	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
AA	AL0005	44.14	3.70	0.00	0.00	2%	0.00	0.00	0.00	0%
AA	AL0005	44.15	1.00	0.00	0.00	1%	0.00	0.00	0.00	0%
AA	AL0005	44.16	3.00	0.00	0.00	2%	0.00	0.00	0.00	0%
AA	AL0005	44.17	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
AA	AL0005	44.18	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
AA	AL0005	44.19	6.20	0.00	0.00	3%	0.00	0.00	0.00	0%
AA	AL0005	44.20	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
AA	AL0005	44.21	2.00	0.00	0.00	1%	0.00	0.00	0.00	0%
AA	AL0005	44.22	3.00	0.00	0.00	2%	0.00	0.00	0.00	0%
AA	AL0005	44.23	4.80	0.00	0.00	2%	0.00	0.00	0.00	0%
AA	AL0005	44.24	3.00	0.00	0.00	2%	4.90	0.00	0.00	3%
AA	AL0005	44.25	7.00	0.00	0.00	4%	0.00	0.00	0.00	0%
AA	AL0005	44.26	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
AA	AL0005	44.27	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
AA	AL0005	44.28	14.40	0.00	0.00	7%	9.90	0.00	0.00	5%
AA	AL0005	44.29	1.00	0.00	0.00	1%	0.00	0.00	0.00	0%
BB	AL0014	70.00	3.90	25.90	0.00	29%	31.60	0.00	0.00	16%
BB	AL0014	70.01	0.00	35.10	0.00	36%	30.10	22.70	0.00	39%
BB	AL0014	70.02	0.00	39.20	0.00	40%	21.80	22.70	0.00	34%
BB	AL0014	70.03	0.00	33.20	0.00	34%	0.00	47.30	0.00	49%
BB	AL0014	70.04	0.00	50.20	0.00	51%	0.00	52.80	0.00	54%
BB	AL0014	70.05	0.00	41.10	0.00	42%	2.00	41.30	0.00	43%
BB	AL0014	70.06	0.00	44.90	0.00	46%	0.00	41.40	9.80	53%
BB	AL0014	70.07	0.00	48.00	0.00	49%	0.00	30.20	22.60	54%
BB	AL0014	70.08	0.00	47.00	0.00	48%	0.00	52.80	0.00	54%

Site	Route	MP	AW1	AW2	AW3	Agency HPMS %	PW1	PW2	PW3	Vendor HPMS %
BB	AL0014	70.09	13.90	17.20	9.90	35%	24.70	11.80	0.00	25%
BB	AL0014	70.10	0.00	33.70	0.00	35%	19.70	27.70	0.00	39%
BB	AL0014	70.11	0.00	19.30	11.40	31%	0.00	16.80	0.00	17%
BB	AL0014	70.12	0.00	33.00	0.00	34%	0.00	18.80	0.00	19%
BB	AL0014	70.13	17.70	20.80	0.00	30%	4.90	44.40	0.00	48%
BB	AL0014	70.14	0.00	9.40	37.40	48%	0.00	52.20	0.00	54%
BB	AL0014	70.15	14.80	31.20	0.00	40%	3.50	49.30	0.00	52%
BB	AL0014	70.16	0.00	40.50	0.00	42%	0.00	38.50	0.00	39%
BB	AL0014	70.17	0.00	35.40	0.00	36%	4.90	39.40	0.00	43%
BB	AL0014	70.18	0.00	25.70	0.00	26%	0.00	34.40	9.90	45%
BB	AL0014	70.19	0.00	35.60	0.00	37%	28.10	6.90	17.80	40%
BB	AL0014	70.20	0.00	48.30	0.00	50%	0.00	52.80	0.00	54%
BB	AL0014	70.21	0.00	50.10	0.00	51%	0.00	52.80	0.00	54%
BB	AL0014	70.22	0.00	49.10	0.00	50%	35.00	17.80	0.00	36%
BB	AL0014	70.23	28.50	0.00	0.00	15%	13.40	39.40	0.00	47%
BB	AL0014	70.24	0.00	39.90	0.00	41%	0.00	52.80	0.00	54%
BB	AL0014	70.25	0.00	37.10	0.00	38%	29.60	14.80	0.00	30%
BB	AL0014	70.26	37.00	0.00	0.00	19%	29.50	6.90	0.00	22%
BB	AL0014	70.27	0.00	28.70	0.00	29%	9.80	39.30	0.00	45%
BB	AL0014	70.28	17.10	0.00	0.00	9%	52.80	0.00	0.00	27%
BB	AL0014	70.29	0.00	33.90	0.00	35%	18.30	34.50	0.00	45%
CC	AL0017	175.00	52.80	0.00	0.00	27%	28.10	24.70	0.00	40%
CC	AL0017	175.01	52.80	0.00	0.00	27%	0.00	27.60	0.00	28%
CC	AL0017	175.02	52.40	0.00	0.00	27%	3.50	49.30	0.00	52%
CC	AL0017	175.03	52.10	0.00	0.00	27%	45.90	6.90	0.00	31%
CC	AL0017	175.04	52.10	0.00	0.00	27%	28.20	24.60	0.00	40%
CC	AL0017	175.05	46.10	0.00	0.00	24%	52.80	0.00	0.00	27%
CC	AL0017	175.06	42.20	0.00	0.00	22%	33.00	19.80	0.00	37%
CC	AL0017	175.07	43.40	0.00	0.00	22%	44.30	0.00	0.00	23%
CC	AL0017	175.08	50.60	0.00	0.00	26%	6.90	29.60	0.00	34%
CC	AL0017	175.09	49.60	0.00	0.00	25%	44.30	0.00	0.00	23%
CC	AL0017	175.10	52.80	0.00	0.00	27%	31.50	19.80	0.00	36%
CC	AL0017	175.11	47.20	0.00	0.00	24%	52.80	0.00	0.00	27%
CC	AL0017	175.12	41.00	0.00	0.00	21%	52.80	0.00	0.00	27%
CC	AL0017	175.13	52.60	0.00	0.00	27%	52.80	0.00	0.00	27%
CC	AL0017	175.14	43.00	0.00	0.00	22%	52.80	0.00	0.00	27%
CC	AL0017	175.15	28.40	0.00	0.00	15%	33.60	0.00	0.00	17%
CC	AL0017	175.16	51.80	0.00	0.00	27%	49.30	0.00	0.00	25%
CC	AL0017	175.17	52.80	0.00	0.00	27%	50.30	0.00	0.00	26%
CC	AL0017	175.18	41.50	0.00	0.00	21%	26.70	0.00	0.00	14%
CC	AL0017	175.19	52.80	0.00	0.00	27%	49.30	0.00	0.00	25%
CC	AL0017	175.20	52.00	0.00	0.00	27%	16.80	0.00	0.00	9%
CC	AL0017	175.21	49.60	0.00	0.00	25%	39.40	0.00	0.00	20%
CC	AL0017	175.22	50.20	0.00	0.00	26%	17.70	0.00	0.00	9%
CC	AL0017	175.23	23.10	0.00	0.00	12%	16.80	0.00	0.00	9%
CC	AL0017	175.24	27.70	0.00	0.00	14%	39.40	0.00	0.00	20%
CC	AL0017	175.25	32.60	0.00	0.00	17%	25.60	0.00	0.00	13%
CC	AL0017	175.26	27.70	0.00	0.00	14%	41.00	11.80	0.00	33%
CC	AL0017	175.27	25.50	0.00	0.00	13%	29.50	19.80	0.00	35%
CC	AL0017	175.28	49.10	0.00	0.00	25%	52.80	0.00	0.00	27%
CC	AL0017	175.29	50.90	0.00	0.00	26%	49.30	0.00	0.00	25%

Site	Route	MP	AW1	AW2	AW3	Agency HPMS %	PW1	PW2	PW3	Vendor HPMS %
DD	AL0022	10.00	26.70	0.00	0.00	14%	0.00	0.00	0.00	0%
DD	AL0022	10.01	17.10	0.00	0.00	9%	0.00	0.00	0.00	0%
DD	AL0022	10.02	1.00	0.00	0.00	1%	0.00	0.00	0.00	0%
DD	AL0022	10.03	9.60	0.00	0.00	5%	16.80	0.00	0.00	9%
DD	AL0022	10.04	2.00	0.00	0.00	1%	2.60	0.00	0.00	1%
DD	AL0022	10.05	1.00	1.00	0.00	2%	0.00	0.00	0.00	0%
DD	AL0022	10.06	9.40	1.00	0.00	6%	0.00	0.00	0.00	0%
DD	AL0022	10.07	0.00	1.00	0.00	1%	0.00	0.00	0.00	0%
DD	AL0022	10.08	9.90	0.00	0.00	5%	0.00	0.00	0.00	0%
DD	AL0022	10.09	29.50	0.00	0.00	15%	32.50	0.00	0.00	17%
DD	AL0022	10.10	39.10	0.00	0.00	20%	52.80	0.00	0.00	27%
DD	AL0022	10.11	8.60	1.00	0.00	5%	17.80	0.00	0.00	9%
DD	AL0022	10.12	9.80	0.00	0.00	5%	17.70	0.00	0.00	9%
DD	AL0022	10.13	2.90	1.00	0.00	3%	0.00	0.00	0.00	0%
DD	AL0022	10.14	40.20	0.00	0.00	21%	34.50	0.00	0.00	18%
DD	AL0022	10.15	32.60	0.00	0.00	17%	52.80	0.00	0.00	27%
DD	AL0022	10.16	22.30	0.00	0.00	11%	19.70	0.00	0.00	10%
DD	AL0022	10.17	5.30	0.00	0.00	3%	0.00	0.00	0.00	0%
DD	AL0022	10.18	17.40	0.00	0.00	9%	0.00	0.00	0.00	0%
DD	AL0022	10.19	0.00	1.00	0.00	1%	0.00	0.00	0.00	0%
DD	AL0022	10.20	4.80	0.00	0.00	2%	0.00	0.00	0.00	0%
DD	AL0022	10.21	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
DD	AL0022	10.22	1.00	0.00	0.00	1%	0.00	0.00	0.00	0%
DD	AL0022	10.23	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
DD	AL0022	10.24	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
DD	AL0022	10.25	2.00	0.00	0.00	1%	0.00	0.00	0.00	0%
DD	AL0022	10.26	1.00	0.00	0.00	1%	0.00	0.00	0.00	0%
DD	AL0022	10.27	1.00	0.00	0.00	1%	14.80	0.00	0.00	8%
DD	AL0022	10.28	18.30	2.00	0.00	11%	52.80	0.00	0.00	27%
DD	AL0022	10.29	38.40	0.00	0.00	20%	52.80	0.00	0.00	27%
EE	AL0025	7.00	7.80	0.00	0.00	4%	0.00	0.00	0.00	0%
EE	AL0025	7.01	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
EE	AL0025	7.02	9.40	0.00	0.00	5%	12.80	0.00	0.00	7%
EE	AL0025	7.03	7.90	0.00	0.00	4%	0.00	0.00	0.00	0%
EE	AL0025	7.04	1.00	0.00	0.00	1%	0.00	0.00	0.00	0%
EE	AL0025	7.05	26.80	0.00	0.00	14%	0.00	0.00	0.00	0%
EE	AL0025	7.06	22.10	0.00	0.00	11%	49.30	0.00	0.00	25%
EE	AL0025	7.07	28.90	3.50	0.00	18%	34.50	9.80	0.00	28%
EE	AL0025	7.08	20.00	32.30	0.00	43%	0.00	52.80	0.00	54%
EE	AL0025	7.09	14.10	27.70	0.00	36%	5.50	47.30	0.00	51%
EE	AL0025	7.10	13.80	0.00	0.00	7%	41.40	0.00	0.00	21%
EE	AL0025	7.11	3.20	0.00	0.00	2%	0.00	0.00	0.00	0%
EE	AL0025	7.12	6.20	0.00	0.00	3%	0.00	0.00	0.00	0%
EE	AL0025	7.13	25.80	0.00	0.00	13%	24.70	0.00	0.00	13%
EE	AL0025	7.14	41.90	0.00	0.00	21%	9.80	42.30	0.00	48%
EE	AL0025	7.15	7.60	0.00	0.00	4%	0.00	14.80	0.00	15%
EE	AL0025	7.16	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
EE	AL0025	7.17	10.50	0.00	0.00	5%	7.80	0.00	0.00	4%
EE	AL0025	7.18	16.00	0.00	0.00	8%	37.40	0.00	0.00	19%
EE	AL0025	7.19	32.40	0.00	0.00	17%	37.50	0.00	0.00	19%
EE	AL0025	7.20	30.50	0.00	0.00	16%	46.30	0.00	0.00	24%

Site	Route	MP	AW1	AW2	AW3	Agency HPMS %	PW1	PW2	PW3	Vendor HPMS %
EE	AL0025	7.21	39.90	0.00	0.00	20%	52.80	0.00	0.00	27%
EE	AL0025	7.22	26.30	0.00	0.00	13%	31.60	0.00	0.00	16%
EE	AL0025	7.23	10.70	0.00	0.00	5%	4.00	0.00	0.00	2%
EE	AL0025	7.24	47.80	0.00	0.00	25%	24.70	26.60	0.00	40%
EE	AL0025	7.25	52.80	0.00	0.00	27%	0.00	52.80	0.00	54%
EE	AL0025	7.26	52.10	0.00	0.00	27%	0.00	52.80	0.00	54%
EE	AL0025	7.27	43.80	0.00	0.00	22%	0.00	47.30	0.00	49%
EE	AL0025	7.28	52.80	0.00	0.00	27%	0.00	52.80	0.00	54%
EE	AL0025	7.29	49.50	0.00	0.00	25%	29.60	22.70	0.00	38%
FF	AL0007	201.00	0.00	52.80	0.00	54%	0.00	52.80	0.00	54%
FF	AL0007	201.01	14.20	38.60	0.00	47%	0.00	52.30	0.00	54%
FF	AL0007	201.02	0.00	37.70	15.10	54%	0.00	52.80	0.00	54%
FF	AL0007	201.03	0.00	52.80	0.00	54%	0.00	52.80	0.00	54%
FF	AL0007	201.04	0.00	52.80	0.00	54%	0.00	52.80	0.00	54%
FF	AL0007	201.05	0.00	45.60	0.00	47%	27.60	21.70	0.00	36%
FF	AL0007	201.06	0.00	44.50	0.00	46%	19.70	16.80	0.00	27%
FF	AL0007	201.07	0.00	34.50	0.00	35%	20.30	32.50	0.00	44%
FF	AL0007	201.08	0.00	50.50	0.00	52%	0.00	52.80	0.00	54%
FF	AL0007	201.09	0.00	32.00	20.80	54%	0.00	52.80	0.00	54%
FF	AL0007	201.10	0.00	51.80	0.00	53%	0.00	51.20	0.00	53%
FF	AL0007	201.11	11.10	25.20	8.00	40%	0.00	52.80	0.00	54%
FF	AL0007	201.12	0.00	52.80	0.00	54%	0.00	52.80	0.00	54%
FF	AL0007	201.13	0.00	52.80	0.00	54%	0.00	52.80	0.00	54%
FF	AL0007	201.14	0.00	52.80	0.00	54%	0.00	52.80	0.00	54%
FF	AL0007	201.15	0.00	52.80	0.00	54%	0.00	52.80	0.00	54%
FF	AL0007	201.16	0.00	48.90	0.00	50%	0.00	52.80	0.00	54%
FF	AL0007	201.17	0.00	52.80	0.00	54%	0.00	52.80	0.00	54%
FF	AL0007	201.18	0.00	52.80	0.00	54%	0.00	52.80	0.00	54%
FF	AL0007	201.19	9.70	43.10	0.00	49%	0.00	52.80	0.00	54%
FF	AL0007	201.20	0.00	52.80	0.00	54%	0.00	52.80	0.00	54%
FF	AL0007	201.21	2.50	44.10	4.40	51%	0.00	52.80	0.00	54%
FF	AL0007	201.22	0.00	52.80	0.00	54%	0.00	52.80	0.00	54%
FF	AL0007	201.23	0.00	52.80	0.00	54%	0.00	52.80	0.00	54%
FF	AL0007	201.24	0.00	52.80	0.00	54%	0.00	52.80	0.00	54%
FF	AL0007	201.25	0.00	52.80	0.00	54%	1.50	51.30	0.00	53%
FF	AL0007	201.26	44.00	0.00	0.00	23%	37.40	9.80	0.00	29%
FF	AL0007	201.27	12.30	40.50	0.00	48%	0.00	19.70	0.00	20%
FF	AL0007	201.28	44.10	0.00	0.00	23%	0.00	49.30	0.00	51%
FF	AL0007	201.29	20.80	3.20	0.00	14%	0.00	52.80	0.00	54%
GG	AL0021	273.00	44.80	0.00	0.00	23%	52.80	0.00	0.00	27%
GG	AL0021	273.01	47.20	0.00	0.00	24%	39.00	0.00	0.00	20%
GG	AL0021	273.02	52.80	0.00	0.00	27%	43.60	0.00	0.00	22%
GG	AL0021	273.03	52.80	0.00	0.00	27%	52.80	0.00	0.00	27%
GG	AL0021	273.04	28.20	0.00	0.00	14%	49.30	0.00	0.00	25%
GG	AL0021	273.05	31.90	0.00	0.00	16%	24.30	19.70	0.00	33%
GG	AL0021	273.06	51.10	0.00	0.00	26%	28.00	20.70	0.00	36%
GG	AL0021	273.07	41.20	0.00	0.00	21%	36.00	0.00	0.00	18%
GG	AL0021	273.08	45.00	0.00	0.00	23%	52.70	0.00	0.00	27%
GG	AL0021	273.09	36.40	0.00	0.00	19%	52.80	0.00	0.00	27%
GG	AL0021	273.10	36.70	0.00	0.00	19%	52.80	0.00	0.00	27%
GG	AL0021	273.11	50.90	0.00	0.00	26%	26.10	26.70	0.00	41%

Site	Route	MP	AW1	AW2	AW3	Agency HPMS %	PW1	PW2	PW3	Vendor HPMS %
GG	AL0021	273.12	50.70	0.00	0.00	26%	0.00	52.30	0.00	54%
GG	AL0021	273.13	52.80	0.00	0.00	27%	0.50	52.30	0.00	54%
GG	AL0021	273.14	47.70	0.00	0.00	24%	52.80	0.00	0.00	27%
GG	AL0021	273.15	48.30	0.00	0.00	25%	52.80	0.00	0.00	27%
GG	AL0021	273.16	31.50	0.00	0.00	16%	52.80	0.00	0.00	27%
GG	AL0021	273.17	31.40	0.00	0.00	16%	27.90	0.00	0.00	14%
GG	AL0021	273.18	39.60	0.00	0.00	20%	52.80	0.00	0.00	27%
GG	AL0021	273.19	32.30	0.00	0.00	17%	52.80	0.00	0.00	27%
GG	AL0021	273.20	30.70	0.00	0.00	16%	52.80	0.00	0.00	27%
GG	AL0021	273.21	31.70	0.00	0.00	16%	34.40	0.00	0.00	18%
GG	AL0021	273.22	33.60	10.30	0.00	28%	40.00	12.80	0.00	34%
GG	AL0021	273.23	43.70	0.00	0.00	22%	30.10	22.70	0.00	39%
GG	AL0021	273.24	28.60	0.00	0.00	15%	52.80	0.00	0.00	27%
GG	AL0021	273.25	45.20	0.00	0.00	23%	52.80	0.00	0.00	27%
GG	AL0021	273.26	44.20	0.00	0.00	23%	52.80	0.00	0.00	27%
GG	AL0021	273.27	39.50	0.00	0.00	20%	13.40	39.40	0.00	47%
GG	AL0021	273.28	44.30	0.00	0.00	23%	11.40	41.40	0.00	48%
GG	AL0021	273.29	33.70	0.00	0.00	17%	2.40	50.40	0.00	53%
HH	AL0023	8.00	0.00	45.30	0.00	46%	24.70	21.70	0.00	35%
HH	AL0023	8.01	0.00	49.00	0.00	50%	0.00	52.80	0.00	54%
HH	AL0023	8.02	0.00	39.00	0.00	40%	0.00	52.80	0.00	54%
HH	AL0023	8.03	0.00	37.00	0.00	38%	20.80	29.60	0.00	41%
HH	AL0023	8.04	0.00	52.30	0.00	54%	0.00	16.80	29.60	48%
HH	AL0023	8.05	0.00	30.80	13.60	46%	0.00	52.80	0.00	54%
HH	AL0023	8.06	0.00	43.00	0.00	44%	0.00	52.80	0.00	54%
HH	AL0023	8.07	0.00	52.30	0.00	54%	0.00	52.80	0.00	54%
HH	AL0023	8.08	29.50	11.70	0.00	27%	0.00	52.80	0.00	54%
HH	AL0023	8.09	16.70	9.40	0.00	18%	28.10	24.70	0.00	40%
HH	AL0023	8.10	28.20	2.30	0.00	17%	4.90	22.70	0.00	26%
HH	AL0023	8.11	0.00	52.30	0.00	54%	0.00	52.80	0.00	54%
HH	AL0023	8.12	0.00	52.30	0.00	54%	0.00	50.80	2.00	54%
HH	AL0023	8.13	49.60	0.00	0.00	25%	1.50	0.00	51.30	53%
HH	AL0023	8.14	50.10	0.00	0.00	26%	40.40	4.90	0.00	26%
HH	AL0023	8.15	52.80	0.00	0.00	27%	0.00	52.80	0.00	54%
HH	AL0023	8.16	41.10	0.00	0.00	21%	24.60	26.70	0.00	40%
HH	AL0023	8.17	52.80	0.00	0.00	27%	3.00	0.00	0.00	2%
HH	AL0023	8.18	52.80	0.00	0.00	27%	52.80	0.00	0.00	27%
HH	AL0023	8.19	0.00	51.40	0.00	53%	23.20	29.60	0.00	42%
HH	AL0023	8.20	37.40	0.00	0.00	19%	0.00	52.80	0.00	54%
HH	AL0023	8.21	49.70	0.00	0.00	25%	3.50	49.30	0.00	52%
HH	AL0023	8.22	46.40	0.00	0.00	24%	15.30	37.50	0.00	46%
HH	AL0023	8.23	52.80	0.00	0.00	27%	0.00	52.80	0.00	54%
HH	AL0023	8.24	43.20	9.60	0.00	32%	0.00	52.80	0.00	54%
HH	AL0023	8.25	45.80	0.00	0.00	23%	0.00	52.80	0.00	54%
HH	AL0023	8.26	0.00	44.70	0.00	46%	0.00	52.80	0.00	54%
HH	AL0023	8.27	52.60	0.00	0.00	27%	0.00	52.80	0.00	54%
HH	AL0023	8.28	48.00	0.00	0.00	25%	0.00	52.80	0.00	54%
HH	AL0023	8.29	45.20	0.00	0.00	23%	0.00	52.80	0.00	54%
II	AL0035	15.00	0.00	30.70	22.10	54%	0.00	0.00	52.80	54%
II	AL0035	15.01	6.00	4.70	42.10	51%	0.00	0.00	52.80	54%
II	AL0035	15.02	0.00	0.00	52.80	54%	0.00	0.00	52.80	54%

Site	Route	MP	AW1	AW2	AW3	Agency HPMS %	PW1	PW2	PW3	Vendor HPMS %
II	AL0035	15.03	0.00	0.00	52.80	54%	0.00	0.00	52.80	54%
II	AL0035	15.04	0.00	2.10	50.70	54%	0.00	0.00	52.80	54%
II	AL0035	15.05	0.00	0.00	52.80	54%	0.00	0.00	52.80	54%
II	AL0035	15.06	0.00	0.00	52.80	54%	0.00	0.00	52.80	54%
II	AL0035	15.07	0.00	5.80	47.00	54%	0.00	0.00	52.80	54%
II	AL0035	15.08	0.00	5.10	47.70	54%	0.00	11.50	41.30	54%
II	AL0035	15.09	0.00	0.00	52.80	54%	0.00	52.80	0.00	54%
II	AL0035	15.10	0.80	0.00	52.00	54%	0.00	52.80	0.00	54%
II	AL0035	15.11	1.50	0.00	51.30	53%	0.00	52.80	0.00	54%
II	AL0035	15.12	10.20	0.00	30.00	36%	0.00	52.80	0.00	54%
II	AL0035	15.13	2.50	0.00	40.20	43%	0.00	52.80	0.00	54%
II	AL0035	15.14	0.00	0.00	52.80	54%	0.00	52.80	0.00	54%
II	AL0035	15.15	0.00	3.00	26.70	30%	0.00	52.80	0.00	54%
II	AL0035	15.16	5.00	5.00	21.90	30%	0.00	52.80	0.00	54%
II	AL0035	15.17	21.50	10.70	8.90	31%	0.00	52.80	0.00	54%
II	AL0035	15.18	7.00	9.80	17.80	32%	0.00	52.80	0.00	54%
II	AL0035	15.19	0.00	0.00	49.10	50%	0.00	52.80	0.00	54%
II	AL0035	15.20	4.50	3.70	39.80	47%	0.00	52.80	0.00	54%
II	AL0035	15.21	0.00	5.70	47.10	54%	0.00	52.80	0.00	54%
II	AL0035	15.22	0.00	0.00	52.80	54%	0.00	52.80	0.00	54%
II	AL0035	15.23	0.00	0.00	52.80	54%	0.00	52.80	0.00	54%
II	AL0035	15.24	0.00	5.10	47.70	54%	0.00	52.80	0.00	54%
II	AL0035	15.25	0.00	12.60	27.40	41%	0.00	52.80	0.00	54%
II	AL0035	15.26	7.10	0.00	42.10	47%	0.00	52.80	0.00	54%
II	AL0035	15.27	0.00	0.00	52.80	54%	0.00	52.80	0.00	54%
II	AL0035	15.28	0.00	8.70	44.10	54%	0.00	52.80	0.00	54%
II	AL0035	15.29	2.10	0.00	48.50	51%	0.00	52.80	0.00	54%
JJ	IN0759	2.00	52.80	0.00	0.00	27%	0.00	0.00	0.00	0%
JJ	IN0759	2.01	52.80	0.00	0.00	27%	24.60	0.00	0.00	13%
JJ	IN0759	2.02	52.80	0.00	0.00	27%	26.70	0.00	0.00	14%
JJ	IN0759	2.03	52.80	0.00	0.00	27%	36.50	0.00	0.00	19%
JJ	IN0759	2.04	52.80	0.00	0.00	27%	52.80	0.00	0.00	27%
JJ	IN0759	2.05	52.80	0.00	0.00	27%	52.80	0.00	0.00	27%
JJ	IN0759	2.06	49.60	0.00	0.00	25%	52.80	0.00	0.00	27%
JJ	IN0759	2.07	52.80	0.00	0.00	27%	52.80	0.00	0.00	27%
JJ	IN0759	2.08	52.80	0.00	0.00	27%	24.60	0.00	0.00	13%
JJ	IN0759	2.09	36.30	0.00	0.00	19%	0.00	0.00	0.00	0%
JJ	IN0759	2.10	31.70	0.00	0.00	16%	0.00	0.00	0.00	0%
JJ	IN0759	2.11	38.50	0.00	0.00	20%	0.00	0.00	0.00	0%
JJ	IN0759	2.12	39.50	0.00	0.00	20%	0.00	0.00	0.00	0%
JJ	IN0759	2.13	49.70	0.00	0.00	25%	29.60	0.00	0.00	15%
JJ	IN0759	2.14	52.80	0.00	0.00	27%	35.50	0.00	0.00	18%
JJ	IN0759	2.15	52.80	0.00	0.00	27%	46.40	0.00	0.00	24%
JJ	IN0759	2.16	52.80	0.00	0.00	27%	43.30	0.00	0.00	22%
JJ	IN0759	2.17	52.80	0.00	0.00	27%	45.30	0.00	0.00	23%
JJ	IN0759	2.18	52.80	0.00	0.00	27%	52.80	0.00	0.00	27%
JJ	IN0759	2.19	52.80	0.00	0.00	27%	52.80	0.00	0.00	27%
JJ	IN0759	2.20	52.80	0.00	0.00	27%	52.80	0.00	0.00	27%
JJ	IN0759	2.21	52.80	0.00	0.00	27%	9.80	0.00	0.00	5%
JJ	IN0759	2.22	52.80	0.00	0.00	27%	0.00	0.00	0.00	0%
JJ	IN0759	2.23	52.80	0.00	0.00	27%	0.00	0.00	0.00	0%

Site	Route	MP	AW1	AW2	AW3	Agency HPMS %	PW1	PW2	PW3	Vendor HPMS %
JJ	IN0759	2.24	52.80	0.00	0.00	27%	0.00	0.00	0.00	0%
JJ	IN0759	2.25	47.00	0.00	0.00	24%	0.00	0.00	0.00	0%
JJ	IN0759	2.26	48.60	0.00	0.00	25%	1.70	0.00	0.00	1%
JJ	IN0759	2.27	52.80	0.00	0.00	27%	14.80	0.00	0.00	8%
JJ	IN0759	2.28	38.70	0.00	0.00	20%	0.00	0.00	0.00	0%
JJ	IN0759	2.29	46.00	0.00	0.00	24%	9.80	0.00	0.00	5%

Table 32. HPMS cracking ratings from 10 XDOT DOT control sites in 2015 (vendor 1 and agency).

Site	Route	MP	AW1	AW2	AW3	Agency HPMS	VW1	VW2	VW3	Vendor 1HPMS
AAA	AL0013	67.00	0.00	0.00	9.90	10%	9.80	0.00	0.00	5%
AAA	AL0013	67.01	0.00	0.00	10.10	10%	0.00	9.90	0.00	10%
AAA	AL0013	67.02	0.00	0.00	4.30	4%	4.90	4.90	0.00	8%
AAA	AL0013	67.03	0.00	0.00	16.50	17%	11.90	9.80	0.00	16%
AAA	AL0013	67.04	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
AAA	AL0013	67.05	0.00	0.00	2.00	2%	9.80	0.00	0.00	5%
AAA	AL0013	67.06	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
AAA	AL0013	67.07	0.00	0.00	1.00	1%	0.00	4.90	0.00	5%
AAA	AL0013	67.08	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
AAA	AL0013	67.09	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
AAA	AL0013	67.10	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
AAA	AL0013	67.11	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
AAA	AL0013	67.12	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
AAA	AL0013	67.13	0.00	0.00	3.40	3%	5.00	0.00	0.00	3%
AAA	AL0013	67.14	0.00	0.00	2.00	2%	0.00	4.90	0.00	5%
AAA	AL0013	67.15	0.00	0.00	39.70	41%	1.90	26.70	14.80	44%
AAA	AL0013	67.16	0.00	0.00	41.70	43%	0.00	25.10	27.70	54%
AAA	AL0013	67.17	0.00	0.00	40.60	42%	0.00	0.00	52.80	54%
AAA	AL0013	67.18	0.00	28.70	2.00	31%	27.60	11.90	7.80	34%
AAA	AL0013	67.19	0.00	0.00	4.70	5%	4.90	7.00	0.00	10%
AAA	AL0013	67.20	0.00	0.00	1.00	1%	4.90	0.00	0.00	3%
AAA	AL0013	67.21	0.00	0.00	15.60	16%	0.00	29.70	0.00	30%
AAA	AL0013	67.22	0.00	0.00	21.20	22%	5.00	40.50	0.00	44%
AAA	AL0013	67.23	0.00	0.00	14.90	15%	0.00	52.80	0.00	54%
AAA	AL0013	67.24	0.00	0.00	34.90	36%	0.40	52.40	0.00	54%
AAA	AL0013	67.25	0.00	14.50	32.50	48%	25.10	27.70	0.00	41%
AAA	AL0013	67.26	0.00	1.90	1.00	3%	9.80	0.00	0.00	5%
AAA	AL0013	67.27	0.00	0.00	25.40	26%	5.00	27.70	0.00	31%
AAA	AL0013	67.28	0.00	0.00	51.40	53%	0.00	17.80	29.60	49%
AAA	AL0013	67.29	0.00	0.00	29.60	30%	5.00	0.00	0.00	3%
BBB	AL0012	56.00	2.00	0.00	0.00	1%	0.00	0.00	0.00	0%
BBB	AL0012	56.01	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
BBB	AL0012	56.02	2.70	0.00	0.00	1%	0.00	0.00	0.00	0%
BBB	AL0012	56.03	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
BBB	AL0012	56.04	2.00	0.00	0.00	1%	0.00	0.00	0.00	0%
BBB	AL0012	56.05	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
BBB	AL0012	56.06	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
BBB	AL0012	56.07	14.40	0.00	0.00	7%	0.00	0.00	0.00	0%
BBB	AL0012	56.08	3.00	0.00	0.00	2%	0.00	0.00	0.00	0%
BBB	AL0012	56.09	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
BBB	AL0012	56.10	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
BBB	AL0012	56.11	2.00	0.00	0.00	1%	4.90	0.00	0.00	3%
BBB	AL0012	56.12	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
BBB	AL0012	56.13	2.00	0.00	0.00	1%	0.00	0.00	0.00	0%
BBB	AL0012	56.14	2.00	0.00	0.00	1%	0.00	0.00	0.00	0%
BBB	AL0012	56.15	1.00	0.00	0.00	1%	0.00	0.00	0.00	0%
BBB	AL0012	56.16	1.00	0.00	0.00	1%	0.00	0.00	0.00	0%
BBB	AL0012	56.17	1.00	0.00	0.00	1%	0.00	0.00	0.00	0%
BBB	AL0012	56.18	1.50	0.00	0.00	1%	0.00	0.00	0.00	0%
BBB	AL0012	56.19	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%

Site	Route	MP	AW1	AW2	AW3	Agency HPMS	VW1	VW2	VW3	Vendor 1HPMS
BBB	AL0012	56.20	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
BBB	AL0012	56.21	3.00	0.00	0.00	2%	0.00	0.00	0.00	0%
BBB	AL0012	56.22	3.00	0.00	0.00	2%	0.00	0.00	0.00	0%
BBB	AL0012	56.23	2.00	0.00	0.00	1%	0.00	0.00	0.00	0%
BBB	AL0012	56.24	2.00	0.00	0.00	1%	0.00	0.00	0.00	0%
BBB	AL0012	56.25	2.00	0.00	0.00	1%	0.00	0.00	0.00	0%
BBB	AL0012	56.26	33.30	0.00	0.00	17%	0.00	0.00	0.00	0%
BBB	AL0012	56.27	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
BBB	AL0012	56.28	16.80	0.00	0.00	9%	0.00	0.00	0.00	0%
BBB	AL0012	56.29	9.30	0.00	0.00	5%	0.00	0.00	0.00	0%
CCC	AL0012	79.00	6.00	0.00	0.00	3%	12.00	0.00	0.00	6%
CCC	AL0012	79.01	11.60	0.00	0.00	6%	9.80	0.00	0.00	5%
CCC	AL0012	79.02	9.40	0.00	0.00	5%	21.80	0.00	0.00	11%
CCC	AL0012	79.03	5.50	0.00	0.00	3%	0.00	0.00	0.00	0%
CCC	AL0012	79.04	4.10	0.00	0.00	2%	0.00	0.00	0.00	0%
CCC	AL0012	79.05	2.00	0.00	0.00	1%	0.00	0.00	0.00	0%
CCC	AL0012	79.06	21.80	0.00	0.00	11%	1.00	0.00	0.00	1%
CCC	AL0012	79.07	21.90	0.00	0.00	11%	0.00	0.00	0.00	0%
CCC	AL0012	79.08	27.90	0.00	0.00	14%	0.00	0.00	0.00	0%
CCC	AL0012	79.09	14.40	0.00	0.00	7%	0.00	0.00	0.00	0%
CCC	AL0012	79.10	30.70	0.00	0.00	16%	2.90	0.00	0.00	1%
CCC	AL0012	79.11	47.20	0.00	0.00	24%	29.70	0.00	0.00	15%
CCC	AL0012	79.12	27.90	0.00	0.00	14%	0.00	0.00	0.00	0%
CCC	AL0012	79.13	37.50	0.00	0.00	19%	27.70	0.00	0.00	14%
CCC	AL0012	79.14	37.40	0.00	0.00	19%	50.40	0.00	0.00	26%
CCC	AL0012	79.15	52.20	0.00	0.00	27%	52.80	0.00	0.00	27%
CCC	AL0012	79.16	51.80	0.00	0.00	27%	52.80	0.00	0.00	27%
CCC	AL0012	79.17	50.10	0.00	0.00	26%	49.40	0.00	0.00	25%
CCC	AL0012	79.18	51.90	0.00	0.00	27%	36.60	0.00	0.00	19%
CCC	AL0012	79.19	52.80	0.00	0.00	27%	21.70	0.00	0.00	11%
CCC	AL0012	79.20	40.60	0.00	0.00	21%	14.80	0.00	0.00	8%
CCC	AL0012	79.21	29.60	0.00	0.00	15%	7.90	0.00	0.00	4%
CCC	AL0012	79.22	26.40	0.00	0.00	14%	4.90	0.00	0.00	3%
CCC	AL0012	79.23	29.40	0.00	0.00	15%	22.70	0.00	0.00	12%
CCC	AL0012	79.24	43.80	0.00	0.00	22%	39.60	0.00	0.00	20%
CCC	AL0012	79.25	38.90	0.00	0.00	20%	21.80	0.00	0.00	11%
CCC	AL0012	79.26	24.50	0.00	0.00	13%	32.70	0.00	0.00	17%
CCC	AL0012	79.27	46.80	0.00	0.00	24%	42.50	0.00	0.00	22%
CCC	AL0012	79.28	23.90	0.00	0.00	12%	19.80	0.00	0.00	10%
CCC	AL0012	79.29	15.30	0.00	0.00	8%	0.00	0.00	0.00	0%
DDD	AL0012	119.00	46.00	0.00	0.00	24%	19.80	0.00	0.00	10%
DDD	AL0012	119.01	35.70	0.00	0.00	18%	17.80	0.00	0.00	9%
DDD	AL0012	119.02	36.20	0.00	0.00	19%	7.90	0.00	0.00	4%
DDD	AL0012	119.03	40.70	0.00	0.00	21%	9.80	0.00	0.00	5%
DDD	AL0012	119.04	18.30	0.00	0.00	9%	4.90	0.00	0.00	3%
DDD	AL0012	119.05	51.30	0.00	0.00	26%	5.00	0.00	0.00	3%
DDD	AL0012	119.06	51.90	0.00	0.00	27%	19.70	0.00	0.00	10%
DDD	AL0012	119.07	47.60	0.00	0.00	24%	23.80	0.00	0.00	12%
DDD	AL0012	119.08	44.70	0.00	0.00	23%	11.80	0.00	0.00	6%
DDD	AL0012	119.09	45.40	0.00	0.00	23%	0.00	0.00	0.00	0%
DDD	AL0012	119.10	35.30	0.00	0.00	18%	0.00	0.00	0.00	0%

Site	Route	MP	AW1	AW2	AW3	Agency HPMS	VW1	VW2	VW3	Vendor 1HPMS
DDD	AL0012	119.11	29.50	0.00	0.00	15%	5.00	0.00	0.00	3%
DDD	AL0012	119.12	19.50	0.00	0.00	10%	9.80	0.00	0.00	5%
DDD	AL0012	119.13	45.40	0.00	0.00	23%	0.00	0.00	0.00	0%
DDD	AL0012	119.14	17.60	0.00	0.00	9%	6.90	0.00	0.00	4%
DDD	AL0012	119.15	36.10	0.00	0.00	19%	29.80	0.00	0.00	15%
DDD	AL0012	119.16	17.10	0.00	0.00	9%	0.00	0.00	0.00	0%
DDD	AL0012	119.17	36.70	0.00	0.00	19%	0.00	0.00	0.00	0%
DDD	AL0012	119.18	38.90	0.00	0.00	20%	0.00	0.00	0.00	0%
DDD	AL0012	119.19	16.50	0.00	0.00	8%	0.00	0.00	0.00	0%
DDD	AL0012	119.20	18.20	0.00	0.00	9%	0.00	0.00	0.00	0%
DDD	AL0012	119.21	9.90	0.00	0.00	5%	0.00	0.00	0.00	0%
DDD	AL0012	119.22	9.10	0.00	0.00	5%	0.00	0.00	0.00	0%
DDD	AL0012	119.23	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
DDD	AL0012	119.24	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
DDD	AL0012	119.25	9.60	0.00	0.00	5%	0.00	0.00	0.00	0%
DDD	AL0012	119.26	12.20	0.00	0.00	6%	0.00	0.00	0.00	0%
DDD	AL0012	119.27	33.30	0.00	0.00	17%	0.00	0.00	0.00	0%
DDD	AL0012	119.28	23.00	0.00	0.00	12%	0.00	0.00	0.00	0%
DDD	AL0012	119.29	30.30	0.00	0.00	16%	0.00	0.00	0.00	0%
EEE	AL0012	130.00	9.50	41.30	0.00	47%	0.00	52.80	0.00	54%
EEE	AL0012	130.01	30.60	22.20	0.00	38%	33.50	6.00	0.00	23%
EEE	AL0012	130.02	0.00	46.70	6.10	54%	0.00	52.40	0.00	54%
EEE	AL0012	130.03	32.30	20.50	0.00	38%	21.70	29.70	0.00	42%
EEE	AL0012	130.04	8.30	44.50	0.00	50%	11.80	0.00	0.00	6%
EEE	AL0012	130.05	3.10	49.70	0.00	53%	47.40	0.00	0.00	24%
EEE	AL0012	130.06	14.50	38.30	0.00	47%	16.80	0.00	0.00	9%
EEE	AL0012	130.07	21.30	31.50	0.00	43%	50.50	0.00	0.00	26%
EEE	AL0012	130.08	11.80	7.60	0.00	14%	17.70	0.00	0.00	9%
EEE	AL0012	130.09	11.50	26.30	2.60	36%	11.90	0.00	0.00	6%
EEE	AL0012	130.10	0.00	36.20	13.50	51%	36.60	0.00	0.00	19%
EEE	AL0012	130.11	0.00	41.80	11.00	54%	52.80	0.00	0.00	27%
EEE	AL0012	130.12	0.00	47.60	5.20	54%	19.80	11.80	0.00	22%
EEE	AL0012	130.13	6.30	46.50	0.00	51%	7.90	41.50	0.00	47%
EEE	AL0012	130.14	0.00	52.80	0.00	54%	26.70	0.00	0.00	14%
EEE	AL0012	130.15	0.00	49.10	0.00	50%	17.80	0.00	0.00	9%
EEE	AL0012	130.16	49.70	0.00	0.00	25%	27.70	0.00	0.00	14%
EEE	AL0012	130.17	0.00	43.60	9.20	54%	18.20	34.60	0.00	45%
EEE	AL0012	130.18	0.00	50.80	0.00	52%	16.20	36.60	0.00	46%
EEE	AL0012	130.19	8.80	44.00	0.00	50%	0.00	51.30	0.00	53%
EEE	AL0012	130.20	17.80	35.00	0.00	45%	0.00	49.80	3.00	54%
EEE	AL0012	130.21	0.00	31.40	21.40	54%	0.00	0.00	52.80	54%
EEE	AL0012	130.22	0.00	41.90	10.90	54%	0.00	23.20	29.60	54%
EEE	AL0012	130.23	0.00	52.80	0.00	54%	0.00	28.10	24.70	54%
EEE	AL0012	130.24	0.00	36.90	15.90	54%	0.00	20.10	32.70	54%
EEE	AL0012	130.25	0.00	52.80	0.00	54%	0.00	52.80	0.00	54%
EEE	AL0012	130.26	0.00	0.00	52.80	54%	0.00	5.40	47.40	54%
EEE	AL0012	130.27	0.00	0.00	52.80	54%	0.00	0.00	52.80	54%
EEE	AL0012	130.28	0.00	0.00	52.80	54%	0.00	0.00	52.80	54%
EEE	AL0012	130.29	0.00	0.00	52.80	54%	0.00	0.00	52.80	54%
FFF	AL0009	521.00	26.60	0.00	0.00	14%	22.80	0.00	0.00	12%
FFF	AL0009	520.99	19.00	0.00	0.00	10%	9.80	0.00	0.00	5%

Site	Route	MP	AW1	AW2	AW3	Agency HPMS	VW1	VW2	VW3	Vendor 1HPMS
FFF	AL0009	520.98	12.60	0.00	0.00	6%	0.00	0.00	0.00	0%
FFF	AL0009	520.97	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
FFF	AL0009	520.96	28.20	0.00	0.00	14%	0.00	0.00	0.00	0%
FFF	AL0009	520.95	24.80	0.00	0.00	13%	0.00	0.00	0.00	0%
FFF	AL0009	520.94	36.30	0.00	0.00	19%	0.00	0.00	0.00	0%
FFF	AL0009	520.93	20.00	0.00	0.00	10%	0.00	0.00	0.00	0%
FFF	AL0009	520.92	25.90	0.00	0.00	13%	12.80	0.00	0.00	7%
FFF	AL0009	520.91	14.80	0.00	0.00	8%	7.90	0.00	0.00	4%
FFF	AL0009	520.90	3.40	0.00	0.00	2%	0.00	0.00	0.00	0%
FFF	AL0009	520.89	4.20	0.00	0.00	2%	0.00	0.00	0.00	0%
FFF	AL0009	520.88	1.10	0.00	0.00	1%	7.90	0.00	0.00	4%
FFF	AL0009	520.87	26.30	0.00	0.00	13%	0.00	27.70	0.00	28%
FFF	AL0009	520.86	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
FFF	AL0009	520.85	14.70	0.00	0.00	8%	0.00	0.00	0.00	0%
FFF	AL0009	520.84	21.00	0.00	0.00	11%	0.00	0.00	0.00	0%
FFF	AL0009	520.83	13.10	0.00	0.00	7%	0.00	0.00	0.00	0%
FFF	AL0009	520.82	22.00	0.00	0.00	11%	12.80	0.00	0.00	7%
FFF	AL0009	520.81	2.10	0.00	0.00	1%	0.00	0.00	0.00	0%
FFF	AL0009	520.80	17.80	0.00	0.00	9%	9.80	0.00	0.00	5%
FFF	AL0009	520.79	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
FFF	AL0009	520.78	5.10	0.00	0.00	3%	0.00	0.00	0.00	0%
FFF	AL0009	520.77	23.10	0.00	0.00	12%	0.00	0.00	0.00	0%
FFF	AL0009	520.76	10.50	0.00	0.00	5%	0.00	0.00	0.00	0%
FFF	AL0009	520.75	16.70	0.00	0.00	9%	0.00	0.00	0.00	0%
FFF	AL0009	520.74	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
FFF	AL0009	520.73	4.40	0.00	0.00	2%	0.00	0.00	0.00	0%
FFF	AL0009	520.72	5.20	0.00	0.00	3%	0.00	0.00	0.00	0%
FFF	AL0009	520.71	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
GGG	AL0009	524.00	24.80	9.00	19.00	41%	0.00	0.00	31.70	33%
GGG	AL0009	523.99	0.00	46.80	6.00	54%	24.20	11.80	16.80	42%
GGG	AL0009	523.98	51.10	0.00	0.00	26%	0.00	52.80	0.00	54%
GGG	AL0009	523.97	52.80	0.00	0.00	27%	0.00	52.30	0.00	54%
GGG	AL0009	523.96	52.80	0.00	0.00	27%	8.30	44.50	0.00	50%
GGG	AL0009	523.95	39.40	0.00	6.90	27%	14.80	24.80	12.80	46%
GGG	AL0009	523.94	52.80	0.00	0.00	27%	25.10	9.80	17.80	41%
GGG	AL0009	523.93	43.40	0.00	0.00	22%	3.40	49.40	0.00	52%
GGG	AL0009	523.92	51.60	0.00	0.00	26%	9.90	39.50	0.00	46%
GGG	AL0009	523.91	47.60	0.00	0.00	24%	34.60	17.80	0.00	36%
GGG	AL0009	523.90	35.00	0.00	12.00	30%	29.70	11.90	9.80	37%
GGG	AL0009	523.89	44.20	0.00	8.60	31%	24.70	9.90	14.80	38%
GGG	AL0009	523.88	50.00	0.00	0.00	26%	0.00	52.80	0.00	54%
GGG	AL0009	523.87	50.20	0.00	2.60	28%	0.00	52.80	0.00	54%
GGG	AL0009	523.86	52.80	0.00	0.00	27%	0.00	52.40	0.00	54%
GGG	AL0009	523.85	51.10	0.00	0.00	26%	0.00	47.90	4.90	54%
GGG	AL0009	523.84	32.30	20.50	0.00	38%	0.00	25.10	27.70	54%
GGG	AL0009	523.83	52.80	0.00	0.00	27%	0.00	52.80	0.00	54%
GGG	AL0009	523.82	52.80	0.00	0.00	27%	0.00	52.80	0.00	54%
GGG	AL0009	523.81	41.80	0.00	0.00	21%	0.00	44.50	0.00	46%
GGG	AL0009	523.80	49.10	0.00	0.00	25%	47.40	0.00	0.00	24%
GGG	AL0009	523.79	26.90	0.00	25.90	40%	0.50	22.80	29.60	54%
GGG	AL0009	523.78	16.90	0.00	35.90	45%	0.00	3.40	49.40	54%

Site	Route	MP	AW1	AW2	AW3	Agency HPMS	VW1	VW2	VW3	Vendor 1HPMS
GGG	AL0009	523.77	0.00	0.00	52.80	54%	0.00	0.00	52.80	54%
GGG	AL0009	523.76	0.00	52.80	0.00	54%	0.00	39.60	5.00	46%
GGG	AL0009	523.75	0.00	52.80	0.00	54%	0.00	13.30	39.50	54%
GGG	AL0009	523.74	0.00	52.80	0.00	54%	0.00	18.20	34.60	54%
GGG	AL0009	523.73	48.30	0.00	0.00	25%	18.20	29.70	4.90	45%
GGG	AL0009	523.72	52.80	0.00	0.00	27%	6.30	46.50	0.00	51%
GGG	AL0009	523.71	52.80	0.00	0.00	27%	16.20	36.60	0.00	46%
HHH	AL0012	170.00	24.30	0.00	2.00	15%	22.70	4.90	0.00	17%
HHH	AL0012	170.01	35.60	3.00	3.00	24%	35.00	17.80	0.00	36%
HHH	AL0012	170.02	9.20	4.90	10.90	21%	14.80	9.80	0.00	18%
HHH	AL0012	170.03	5.00	13.40	6.00	22%	19.80	9.80	0.00	20%
HHH	AL0012	170.04	0.00	0.00	46.30	47%	0.00	52.80	0.00	54%
HHH	AL0012	170.05	12.50	0.00	10.20	17%	9.90	12.80	0.00	18%
HHH	AL0012	170.06	0.00	18.60	13.50	33%	0.00	52.80	0.00	54%
HHH	AL0012	170.07	4.20	7.00	23.10	33%	14.80	24.70	0.00	33%
HHH	AL0012	170.08	14.10	0.00	3.00	10%	11.80	0.00	0.00	6%
HHH	AL0012	170.09	19.30	7.10	0.00	17%	6.90	0.00	0.00	4%
HHH	AL0012	170.10	0.00	23.50	11.50	36%	22.80	19.80	0.00	32%
HHH	AL0012	170.11	28.40	0.00	13.30	28%	17.80	11.80	0.00	21%
HHH	AL0012	170.12	21.70	0.00	12.60	24%	34.70	11.80	0.00	30%
HHH	AL0012	170.13	30.60	0.00	10.70	27%	29.70	16.80	0.00	32%
HHH	AL0012	170.14	11.50	28.20	0.00	35%	19.80	16.80	0.00	27%
HHH	AL0012	170.15	6.60	36.90	0.00	41%	0.00	52.80	0.00	54%
HHH	AL0012	170.16	8.60	0.00	11.20	16%	9.80	11.80	0.00	17%
HHH	AL0012	170.17	7.10	4.00	5.00	13%	3.00	0.00	0.00	2%
HHH	AL0012	170.18	25.10	9.70	2.80	26%	34.60	0.00	0.00	18%
HHH	AL0012	170.19	18.10	0.00	12.50	22%	0.00	0.00	0.00	0%
HHH	AL0012	170.20	7.30	0.00	24.70	29%	17.80	24.80	0.00	35%
HHH	AL0012	170.21	13.70	0.00	25.10	33%	14.90	7.90	0.00	16%
HHH	AL0012	170.22	33.90	0.00	7.00	25%	19.80	2.90	0.00	13%
HHH	AL0012	170.23	8.70	0.00	29.30	35%	0.00	52.80	0.00	54%
HHH	AL0012	170.24	7.40	45.40	0.00	50%	0.00	47.40	0.00	49%
HHH	AL0012	170.25	0.00	31.10	21.70	54%	0.00	52.80	0.00	54%
HHH	AL0012	170.26	0.00	4.40	48.40	54%	0.00	52.40	0.00	54%
HHH	AL0012	170.27	0.00	17.40	35.40	54%	14.80	31.70	0.00	40%
HHH	AL0012	170.28	7.00	0.00	45.80	51%	0.00	52.80	0.00	54%
HHH	AL0012	170.29	0.00	0.00	52.80	54%	0.00	52.30	0.00	54%
III	AL0012	573.00	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
III	AL0012	573.01	6.00	0.00	0.00	3%	0.00	0.00	0.00	0%
III	AL0012	573.02	1.00	0.00	0.00	1%	0.00	0.00	0.00	0%
III	AL0012	573.03	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
III	AL0012	573.04	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
III	AL0012	573.05	2.30	0.00	0.00	1%	0.00	0.00	0.00	0%
III	AL0012	573.06	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
III	AL0012	573.07	8.80	0.00	0.00	5%	0.00	0.00	0.00	0%
III	AL0012	573.08	1.50	0.00	0.00	1%	0.00	0.00	0.00	0%
III	AL0012	573.09	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
III	AL0012	573.10	2.70	0.00	0.00	1%	0.00	0.00	0.00	0%
III	AL0012	573.11	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
III	AL0012	573.12	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
III	AL0012	573.13	2.40	0.00	0.00	1%	0.00	0.00	0.00	0%

Site	Route	MP	AW1	AW2	AW3	Agency HPMS	VW1	VW2	VW3	Vendor 1HPMS
III	AL0012	573.14	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
III	AL0012	573.15	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
III	AL0012	573.16	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
III	AL0012	573.17	0.80	0.00	0.00	0%	0.00	0.00	0.00	0%
III	AL0012	573.18	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
III	AL0012	573.19	1.00	0.00	0.00	1%	0.00	0.00	0.00	0%
III	AL0012	573.20	2.00	0.00	0.00	1%	0.00	0.00	0.00	0%
III	AL0012	573.21	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
III	AL0012	573.22	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
III	AL0012	573.23	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
III	AL0012	573.24	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
III	AL0012	573.25	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
III	AL0012	573.26	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
III	AL0012	573.27	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
III	AL0012	573.28	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
III	AL0012	573.29	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
JJJ	AL0012	197.00	51.50	0.00	0.00	26%	41.50	0.00	0.00	21%
JJJ	AL0012	197.01	15.90	36.90	0.00	46%	52.80	0.00	0.00	27%
JJJ	AL0012	197.02	24.90	27.90	0.00	41%	52.80	0.00	0.00	27%
JJJ	AL0012	197.03	0.00	52.80	0.00	54%	52.30	0.00	0.00	27%
JJJ	AL0012	197.04	3.20	49.60	0.00	53%	52.80	0.00	0.00	27%
JJJ	AL0012	197.05	6.20	46.60	0.00	51%	52.40	0.00	0.00	27%
JJJ	AL0012	197.06	52.80	0.00	0.00	27%	52.80	0.00	0.00	27%
JJJ	AL0012	197.07	28.50	22.30	2.00	40%	52.80	0.00	0.00	27%
JJJ	AL0012	197.08	39.60	13.20	0.00	34%	52.80	0.00	0.00	27%
JJJ	AL0012	197.09	50.80	1.00	1.00	28%	52.80	0.00	0.00	27%
JJJ	AL0012	197.10	5.80	47.00	0.00	51%	52.50	0.00	0.00	27%
JJJ	AL0012	197.11	45.30	7.50	0.00	31%	52.80	0.00	0.00	27%
JJJ	AL0012	197.12	10.80	13.70	27.30	48%	20.20	32.60	0.00	44%
JJJ	AL0012	197.13	6.40	30.70	15.70	51%	28.10	24.70	0.00	40%
JJJ	AL0012	197.14	29.70	22.10	1.00	39%	52.80	0.00	0.00	27%
JJJ	AL0012	197.15	0.00	5.30	47.50	54%	23.20	29.60	0.00	42%
JJJ	AL0012	197.16	0.00	52.80	0.00	54%	26.10	26.70	0.00	41%
JJJ	AL0012	197.17	3.80	41.60	7.40	52%	1.40	51.40	0.00	53%
JJJ	AL0012	197.18	3.60	49.20	0.00	52%	0.00	52.80	0.00	54%
JJJ	AL0012	197.19	27.70	25.10	0.00	40%	0.00	52.80	0.00	54%
JJJ	AL0012	197.20	0.00	46.40	6.40	54%	0.00	52.80	0.00	54%
JJJ	AL0012	197.21	0.00	52.60	0.00	54%	0.00	52.80	0.00	54%
JJJ	AL0012	197.22	48.90	0.00	0.00	25%	47.90	4.90	0.00	30%
JJJ	AL0012	197.23	31.50	21.30	0.00	38%	21.70	29.60	0.00	41%
JJJ	AL0012	197.24	2.90	49.90	0.00	53%	0.00	52.80	0.00	54%
JJJ	AL0012	197.25	42.80	0.00	10.00	32%	26.80	5.00	0.00	19%
JJJ	AL0012	197.26	8.30	44.50	0.00	50%	0.00	52.80	0.00	54%
JJJ	AL0012	197.27	0.00	31.40	21.40	54%	0.00	52.80	0.00	54%
JJJ	AL0012	197.28	0.00	25.70	27.10	54%	0.00	52.80	0.00	54%
JJJ	AL0012	197.29	0.00	31.90	20.90	54%	0.00	52.40	0.00	54%

Table 33. HPMS cracking ratings from 10 XDOT DOT control sites in 2015 (vendor 2 and agency).

Site	Route	MP	AW1	AW2	AW3	Agency HPMS %	VW1	VW2	VW3	Vendor2 HPMS %
AAA	AL0013	67.00	0.00	0.00	9.90	10%	0.20	0.30	3.30	4%
AAA	AL0013	67.01	0.00	0.00	10.10	10%	0.20	1.70	12.10	14%
AAA	AL0013	67.02	0.00	0.00	4.30	4%	0.20	0.50	0.60	1%
AAA	AL0013	67.03	0.00	0.00	16.50	17%	0.40	1.10	17.60	19%
AAA	AL0013	67.04	0.00	0.00	0.00	0%	0.80	1.60	4.30	6%
AAA	AL0013	67.05	0.00	0.00	2.00	2%	0.20	0.30	2.60	3%
AAA	AL0013	67.06	0.00	0.00	0.00	0%	0.10	0.10	5.40	6%
AAA	AL0013	67.07	0.00	0.00	1.00	1%	0.20	1.40	8.60	10%
AAA	AL0013	67.08	0.00	0.00	0.00	0%	0.20	0.50	4.30	5%
AAA	AL0013	67.09	0.00	0.00	0.00	0%	1.20	2.00	11.70	15%
AAA	AL0013	67.10	0.00	0.00	0.00	0%	0.00	0.00	0.60	1%
AAA	AL0013	67.11	0.00	0.00	0.00	0%	0.00	0.50	2.20	3%
AAA	AL0013	67.12	0.00	0.00	0.00	0%	0.20	0.50	6.20	7%
AAA	AL0013	67.13	0.00	0.00	3.40	3%	0.70	1.20	2.10	4%
AAA	AL0013	67.14	0.00	0.00	2.00	2%	0.10	1.10	4.70	6%
AAA	AL0013	67.15	0.00	0.00	39.70	41%	0.20	1.10	40.90	43%
AAA	AL0013	67.16	0.00	0.00	41.70	43%	0.20	1.30	37.70	40%
AAA	AL0013	67.17	0.00	0.00	40.60	42%	0.60	6.50	32.70	41%
AAA	AL0013	67.18	0.00	28.70	2.00	31%	2.60	4.60	12.30	19%
AAA	AL0013	67.19	0.00	0.00	4.70	5%	0.30	2.10	17.10	20%
AAA	AL0013	67.20	0.00	0.00	1.00	1%	0.20	0.20	3.80	4%
AAA	AL0013	67.21	0.00	0.00	15.60	16%	0.20	2.20	13.20	16%
AAA	AL0013	67.22	0.00	0.00	21.20	22%	0.90	1.10	26.10	28%
AAA	AL0013	67.23	0.00	0.00	14.90	15%	0.60	3.40	40.90	46%
AAA	AL0013	67.24	0.00	0.00	34.90	36%	0.50	5.30	42.30	49%
AAA	AL0013	67.25	0.00	14.50	32.50	48%	0.40	4.00	32.90	38%
AAA	AL0013	67.26	0.00	1.90	1.00	3%	0.50	6.10	6.80	13%
AAA	AL0013	67.27	0.00	0.00	25.40	26%	0.20	2.20	33.90	37%
AAA	AL0013	67.28	0.00	0.00	51.40	53%	0.60	5.40	40.20	47%
AAA	AL0013	67.29	0.00	0.00	29.60	30%	0.40	6.10	25.00	32%
BBB	AL0012	56.00	2.00	0.00	0.00	1%	0.00	0.00	0.00	0%
BBB	AL0012	56.01	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
BBB	AL0012	56.02	2.70	0.00	0.00	1%	0.00	0.00	0.00	0%
BBB	AL0012	56.03	0.00	0.00	0.00	0%	0.20	0.90	0.00	1%
BBB	AL0012	56.04	2.00	0.00	0.00	1%	0.20	0.50	0.20	1%
BBB	AL0012	56.05	0.00	0.00	0.00	0%	0.00	0.10	0.00	0%
BBB	AL0012	56.06	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
BBB	AL0012	56.07	14.40	0.00	0.00	7%	3.60	0.00	0.00	2%
BBB	AL0012	56.08	3.00	0.00	0.00	2%	0.00	0.10	0.10	0%
BBB	AL0012	56.09	0.00	0.00	0.00	0%	0.10	0.10	0.20	0%
BBB	AL0012	56.10	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
BBB	AL0012	56.11	2.00	0.00	0.00	1%	0.10	0.40	0.10	1%
BBB	AL0012	56.12	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
BBB	AL0012	56.13	2.00	0.00	0.00	1%	0.30	0.50	0.10	1%
BBB	AL0012	56.14	2.00	0.00	0.00	1%	37.40	0.00	0.00	19%
BBB	AL0012	56.15	1.00	0.00	0.00	1%	0.10	0.10	0.20	0%
BBB	AL0012	56.16	1.00	0.00	0.00	1%	0.10	0.20	0.30	1%
BBB	AL0012	56.17	1.00	0.00	0.00	1%	0.10	0.10	0.00	0%
BBB	AL0012	56.18	1.50	0.00	0.00	1%	0.00	0.00	0.00	0%
BBB	AL0012	56.19	0.00	0.00	0.00	0%	0.20	0.20	0.00	0%

Site	Route	MP	AW1	AW2	AW3	Agency HPMS %	VW1	VW2	VW3	Vendor2 HPMS %
BBB	AL0012	56.20	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
BBB	AL0012	56.21	3.00	0.00	0.00	2%	0.00	0.00	0.00	0%
BBB	AL0012	56.22	3.00	0.00	0.00	2%	0.20	0.40	0.00	1%
BBB	AL0012	56.23	2.00	0.00	0.00	1%	0.00	0.20	0.20	0%
BBB	AL0012	56.24	2.00	0.00	0.00	1%	0.00	0.30	0.30	1%
BBB	AL0012	56.25	2.00	0.00	0.00	1%	7.00	2.10	0.10	6%
BBB	AL0012	56.26	33.30	0.00	0.00	17%	11.00	6.90	0.50	13%
BBB	AL0012	56.27	0.00	0.00	0.00	0%	10.50	0.80	0.10	6%
BBB	AL0012	56.28	16.80	0.00	0.00	9%	0.10	0.40	0.00	0%
BBB	AL0012	56.29	9.30	0.00	0.00	5%	14.40	1.50	0.10	9%
CCC	AL0012	79.00	6.00	0.00	0.00	3%	1.20	1.00	0.10	2%
CCC	AL0012	79.01	11.60	0.00	0.00	6%	16.70	3.70	0.20	13%
CCC	AL0012	79.02	9.40	0.00	0.00	5%	15.80	0.20	0.10	8%
CCC	AL0012	79.03	5.50	0.00	0.00	3%	8.00	1.10	0.50	6%
CCC	AL0012	79.04	4.10	0.00	0.00	2%	0.60	0.30	0.00	1%
CCC	AL0012	79.05	2.00	0.00	0.00	1%	4.70	0.30	0.10	3%
CCC	AL0012	79.06	21.80	0.00	0.00	11%	6.10	8.50	0.50	12%
CCC	AL0012	79.07	21.90	0.00	0.00	11%	12.00	8.70	0.20	15%
CCC	AL0012	79.08	27.90	0.00	0.00	14%	9.00	2.30	0.20	7%
CCC	AL0012	79.09	14.40	0.00	0.00	7%	20.10	6.50	1.10	18%
CCC	AL0012	79.10	30.70	0.00	0.00	16%	3.20	21.30	2.00	26%
CCC	AL0012	79.11	47.20	0.00	0.00	24%	8.00	27.00	2.00	34%
CCC	AL0012	79.12	27.90	0.00	0.00	14%	27.10	10.60	1.00	26%
CCC	AL0012	79.13	37.50	0.00	0.00	19%	26.90	14.50	1.30	30%
CCC	AL0012	79.14	37.40	0.00	0.00	19%	23.40	22.70	1.60	37%
CCC	AL0012	79.15	52.20	0.00	0.00	27%	18.40	31.90	2.50	45%
CCC	AL0012	79.16	51.80	0.00	0.00	27%	16.20	22.60	1.40	33%
CCC	AL0012	79.17	50.10	0.00	0.00	26%	14.60	25.80	2.20	36%
CCC	AL0012	79.18	51.90	0.00	0.00	27%	11.50	24.20	2.10	33%
CCC	AL0012	79.19	52.80	0.00	0.00	27%	7.30	8.60	0.40	13%
CCC	AL0012	79.20	40.60	0.00	0.00	21%	6.90	7.80	0.30	12%
CCC	AL0012	79.21	29.60	0.00	0.00	15%	5.50	1.30	0.10	4%
CCC	AL0012	79.22	26.40	0.00	0.00	14%	4.20	9.60	1.10	13%
CCC	AL0012	79.23	29.40	0.00	0.00	15%	3.40	10.10	0.20	12%
CCC	AL0012	79.24	43.80	0.00	0.00	22%	3.50	20.70	1.50	25%
CCC	AL0012	79.25	38.90	0.00	0.00	20%	4.00	13.40	1.00	17%
CCC	AL0012	79.26	24.50	0.00	0.00	13%	2.30	18.70	1.20	22%
CCC	AL0012	79.27	46.80	0.00	0.00	24%	2.80	20.20	2.20	24%
CCC	AL0012	79.28	23.90	0.00	0.00	12%	3.00	8.30	0.90	11%
CCC	AL0012	79.29	15.30	0.00	0.00	8%	3.20	4.70	0.20	7%
DDD	AL0012	119.00	46.00	0.00	0.00	24%	43.30	8.00	1.50	32%
DDD	AL0012	119.01	35.70	0.00	0.00	18%	20.60	6.80	0.60	18%
DDD	AL0012	119.02	36.20	0.00	0.00	19%	23.30	3.50	0.00	16%
DDD	AL0012	119.03	40.70	0.00	0.00	21%	42.70	8.10	0.90	31%
DDD	AL0012	119.04	18.30	0.00	0.00	9%	0.50	3.50	0.40	4%
DDD	AL0012	119.05	51.30	0.00	0.00	26%	6.40	2.90	0.50	7%
DDD	AL0012	119.06	51.90	0.00	0.00	27%	24.90	8.80	1.50	23%
DDD	AL0012	119.07	47.60	0.00	0.00	24%	20.00	9.50	2.20	22%
DDD	AL0012	119.08	44.70	0.00	0.00	23%	21.00	6.00	0.60	18%
DDD	AL0012	119.09	45.40	0.00	0.00	23%	6.00	2.30	0.10	6%
DDD	AL0012	119.10	35.30	0.00	0.00	18%	3.40	4.80	0.40	7%

Site	Route	MP	AW1	AW2	AW3	Agency HPMS %	VW1	VW2	VW3	Vendor2 HPMS %
DDD	AL0012	119.11	29.50	0.00	0.00	15%	18.10	0.00	0.00	9%
DDD	AL0012	119.12	19.50	0.00	0.00	10%	6.10	5.20	0.20	9%
DDD	AL0012	119.13	45.40	0.00	0.00	23%	14.80	6.30	0.30	14%
DDD	AL0012	119.14	17.60	0.00	0.00	9%	7.00	3.90	0.10	8%
DDD	AL0012	119.15	36.10	0.00	0.00	19%	5.40	11.70	0.80	16%
DDD	AL0012	119.16	17.10	0.00	0.00	9%	6.60	3.30	0.00	7%
DDD	AL0012	119.17	36.70	0.00	0.00	19%	13.20	4.90	0.20	12%
DDD	AL0012	119.18	38.90	0.00	0.00	20%	10.80	13.60	0.40	20%
DDD	AL0012	119.19	16.50	0.00	0.00	8%	9.00	0.10	0.00	5%
DDD	AL0012	119.20	18.20	0.00	0.00	9%	3.80	7.20	0.30	10%
DDD	AL0012	119.21	9.90	0.00	0.00	5%	2.20	1.50	0.00	3%
DDD	AL0012	119.22	9.10	0.00	0.00	5%	2.20	1.00	0.10	2%
DDD	AL0012	119.23	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
DDD	AL0012	119.24	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
DDD	AL0012	119.25	9.60	0.00	0.00	5%	6.90	0.60	0.00	4%
DDD	AL0012	119.26	12.20	0.00	0.00	6%	0.80	1.60	0.00	2%
DDD	AL0012	119.27	33.30	0.00	0.00	17%	14.00	7.60	0.80	16%
DDD	AL0012	119.28	23.00	0.00	0.00	12%	2.60	4.30	0.20	6%
DDD	AL0012	119.29	30.30	0.00	0.00	16%	6.80	7.50	0.90	12%
EEE	AL0012	130.00	9.50	41.30	0.00	47%	0.40	35.30	16.60	53%
EEE	AL0012	130.01	30.60	22.20	0.00	38%	3.80	38.30	10.70	52%
EEE	AL0012	130.02	0.00	46.70	6.10	54%	0.60	30.70	19.40	52%
EEE	AL0012	130.03	32.30	20.50	0.00	38%	3.40	38.50	10.90	52%
EEE	AL0012	130.04	8.30	44.50	0.00	50%	9.80	34.20	8.80	49%
EEE	AL0012	130.05	3.10	49.70	0.00	53%	6.00	37.50	9.30	51%
EEE	AL0012	130.06	14.50	38.30	0.00	47%	8.90	36.60	6.50	49%
EEE	AL0012	130.07	21.30	31.50	0.00	43%	11.50	34.50	6.80	48%
EEE	AL0012	130.08	11.80	7.60	0.00	14%	8.80	6.70	2.20	14%
EEE	AL0012	130.09	11.50	26.30	2.60	36%	17.00	29.00	6.50	45%
EEE	AL0012	130.10	0.00	36.20	13.50	51%	5.40	37.00	10.40	51%
EEE	AL0012	130.11	0.00	41.80	11.00	54%	1.30	36.20	14.80	53%
EEE	AL0012	130.12	0.00	47.60	5.20	54%	3.50	37.80	11.50	52%
EEE	AL0012	130.13	6.30	46.50	0.00	51%	3.20	31.30	17.10	51%
EEE	AL0012	130.14	0.00	52.80	0.00	54%	4.00	33.30	15.50	52%
EEE	AL0012	130.15	0.00	49.10	0.00	50%	3.30	36.10	13.00	52%
EEE	AL0012	130.16	49.70	0.00	0.00	25%	5.10	30.90	7.40	42%
EEE	AL0012	130.17	0.00	43.60	9.20	54%	1.90	32.00	18.20	52%
EEE	AL0012	130.18	0.00	50.80	0.00	52%	3.60	30.10	14.20	47%
EEE	AL0012	130.19	8.80	44.00	0.00	50%	4.60	35.60	12.60	52%
EEE	AL0012	130.20	17.80	35.00	0.00	45%	1.20	30.30	21.30	54%
EEE	AL0012	130.21	0.00	31.40	21.40	54%	0.50	9.20	43.10	54%
EEE	AL0012	130.22	0.00	41.90	10.90	54%	0.80	18.70	31.40	52%
EEE	AL0012	130.23	0.00	52.80	0.00	54%	1.10	23.00	28.70	54%
EEE	AL0012	130.24	0.00	36.90	15.90	54%	1.10	20.90	30.80	54%
EEE	AL0012	130.25	0.00	52.80	0.00	54%	0.40	22.10	29.10	53%
EEE	AL0012	130.26	0.00	0.00	52.80	54%	0.10	9.80	42.00	53%
EEE	AL0012	130.27	0.00	0.00	52.80	54%	0.00	2.40	50.10	54%
EEE	AL0012	130.28	0.00	0.00	52.80	54%	0.30	5.70	46.80	54%
EEE	AL0012	130.29	0.00	0.00	52.80	54%	0.40	8.40	44.00	54%
FFF	AL0009	521.00	26.60	0.00	0.00	14%	6.10	9.70	6.00	19%
FFF	AL0009	520.99	19.00	0.00	0.00	10%	0.90	5.80	4.10	11%

Site	Route	MP	AW1	AW2	AW3	Agency HPMS %	VW1	VW2	VW3	Vendor2 HPMS %
FFF	AL0009	520.98	12.60	0.00	0.00	6%	0.20	1.70	1.00	3%
FFF	AL0009	520.97	0.00	0.00	0.00	0%	0.00	1.30	0.60	2%
FFF	AL0009	520.96	28.20	0.00	0.00	14%	1.50	7.50	16.50	25%
FFF	AL0009	520.95	24.80	0.00	0.00	13%	2.20	12.70	10.80	25%
FFF	AL0009	520.94	36.30	0.00	0.00	19%	0.70	8.00	11.40	20%
FFF	AL0009	520.93	20.00	0.00	0.00	10%	4.70	4.20	2.10	9%
FFF	AL0009	520.92	25.90	0.00	0.00	13%	12.30	5.00	6.00	18%
FFF	AL0009	520.91	14.80	0.00	0.00	8%	0.10	0.10	0.10	0%
FFF	AL0009	520.90	3.40	0.00	0.00	2%	0.60	1.90	3.40	6%
FFF	AL0009	520.89	4.20	0.00	0.00	2%	0.60	1.00	0.30	2%
FFF	AL0009	520.88	1.10	0.00	0.00	1%	0.50	2.20	4.00	7%
FFF	AL0009	520.87	26.30	0.00	0.00	13%	15.20	3.50	9.70	21%
FFF	AL0009	520.86	0.00	0.00	0.00	0%	0.00	0.50	0.80	1%
FFF	AL0009	520.85	14.70	0.00	0.00	8%	8.90	6.10	5.40	16%
FFF	AL0009	520.84	21.00	0.00	0.00	11%	0.50	3.60	1.50	5%
FFF	AL0009	520.83	13.10	0.00	0.00	7%	1.50	5.40	3.40	10%
FFF	AL0009	520.82	22.00	0.00	0.00	11%	10.10	4.00	5.70	15%
FFF	AL0009	520.81	2.10	0.00	0.00	1%	6.10	0.60	0.40	4%
FFF	AL0009	520.80	17.80	0.00	0.00	9%	4.20	3.90	2.70	9%
FFF	AL0009	520.79	0.00	0.00	0.00	0%	0.00	0.50	0.10	1%
FFF	AL0009	520.78	5.10	0.00	0.00	3%	1.00	4.50	5.80	11%
FFF	AL0009	520.77	23.10	0.00	0.00	12%	1.50	8.30	7.20	17%
FFF	AL0009	520.76	10.50	0.00	0.00	5%	0.50	2.30	2.50	5%
FFF	AL0009	520.75	16.70	0.00	0.00	9%	5.90	6.10	5.30	15%
FFF	AL0009	520.74	0.00	0.00	0.00	0%	0.20	0.00	0.10	0%
FFF	AL0009	520.73	4.40	0.00	0.00	2%	0.10	1.70	4.60	7%
FFF	AL0009	520.72	5.20	0.00	0.00	3%	0.20	1.60	2.70	5%
FFF	AL0009	520.71	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
GGG	AL0009	524.00	24.80	9.00	19.00	41%	10.50	16.90	25.40	49%
GGG	AL0009	523.99	0.00	46.80	6.00	54%	5.40	21.90	25.50	51%
GGG	AL0009	523.98	51.10	0.00	0.00	26%	4.80	22.10	25.90	52%
GGG	AL0009	523.97	52.80	0.00	0.00	27%	0.60	21.70	30.20	54%
GGG	AL0009	523.96	52.80	0.00	0.00	27%	2.30	25.50	25.00	53%
GGG	AL0009	523.95	39.40	0.00	6.90	27%	5.60	22.90	24.30	51%
GGG	AL0009	523.94	52.80	0.00	0.00	27%	0.90	16.50	33.40	52%
GGG	AL0009	523.93	43.40	0.00	0.00	22%	4.30	23.90	21.40	49%
GGG	AL0009	523.92	51.60	0.00	0.00	26%	1.80	24.20	22.80	49%
GGG	AL0009	523.91	47.60	0.00	0.00	24%	2.00	29.10	20.30	52%
GGG	AL0009	523.90	35.00	0.00	12.00	30%	5.80	19.00	28.00	51%
GGG	AL0009	523.89	44.20	0.00	8.60	31%	0.90	13.40	36.00	51%
GGG	AL0009	523.88	50.00	0.00	0.00	26%	6.70	18.50	27.60	51%
GGG	AL0009	523.87	50.20	0.00	2.60	28%	2.00	18.20	29.60	50%
GGG	AL0009	523.86	52.80	0.00	0.00	27%	2.00	17.20	31.90	51%
GGG	AL0009	523.85	51.10	0.00	0.00	26%	0.80	18.60	32.40	53%
GGG	AL0009	523.84	32.30	20.50	0.00	38%	0.60	16.30	33.60	51%
GGG	AL0009	523.83	52.80	0.00	0.00	27%	4.30	15.60	32.90	52%
GGG	AL0009	523.82	52.80	0.00	0.00	27%	2.40	19.60	30.80	53%
GGG	AL0009	523.81	41.80	0.00	0.00	21%	8.70	17.90	26.20	50%
GGG	AL0009	523.80	49.10	0.00	0.00	25%	10.90	21.80	20.10	49%
GGG	AL0009	523.79	26.90	0.00	25.90	40%	2.50	8.60	41.70	53%
GGG	AL0009	523.78	16.90	0.00	35.90	45%	0.90	6.70	45.20	54%

Site	Route	MP	AW1	AW2	AW3	Agency HPMS %	VW1	VW2	VW3	Vendor2 HPMS %
GGG	AL0009	523.77	0.00	0.00	52.80	54%	0.60	2.80	49.40	54%
GGG	AL0009	523.76	0.00	52.80	0.00	54%	4.50	6.40	41.10	51%
GGG	AL0009	523.75	0.00	52.80	0.00	54%	0.40	8.20	43.40	53%
GGG	AL0009	523.74	0.00	52.80	0.00	54%	0.30	7.90	43.10	52%
GGG	AL0009	523.73	48.30	0.00	0.00	25%	7.50	18.00	27.30	50%
GGG	AL0009	523.72	52.80	0.00	0.00	27%	6.20	23.10	23.50	51%
GGG	AL0009	523.71	52.80	0.00	0.00	27%	3.30	18.90	30.60	52%
HHH	AL0012	170.00	24.30	0.00	2.00	15%	1.00	11.80	2.30	15%
HHH	AL0012	170.01	35.60	3.00	3.00	24%	4.40	17.30	3.70	24%
HHH	AL0012	170.02	9.20	4.90	10.90	21%	1.90	10.10	3.70	15%
HHH	AL0012	170.03	5.00	13.40	6.00	22%	1.40	6.20	3.10	10%
HHH	AL0012	170.04	0.00	0.00	46.30	47%	0.80	28.80	12.90	43%
HHH	AL0012	170.05	12.50	0.00	10.20	17%	1.10	8.60	2.70	12%
HHH	AL0012	170.06	0.00	18.60	13.50	33%	4.00	16.80	10.10	30%
HHH	AL0012	170.07	4.20	7.00	23.10	33%	1.80	20.10	10.60	32%
HHH	AL0012	170.08	14.10	0.00	3.00	10%	1.70	6.00	0.50	8%
HHH	AL0012	170.09	19.30	7.10	0.00	17%	1.60	8.20	1.50	11%
HHH	AL0012	170.10	0.00	23.50	11.50	36%	5.60	19.10	5.80	28%
HHH	AL0012	170.11	28.40	0.00	13.30	28%	3.50	16.20	3.80	22%
HHH	AL0012	170.12	21.70	0.00	12.60	24%	4.00	16.20	4.50	23%
HHH	AL0012	170.13	30.60	0.00	10.70	27%	5.30	21.10	2.50	27%
HHH	AL0012	170.14	11.50	28.20	0.00	35%	1.50	17.40	3.70	22%
HHH	AL0012	170.15	6.60	36.90	0.00	41%	2.80	27.50	7.10	37%
HHH	AL0012	170.16	8.60	0.00	11.20	16%	1.10	12.60	6.00	20%
HHH	AL0012	170.17	7.10	4.00	5.00	13%	1.00	5.00	1.70	7%
HHH	AL0012	170.18	25.10	9.70	2.80	26%	4.30	16.50	3.30	23%
HHH	AL0012	170.19	18.10	0.00	12.50	22%	1.90	9.30	8.00	19%
HHH	AL0012	170.20	7.30	0.00	24.70	29%	3.60	22.50	9.70	35%
HHH	AL0012	170.21	13.70	0.00	25.10	33%	2.70	22.30	7.20	32%
HHH	AL0012	170.22	33.90	0.00	7.00	25%	4.10	16.50	2.50	22%
HHH	AL0012	170.23	8.70	0.00	29.30	35%	1.30	19.60	11.10	32%
HHH	AL0012	170.24	7.40	45.40	0.00	50%	1.70	32.40	7.50	42%
HHH	AL0012	170.25	0.00	31.10	21.70	54%	0.60	27.00	17.90	46%
HHH	AL0012	170.26	0.00	4.40	48.40	54%	0.90	23.60	19.90	45%
HHH	AL0012	170.27	0.00	17.40	35.40	54%	1.60	31.90	10.10	44%
HHH	AL0012	170.28	7.00	0.00	45.80	51%	2.00	25.00	15.00	42%
HHH	AL0012	170.29	0.00	0.00	52.80	54%	0.30	10.70	31.90	44%
III	AL0012	573.00	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
III	AL0012	573.01	6.00	0.00	0.00	3%	0.00	0.00	0.00	0%
III	AL0012	573.02	1.00	0.00	0.00	1%	0.00	0.00	0.00	0%
III	AL0012	573.03	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
III	AL0012	573.04	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
III	AL0012	573.05	2.30	0.00	0.00	1%	0.00	0.00	0.00	0%
III	AL0012	573.06	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
III	AL0012	573.07	8.80	0.00	0.00	5%	0.00	0.00	0.00	0%
III	AL0012	573.08	1.50	0.00	0.00	1%	0.00	0.00	0.00	0%
III	AL0012	573.09	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
III	AL0012	573.10	2.70	0.00	0.00	1%	0.60	0.70	0.20	1%
III	AL0012	573.11	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
III	AL0012	573.12	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
III	AL0012	573.13	2.40	0.00	0.00	1%	0.00	0.00	0.00	0%

Site	Route	MP	AW1	AW2	AW3	Agency HPMS %	VW1	VW2	VW3	Vendor2 HPMS %
III	AL0012	573.14	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
III	AL0012	573.15	0.00	0.00	0.00	0%	0.50	0.00	0.00	0%
III	AL0012	573.16	0.00	0.00	0.00	0%	0.20	0.40	0.00	1%
III	AL0012	573.17	0.80	0.00	0.00	0%	0.00	0.00	0.00	0%
III	AL0012	573.18	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
III	AL0012	573.19	1.00	0.00	0.00	1%	0.00	0.00	0.00	0%
III	AL0012	573.20	2.00	0.00	0.00	1%	0.10	1.40	0.20	2%
III	AL0012	573.21	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
III	AL0012	573.22	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
III	AL0012	573.23	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
III	AL0012	573.24	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
III	AL0012	573.25	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
III	AL0012	573.26	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
III	AL0012	573.27	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
III	AL0012	573.28	0.00	0.00	0.00	0%	1.10	0.10	0.20	1%
III	AL0012	573.29	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
JJJ	AL0012	197.00	51.50	0.00	0.00	26%	36.30	14.00	2.50	36%
JJJ	AL0012	197.01	15.90	36.90	0.00	46%	23.10	22.70	6.30	42%
JJJ	AL0012	197.02	24.90	27.90	0.00	41%	7.90	31.00	13.90	50%
JJJ	AL0012	197.03	0.00	52.80	0.00	54%	6.80	34.80	11.20	51%
JJJ	AL0012	197.04	3.20	49.60	0.00	53%	7.30	36.90	8.60	50%
JJJ	AL0012	197.05	6.20	46.60	0.00	51%	7.70	33.50	11.60	50%
JJJ	AL0012	197.06	52.80	0.00	0.00	27%	12.70	28.90	11.20	48%
JJJ	AL0012	197.07	28.50	22.30	2.00	40%	6.00	34.00	12.80	51%
JJJ	AL0012	197.08	39.60	13.20	0.00	34%	11.40	27.80	13.60	48%
JJJ	AL0012	197.09	50.80	1.00	1.00	28%	14.60	26.30	11.90	47%
JJJ	AL0012	197.10	5.80	47.00	0.00	51%	11.10	29.10	12.60	48%
JJJ	AL0012	197.11	45.30	7.50	0.00	31%	7.80	30.00	15.00	50%
JJJ	AL0012	197.12	10.80	13.70	27.30	48%	8.40	24.70	19.70	50%
JJJ	AL0012	197.13	6.40	30.70	15.70	51%	13.70	18.40	20.70	47%
JJJ	AL0012	197.14	29.70	22.10	1.00	39%	11.00	25.30	16.50	49%
JJJ	AL0012	197.15	0.00	5.30	47.50	54%	5.90	28.50	18.40	51%
JJJ	AL0012	197.16	0.00	52.80	0.00	54%	4.30	29.60	18.90	52%
JJJ	AL0012	197.17	3.80	41.60	7.40	52%	10.50	20.80	21.50	49%
JJJ	AL0012	197.18	3.60	49.20	0.00	52%	2.80	24.40	25.60	53%
JJJ	AL0012	197.19	27.70	25.10	0.00	40%	9.80	23.30	18.20	48%
JJJ	AL0012	197.20	0.00	46.40	6.40	54%	2.30	21.70	26.90	51%
JJJ	AL0012	197.21	0.00	52.60	0.00	54%	1.30	22.90	26.90	52%
JJJ	AL0012	197.22	48.90	0.00	0.00	25%	9.60	23.50	11.50	41%
JJJ	AL0012	197.23	31.50	21.30	0.00	38%	11.70	18.90	16.60	42%
JJJ	AL0012	197.24	2.90	49.90	0.00	53%	0.70	24.00	24.60	50%
JJJ	AL0012	197.25	42.80	0.00	10.00	32%	17.40	18.20	12.10	40%
JJJ	AL0012	197.26	8.30	44.50	0.00	50%	6.90	21.20	24.70	51%
JJJ	AL0012	197.27	0.00	31.40	21.40	54%	3.00	20.80	29.00	53%
JJJ	AL0012	197.28	0.00	25.70	27.10	54%	0.20	17.50	34.50	53%
JJJ	AL0012	197.29	0.00	31.90	20.90	54%	3.30	19.40	30.10	52%

Table 34. HPMS cracking ratings from 10 XDOT DOT control sites in 2015 (vendor 3 and agency).

Site	Route	MP	AW1	AW2	AW3	Agency HPMS	VW1	VW2	VW3	Vendor 3HPMS
AAA	AL0013	67.00	0.00	0.00	9.90	10%	0.00	2.10	8.30	11%
AAA	AL0013	67.01	0.00	0.00	10.10	10%	0.00	0.00	1.10	1%
AAA	AL0013	67.02	0.00	0.00	4.30	4%	0.00	0.00	12.90	13%
AAA	AL0013	67.03	0.00	0.00	16.50	17%	0.00	0.00	11.50	12%
AAA	AL0013	67.04	0.00	0.00	0.00	0%	0.00	0.00	8.20	8%
AAA	AL0013	67.05	0.00	0.00	2.00	2%	0.00	0.00	22.00	23%
AAA	AL0013	67.06	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
AAA	AL0013	67.07	0.00	0.00	1.00	1%	0.00	0.00	0.00	0%
AAA	AL0013	67.08	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
AAA	AL0013	67.09	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
AAA	AL0013	67.10	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
AAA	AL0013	67.11	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
AAA	AL0013	67.12	0.00	0.00	0.00	0%	0.00	0.80	0.00	1%
AAA	AL0013	67.13	0.00	0.00	3.40	3%	0.00	0.00	0.00	0%
AAA	AL0013	67.14	0.00	0.00	2.00	2%	0.00	0.00	0.00	0%
AAA	AL0013	67.15	0.00	0.00	39.70	41%	0.00	0.00	2.90	3%
AAA	AL0013	67.16	0.00	0.00	41.70	43%	0.00	0.00	3.50	4%
AAA	AL0013	67.17	0.00	0.00	40.60	42%	0.00	0.00	44.10	45%
AAA	AL0013	67.18	0.00	28.70	2.00	31%	0.00	0.00	52.70	54%
AAA	AL0013	67.19	0.00	0.00	4.70	5%	0.00	0.00	46.40	48%
AAA	AL0013	67.20	0.00	0.00	1.00	1%	0.00	0.00	34.80	36%
AAA	AL0013	67.21	0.00	0.00	15.60	16%	0.00	0.00	21.10	22%
AAA	AL0013	67.22	0.00	0.00	21.20	22%	0.00	0.10	1.20	1%
AAA	AL0013	67.23	0.00	0.00	14.90	15%	0.00	0.00	28.80	30%
AAA	AL0013	67.24	0.00	0.00	34.90	36%	0.00	0.00	25.80	26%
AAA	AL0013	67.25	0.00	14.50	32.50	48%	0.00	0.00	47.10	48%
AAA	AL0013	67.26	0.00	1.90	1.00	3%	0.00	0.00	51.70	53%
AAA	AL0013	67.27	0.00	0.00	25.40	26%	0.00	0.00	45.70	47%
AAA	AL0013	67.28	0.00	0.00	51.40	53%	0.00	0.00	5.00	5%
AAA	AL0013	67.29	0.00	0.00	29.60	30%	0.00	0.00	32.80	34%
BBB	AL0012	56.00	2.00	0.00	0.00	1%	0.00	0.00	0.00	0%
BBB	AL0012	56.01	0.00	0.00	0.00	0%	0.10	0.00	0.00	0%
BBB	AL0012	56.02	2.70	0.00	0.00	1%	0.40	0.00	0.00	0%
BBB	AL0012	56.03	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
BBB	AL0012	56.04	2.00	0.00	0.00	1%	0.00	0.00	0.00	0%
BBB	AL0012	56.05	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
BBB	AL0012	56.06	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
BBB	AL0012	56.07	14.40	0.00	0.00	7%	0.00	0.00	0.00	0%
BBB	AL0012	56.08	3.00	0.00	0.00	2%	0.30	0.00	0.00	0%
BBB	AL0012	56.09	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
BBB	AL0012	56.10	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
BBB	AL0012	56.11	2.00	0.00	0.00	1%	0.00	0.00	0.00	0%
BBB	AL0012	56.12	0.00	0.00	0.00	0%	1.20	0.00	0.00	1%
BBB	AL0012	56.13	2.00	0.00	0.00	1%	14.60	0.00	0.00	7%
BBB	AL0012	56.14	2.00	0.00	0.00	1%	0.00	0.00	0.00	0%
BBB	AL0012	56.15	1.00	0.00	0.00	1%	0.00	0.00	0.00	0%
BBB	AL0012	56.16	1.00	0.00	0.00	1%	1.10	0.00	0.00	1%
BBB	AL0012	56.17	1.00	0.00	0.00	1%	0.00	0.00	0.00	0%
BBB	AL0012	56.18	1.50	0.00	0.00	1%	0.00	0.00	0.00	0%
BBB	AL0012	56.19	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%

Site	Route	MP	AW1	AW2	AW3	Agency HPMS	VW1	VW2	VW3	Vendor 3HPMS
BBB	AL0012	56.20	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
BBB	AL0012	56.21	3.00	0.00	0.00	2%	0.00	0.00	0.00	0%
BBB	AL0012	56.22	3.00	0.00	0.00	2%	0.00	0.00	0.00	0%
BBB	AL0012	56.23	2.00	0.00	0.00	1%	0.00	0.00	0.00	0%
BBB	AL0012	56.24	2.00	0.00	0.00	1%	0.00	0.00	0.00	0%
BBB	AL0012	56.25	2.00	0.00	0.00	1%	0.00	0.00	0.00	0%
BBB	AL0012	56.26	33.30	0.00	0.00	17%	0.00	0.00	0.00	0%
BBB	AL0012	56.27	0.00	0.00	0.00	0%	0.50	0.00	0.00	0%
BBB	AL0012	56.28	16.80	0.00	0.00	9%	0.00	0.00	0.00	0%
BBB	AL0012	56.29	9.30	0.00	0.00	5%	0.00	0.00	0.00	0%
CCC	AL0012	79.00	6.00	0.00	0.00	3%	0.00	0.00	0.00	0%
CCC	AL0012	79.01	11.60	0.00	0.00	6%	0.40	4.20	0.00	5%
CCC	AL0012	79.02	9.40	0.00	0.00	5%	4.50	12.90	0.00	16%
CCC	AL0012	79.03	5.50	0.00	0.00	3%	30.00	0.90	0.00	16%
CCC	AL0012	79.04	4.10	0.00	0.00	2%	0.50	0.00	0.00	0%
CCC	AL0012	79.05	2.00	0.00	0.00	1%	0.00	0.00	0.00	0%
CCC	AL0012	79.06	21.80	0.00	0.00	11%	0.00	1.40	0.00	1%
CCC	AL0012	79.07	21.90	0.00	0.00	11%	1.20	31.70	0.00	33%
CCC	AL0012	79.08	27.90	0.00	0.00	14%	25.20	9.70	0.00	23%
CCC	AL0012	79.09	14.40	0.00	0.00	7%	1.00	2.00	0.00	3%
CCC	AL0012	79.10	30.70	0.00	0.00	16%	0.00	32.90	0.00	34%
CCC	AL0012	79.11	47.20	0.00	0.00	24%	0.00	47.90	0.00	49%
CCC	AL0012	79.12	27.90	0.00	0.00	14%	0.00	46.30	0.00	47%
CCC	AL0012	79.13	37.50	0.00	0.00	19%	15.30	5.60	0.00	14%
CCC	AL0012	79.14	37.40	0.00	0.00	19%	14.80	28.10	0.70	37%
CCC	AL0012	79.15	52.20	0.00	0.00	27%	13.90	30.20	0.00	38%
CCC	AL0012	79.16	51.80	0.00	0.00	27%	0.00	52.70	0.00	54%
CCC	AL0012	79.17	50.10	0.00	0.00	26%	9.10	42.40	0.00	48%
CCC	AL0012	79.18	51.90	0.00	0.00	27%	7.90	43.50	0.00	49%
CCC	AL0012	79.19	52.80	0.00	0.00	27%	0.00	52.70	0.00	54%
CCC	AL0012	79.20	40.60	0.00	0.00	21%	0.00	52.80	0.00	54%
CCC	AL0012	79.21	29.60	0.00	0.00	15%	23.50	28.50	0.00	41%
CCC	AL0012	79.22	26.40	0.00	0.00	14%	11.20	7.70	0.00	14%
CCC	AL0012	79.23	29.40	0.00	0.00	15%	13.50	19.20	0.00	27%
CCC	AL0012	79.24	43.80	0.00	0.00	22%	4.20	31.70	0.00	35%
CCC	AL0012	79.25	38.90	0.00	0.00	20%	27.50	14.00	0.00	28%
CCC	AL0012	79.26	24.50	0.00	0.00	13%	4.90	17.70	0.00	21%
CCC	AL0012	79.27	46.80	0.00	0.00	24%	0.00	33.50	0.00	34%
CCC	AL0012	79.28	23.90	0.00	0.00	12%	13.40	23.10	0.00	31%
CCC	AL0012	79.29	15.30	0.00	0.00	8%	7.10	11.00	0.00	15%
DDD	AL0012	119.00	46.00	0.00	0.00	24%	19.80	0.80	0.00	11%
DDD	AL0012	119.01	35.70	0.00	0.00	18%	20.20	1.30	0.00	12%
DDD	AL0012	119.02	36.20	0.00	0.00	19%	0.00	21.30	0.00	22%
DDD	AL0012	119.03	40.70	0.00	0.00	21%	24.70	1.20	0.00	14%
DDD	AL0012	119.04	18.30	0.00	0.00	9%	15.50	35.60	0.00	44%
DDD	AL0012	119.05	51.30	0.00	0.00	26%	11.60	0.00	0.00	6%
DDD	AL0012	119.06	51.90	0.00	0.00	27%	25.30	7.40	0.00	21%
DDD	AL0012	119.07	47.60	0.00	0.00	24%	15.50	0.00	0.00	8%
DDD	AL0012	119.08	44.70	0.00	0.00	23%	4.50	4.20	0.00	7%
DDD	AL0012	119.09	45.40	0.00	0.00	23%	23.50	1.70	0.00	14%
DDD	AL0012	119.10	35.30	0.00	0.00	18%	10.10	27.10	0.00	33%

Site	Route	MP	AW1	AW2	AW3	Agency HPMS	VW1	VW2	VW3	Vendor 3HPMS
DDD	AL0012	119.11	29.50	0.00	0.00	15%	31.90	10.90	0.00	28%
DDD	AL0012	119.12	19.50	0.00	0.00	10%	18.90	5.50	0.00	15%
DDD	AL0012	119.13	45.40	0.00	0.00	23%	0.50	6.50	0.00	7%
DDD	AL0012	119.14	17.60	0.00	0.00	9%	7.30	6.00	0.00	10%
DDD	AL0012	119.15	36.10	0.00	0.00	19%	6.40	0.00	0.00	3%
DDD	AL0012	119.16	17.10	0.00	0.00	9%	4.30	9.80	0.00	12%
DDD	AL0012	119.17	36.70	0.00	0.00	19%	8.60	9.90	0.00	15%
DDD	AL0012	119.18	38.90	0.00	0.00	20%	12.10	3.80	0.00	10%
DDD	AL0012	119.19	16.50	0.00	0.00	8%	0.00	14.80	0.00	15%
DDD	AL0012	119.20	18.20	0.00	0.00	9%	10.70	1.40	0.00	7%
DDD	AL0012	119.21	9.90	0.00	0.00	5%	36.90	0.00	0.00	19%
DDD	AL0012	119.22	9.10	0.00	0.00	5%	28.00	0.00	0.00	14%
DDD	AL0012	119.23	0.00	0.00	0.00	0%	2.80	0.00	0.00	1%
DDD	AL0012	119.24	0.00	0.00	0.00	0%	14.70	0.00	0.00	8%
DDD	AL0012	119.25	9.60	0.00	0.00	5%	0.80	10.60	0.00	11%
DDD	AL0012	119.26	12.20	0.00	0.00	6%	0.00	1.20	0.00	1%
DDD	AL0012	119.27	33.30	0.00	0.00	17%	0.00	0.00	0.00	0%
DDD	AL0012	119.28	23.00	0.00	0.00	12%	0.50	0.00	0.00	0%
DDD	AL0012	119.29	30.30	0.00	0.00	16%	0.00	4.80	0.00	5%
EEE	AL0012	130.00	9.50	41.30	0.00	47%	0.00	52.80	0.00	54%
EEE	AL0012	130.01	30.60	22.20	0.00	38%	0.00	52.00	0.00	53%
EEE	AL0012	130.02	0.00	46.70	6.10	54%	0.00	52.80	0.00	54%
EEE	AL0012	130.03	32.30	20.50	0.00	38%	0.00	52.70	0.00	54%
EEE	AL0012	130.04	8.30	44.50	0.00	50%	0.00	52.80	0.00	54%
EEE	AL0012	130.05	3.10	49.70	0.00	53%	0.00	48.70	0.00	50%
EEE	AL0012	130.06	14.50	38.30	0.00	47%	0.00	49.40	0.00	51%
EEE	AL0012	130.07	21.30	31.50	0.00	43%	0.00	52.80	0.00	54%
EEE	AL0012	130.08	11.80	7.60	0.00	14%	0.00	23.40	0.00	24%
EEE	AL0012	130.09	11.50	26.30	2.60	36%	1.90	19.00	0.60	21%
EEE	AL0012	130.10	0.00	36.20	13.50	51%	1.50	51.30	0.00	53%
EEE	AL0012	130.11	0.00	41.80	11.00	54%	0.00	51.90	0.00	53%
EEE	AL0012	130.12	0.00	47.60	5.20	54%	0.00	52.50	0.00	54%
EEE	AL0012	130.13	6.30	46.50	0.00	51%	0.00	52.80	0.00	54%
EEE	AL0012	130.14	0.00	52.80	0.00	54%	0.00	52.70	0.00	54%
EEE	AL0012	130.15	0.00	49.10	0.00	50%	0.00	52.80	0.00	54%
EEE	AL0012	130.16	49.70	0.00	0.00	25%	0.00	52.10	0.00	53%
EEE	AL0012	130.17	0.00	43.60	9.20	54%	0.00	50.90	1.80	54%
EEE	AL0012	130.18	0.00	50.80	0.00	52%	0.00	29.30	9.00	39%
EEE	AL0012	130.19	8.80	44.00	0.00	50%	2.20	38.20	0.00	40%
EEE	AL0012	130.20	17.80	35.00	0.00	45%	0.00	51.90	0.00	53%
EEE	AL0012	130.21	0.00	31.40	21.40	54%	0.00	52.60	0.00	54%
EEE	AL0012	130.22	0.00	41.90	10.90	54%	0.00	52.80	0.00	54%
EEE	AL0012	130.23	0.00	52.80	0.00	54%	0.00	52.70	0.00	54%
EEE	AL0012	130.24	0.00	36.90	15.90	54%	0.00	52.70	0.00	54%
EEE	AL0012	130.25	0.00	52.80	0.00	54%	0.00	52.70	0.00	54%
EEE	AL0012	130.26	0.00	0.00	52.80	54%	0.00	52.80	0.00	54%
EEE	AL0012	130.27	0.00	0.00	52.80	54%	0.00	52.70	0.00	54%
EEE	AL0012	130.28	0.00	0.00	52.80	54%	0.00	28.00	24.80	54%
EEE	AL0012	130.29	0.00	0.00	52.80	54%	0.00	44.80	8.00	54%
FFF	AL0009	521.00	26.60	0.00	0.00	14%	0.00	39.10	0.00	40%
FFF	AL0009	520.99	19.00	0.00	0.00	10%	5.70	25.20	0.00	29%

Site	Route	MP	AW1	AW2	AW3	Agency HPMS	VW1	VW2	VW3	Vendor 3HPMS
FFF	AL0009	520.98	12.60	0.00	0.00	6%	0.00	15.70	0.00	16%
FFF	AL0009	520.97	0.00	0.00	0.00	0%	0.00	4.10	0.00	4%
FFF	AL0009	520.96	28.20	0.00	0.00	14%	0.00	33.00	0.00	34%
FFF	AL0009	520.95	24.80	0.00	0.00	13%	0.00	49.80	0.00	51%
FFF	AL0009	520.94	36.30	0.00	0.00	19%	0.00	45.40	0.00	47%
FFF	AL0009	520.93	20.00	0.00	0.00	10%	0.00	14.70	0.00	15%
FFF	AL0009	520.92	25.90	0.00	0.00	13%	0.00	8.50	0.00	9%
FFF	AL0009	520.91	14.80	0.00	0.00	8%	0.00	12.90	0.00	13%
FFF	AL0009	520.90	3.40	0.00	0.00	2%	0.10	0.30	0.00	0%
FFF	AL0009	520.89	4.20	0.00	0.00	2%	0.20	18.50	0.00	19%
FFF	AL0009	520.88	1.10	0.00	0.00	1%	0.00	12.70	0.00	13%
FFF	AL0009	520.87	26.30	0.00	0.00	13%	0.00	21.40	2.50	25%
FFF	AL0009	520.86	0.00	0.00	0.00	0%	0.00	5.90	0.00	6%
FFF	AL0009	520.85	14.70	0.00	0.00	8%	0.00	5.10	2.90	8%
FFF	AL0009	520.84	21.00	0.00	0.00	11%	5.10	10.30	10.10	24%
FFF	AL0009	520.83	13.10	0.00	0.00	7%	0.00	0.40	0.00	0%
FFF	AL0009	520.82	22.00	0.00	0.00	11%	0.20	11.20	2.20	14%
FFF	AL0009	520.81	2.10	0.00	0.00	1%	0.00	9.40	1.50	11%
FFF	AL0009	520.80	17.80	0.00	0.00	9%	0.00	13.00	0.00	13%
FFF	AL0009	520.79	0.00	0.00	0.00	0%	0.00	2.60	0.00	3%
FFF	AL0009	520.78	5.10	0.00	0.00	3%	0.00	1.00	0.00	1%
FFF	AL0009	520.77	23.10	0.00	0.00	12%	0.00	20.60	0.00	21%
FFF	AL0009	520.76	10.50	0.00	0.00	5%	0.00	16.30	0.00	17%
FFF	AL0009	520.75	16.70	0.00	0.00	9%	0.00	4.60	8.70	14%
FFF	AL0009	520.74	0.00	0.00	0.00	0%	0.00	19.70	0.00	20%
FFF	AL0009	520.73	4.40	0.00	0.00	2%	0.00	3.30	0.00	3%
FFF	AL0009	520.72	5.20	0.00	0.00	3%	0.00	15.10	1.00	17%
FFF	AL0009	520.71	0.00	0.00	0.00	0%	0.00	6.60	0.60	7%
GGG	AL0009	524.00	24.80	9.00	19.00	41%	0.00	36.30	13.70	51%
GGG	AL0009	523.99	0.00	46.80	6.00	54%	0.00	51.80	0.00	53%
GGG	AL0009	523.98	51.10	0.00	0.00	26%	0.00	50.10	0.00	51%
GGG	AL0009	523.97	52.80	0.00	0.00	27%	0.00	51.50	0.00	53%
GGG	AL0009	523.96	52.80	0.00	0.00	27%	0.00	52.80	0.00	54%
GGG	AL0009	523.95	39.40	0.00	6.90	27%	0.00	52.70	0.00	54%
GGG	AL0009	523.94	52.80	0.00	0.00	27%	0.00	52.10	0.00	53%
GGG	AL0009	523.93	43.40	0.00	0.00	22%	0.00	50.30	0.00	52%
GGG	AL0009	523.92	51.60	0.00	0.00	26%	0.00	52.70	0.00	54%
GGG	AL0009	523.91	47.60	0.00	0.00	24%	0.00	52.70	0.00	54%
GGG	AL0009	523.90	35.00	0.00	12.00	30%	0.00	20.00	32.40	54%
GGG	AL0009	523.89	44.20	0.00	8.60	31%	0.00	52.40	0.00	54%
GGG	AL0009	523.88	50.00	0.00	0.00	26%	0.00	50.60	0.00	52%
GGG	AL0009	523.87	50.20	0.00	2.60	28%	0.00	52.40	0.00	54%
GGG	AL0009	523.86	52.80	0.00	0.00	27%	0.00	52.80	0.00	54%
GGG	AL0009	523.85	51.10	0.00	0.00	26%	0.00	52.70	0.00	54%
GGG	AL0009	523.84	32.30	20.50	0.00	38%	0.00	52.80	0.00	54%
GGG	AL0009	523.83	52.80	0.00	0.00	27%	0.00	52.60	0.00	54%
GGG	AL0009	523.82	52.80	0.00	0.00	27%	0.00	52.60	0.00	54%
GGG	AL0009	523.81	41.80	0.00	0.00	21%	0.00	52.60	0.00	54%
GGG	AL0009	523.80	49.10	0.00	0.00	25%	0.00	12.70	37.70	52%
GGG	AL0009	523.79	26.90	0.00	25.90	40%	0.00	0.10	52.70	54%
GGG	AL0009	523.78	16.90	0.00	35.90	45%	0.00	32.80	20.00	54%

Site	Route	MP	AW1	AW2	AW3	Agency HPMS	VW1	VW2	VW3	Vendor 3HPMS
GGG	AL0009	523.77	0.00	0.00	52.80	54%	0.00	39.30	13.40	54%
GGG	AL0009	523.76	0.00	52.80	0.00	54%	0.00	52.70	0.00	54%
GGG	AL0009	523.75	0.00	52.80	0.00	54%	0.00	39.10	13.70	54%
GGG	AL0009	523.74	0.00	52.80	0.00	54%	0.00	33.50	19.10	54%
GGG	AL0009	523.73	48.30	0.00	0.00	25%	0.00	52.70	0.00	54%
GGG	AL0009	523.72	52.80	0.00	0.00	27%	0.00	52.80	0.00	54%
GGG	AL0009	523.71	52.80	0.00	0.00	27%	0.00	52.70	0.00	54%
HHH	AL0012	170.00	24.30	0.00	2.00	15%	0.00	34.70	0.00	36%
HHH	AL0012	170.01	35.60	3.00	3.00	24%	0.10	17.70	3.90	22%
HHH	AL0012	170.02	9.20	4.90	10.90	21%	0.00	27.40	0.00	28%
HHH	AL0012	170.03	5.00	13.40	6.00	22%	0.00	32.90	16.70	51%
HHH	AL0012	170.04	0.00	0.00	46.30	47%	0.10	23.70	0.00	24%
HHH	AL0012	170.05	12.50	0.00	10.20	17%	0.00	21.30	24.50	47%
HHH	AL0012	170.06	0.00	18.60	13.50	33%	0.00	17.20	15.00	33%
HHH	AL0012	170.07	4.20	7.00	23.10	33%	0.00	13.80	0.00	14%
HHH	AL0012	170.08	14.10	0.00	3.00	10%	2.70	18.30	0.00	20%
HHH	AL0012	170.09	19.30	7.10	0.00	17%	2.30	39.10	0.00	41%
HHH	AL0012	170.10	0.00	23.50	11.50	36%	0.00	21.10	0.00	22%
HHH	AL0012	170.11	28.40	0.00	13.30	28%	0.00	29.60	0.00	30%
HHH	AL0012	170.12	21.70	0.00	12.60	24%	0.00	39.70	0.00	41%
HHH	AL0012	170.13	30.60	0.00	10.70	27%	0.00	34.80	0.00	36%
HHH	AL0012	170.14	11.50	28.20	0.00	35%	0.00	41.40	0.00	42%
HHH	AL0012	170.15	6.60	36.90	0.00	41%	4.90	12.00	0.00	15%
HHH	AL0012	170.16	8.60	0.00	11.20	16%	0.00	22.20	0.00	23%
HHH	AL0012	170.17	7.10	4.00	5.00	13%	0.00	25.00	0.00	26%
HHH	AL0012	170.18	25.10	9.70	2.80	26%	0.00	12.90	14.50	28%
HHH	AL0012	170.19	18.10	0.00	12.50	22%	0.00	45.20	0.00	46%
HHH	AL0012	170.20	7.30	0.00	24.70	29%	0.00	32.00	0.00	33%
HHH	AL0012	170.21	13.70	0.00	25.10	33%	0.00	39.30	0.00	40%
HHH	AL0012	170.22	33.90	0.00	7.00	25%	0.00	52.60	0.00	54%
HHH	AL0012	170.23	8.70	0.00	29.30	35%	0.00	52.60	0.00	54%
HHH	AL0012	170.24	7.40	45.40	0.00	50%	0.00	51.80	0.00	53%
HHH	AL0012	170.25	0.00	31.10	21.70	54%	0.00	51.00	0.00	52%
HHH	AL0012	170.26	0.00	4.40	48.40	54%	0.00	52.70	0.00	54%
HHH	AL0012	170.27	0.00	17.40	35.40	54%	0.00	19.90	31.30	53%
HHH	AL0012	170.28	7.00	0.00	45.80	51%	0.00	19.90	32.70	54%
HHH	AL0012	170.29	0.00	0.00	52.80	54%	0.00	48.10	0.00	49%
III	AL0012	573.00	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
III	AL0012	573.01	6.00	0.00	0.00	3%	0.00	0.00	0.00	0%
III	AL0012	573.02	1.00	0.00	0.00	1%	0.00	0.00	0.00	0%
III	AL0012	573.03	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
III	AL0012	573.04	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
III	AL0012	573.05	2.30	0.00	0.00	1%	0.00	0.00	0.00	0%
III	AL0012	573.06	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
III	AL0012	573.07	8.80	0.00	0.00	5%	0.00	0.00	0.00	0%
III	AL0012	573.08	1.50	0.00	0.00	1%	0.00	0.00	0.00	0%
III	AL0012	573.09	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
III	AL0012	573.10	2.70	0.00	0.00	1%	0.00	0.00	0.00	0%
III	AL0012	573.11	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
III	AL0012	573.12	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
III	AL0012	573.13	2.40	0.00	0.00	1%	0.00	0.00	0.00	0%

Site	Route	MP	AW1	AW2	AW3	Agency HPMS	VW1	VW2	VW3	Vendor 3HPMS
III	AL0012	573.14	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
III	AL0012	573.15	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
III	AL0012	573.16	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
III	AL0012	573.17	0.80	0.00	0.00	0%	0.00	2.80	0.00	3%
III	AL0012	573.18	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
III	AL0012	573.19	1.00	0.00	0.00	1%	0.00	0.00	0.00	0%
III	AL0012	573.20	2.00	0.00	0.00	1%	0.00	0.00	0.00	0%
III	AL0012	573.21	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
III	AL0012	573.22	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
III	AL0012	573.23	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
III	AL0012	573.24	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
III	AL0012	573.25	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
III	AL0012	573.26	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
III	AL0012	573.27	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
III	AL0012	573.28	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
III	AL0012	573.29	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
JJJ	AL0012	197.00	51.50	0.00	0.00	26%	0.00	47.30	0.00	49%
JJJ	AL0012	197.01	15.90	36.90	0.00	46%	0.00	51.40	0.00	53%
JJJ	AL0012	197.02	24.90	27.90	0.00	41%	0.00	52.70	0.00	54%
JJJ	AL0012	197.03	0.00	52.80	0.00	54%	0.00	51.80	0.00	53%
JJJ	AL0012	197.04	3.20	49.60	0.00	53%	0.00	52.70	0.00	54%
JJJ	AL0012	197.05	6.20	46.60	0.00	51%	0.00	52.50	0.00	54%
JJJ	AL0012	197.06	52.80	0.00	0.00	27%	0.00	49.60	0.00	51%
JJJ	AL0012	197.07	28.50	22.30	2.00	40%	0.00	51.60	0.00	53%
JJJ	AL0012	197.08	39.60	13.20	0.00	34%	0.00	51.50	0.00	53%
JJJ	AL0012	197.09	50.80	1.00	1.00	28%	2.90	49.80	0.00	53%
JJJ	AL0012	197.10	5.80	47.00	0.00	51%	0.00	52.80	0.00	54%
JJJ	AL0012	197.11	45.30	7.50	0.00	31%	0.50	52.30	0.00	54%
JJJ	AL0012	197.12	10.80	13.70	27.30	48%	0.00	51.90	0.00	53%
JJJ	AL0012	197.13	6.40	30.70	15.70	51%	0.00	52.80	0.00	54%
JJJ	AL0012	197.14	29.70	22.10	1.00	39%	0.00	52.80	0.00	54%
JJJ	AL0012	197.15	0.00	5.30	47.50	54%	0.10	52.70	0.00	54%
JJJ	AL0012	197.16	0.00	52.80	0.00	54%	0.50	48.20	0.00	50%
JJJ	AL0012	197.17	3.80	41.60	7.40	52%	0.00	49.50	0.00	51%
JJJ	AL0012	197.18	3.60	49.20	0.00	52%	0.00	39.90	9.10	50%
JJJ	AL0012	197.19	27.70	25.10	0.00	40%	0.00	47.90	4.20	53%
JJJ	AL0012	197.20	0.00	46.40	6.40	54%	0.00	30.60	22.20	54%
JJJ	AL0012	197.21	0.00	52.60	0.00	54%	0.10	52.70	0.00	54%
JJJ	AL0012	197.22	48.90	0.00	0.00	25%	0.00	44.40	0.00	46%
JJJ	AL0012	197.23	31.50	21.30	0.00	38%	0.00	50.70	0.00	52%
JJJ	AL0012	197.24	2.90	49.90	0.00	53%	13.20	37.70	0.00	45%
JJJ	AL0012	197.25	42.80	0.00	10.00	32%	0.00	20.50	25.70	47%
JJJ	AL0012	197.26	8.30	44.50	0.00	50%	0.00	40.00	12.20	54%
JJJ	AL0012	197.27	0.00	31.40	21.40	54%	0.00	35.00	17.00	53%
JJJ	AL0012	197.28	0.00	25.70	27.10	54%	0.00	20.20	32.60	54%
JJJ	AL0012	197.29	0.00	31.90	20.90	54%	0.00	52.80	0.00	54%

Table 35. HPMS cracking ratings from 10 XDOT DOT control sites in 2015 (vendor 4 and agency).

Site	Route	MP	AW1	AW2	AW3	Agency HPMS	VW1	VW2	VW3	Vendor 4HPMS
AAA	AL0013	67.00	0.00	0.00	9.90	10%	0.00	0.00	0.95	1%
AAA	AL0013	67.01	0.00	0.00	10.10	10%	0.00	0.24	8.35	9%
AAA	AL0013	67.02	0.00	0.00	4.30	4%	0.00	0.21	1.39	2%
AAA	AL0013	67.03	0.00	0.00	16.50	17%	0.00	0.00	21.49	22%
AAA	AL0013	67.04	0.00	0.00	0.00	0%	0.00	0.50	2.37	3%
AAA	AL0013	67.05	0.00	0.00	2.00	2%	0.00	0.00	1.10	1%
AAA	AL0013	67.06	0.00	0.00	0.00	0%	0.00	0.00	0.86	1%
AAA	AL0013	67.07	0.00	0.00	1.00	1%	0.00	0.00	2.81	3%
AAA	AL0013	67.08	0.00	0.00	0.00	0%	0.00	0.00	1.57	2%
AAA	AL0013	67.09	0.00	0.00	0.00	0%	0.00	1.69	0.00	2%
AAA	AL0013	67.10	0.00	0.00	0.00	0%	0.00	0.00	0.50	1%
AAA	AL0013	67.11	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
AAA	AL0013	67.12	0.00	0.00	0.00	0%	0.00	0.00	2.58	3%
AAA	AL0013	67.13	0.00	0.00	3.40	3%	0.00	0.41	3.34	4%
AAA	AL0013	67.14	0.00	0.00	2.00	2%	0.00	0.00	7.19	7%
AAA	AL0013	67.15	0.00	0.00	39.70	41%	0.00	0.00	43.01	44%
AAA	AL0013	67.16	0.00	0.00	41.70	43%	0.00	0.00	39.87	41%
AAA	AL0013	67.17	0.00	0.00	40.60	42%	0.56	3.37	37.56	42%
AAA	AL0013	67.18	0.00	28.70	2.00	31%	0.00	2.04	20.37	23%
AAA	AL0013	67.19	0.00	0.00	4.70	5%	0.00	0.00	24.12	25%
AAA	AL0013	67.20	0.00	0.00	1.00	1%	0.00	1.04	0.77	2%
AAA	AL0013	67.21	0.00	0.00	15.60	16%	0.00	0.00	19.21	20%
AAA	AL0013	67.22	0.00	0.00	21.20	22%	0.00	0.00	33.21	34%
AAA	AL0013	67.23	0.00	0.00	14.90	15%	0.00	0.50	46.15	48%
AAA	AL0013	67.24	0.00	0.00	34.90	36%	0.00	0.00	47.92	49%
AAA	AL0013	67.25	0.00	14.50	32.50	48%	0.00	1.81	42.00	45%
AAA	AL0013	67.26	0.00	1.90	1.00	3%	0.00	0.00	6.75	7%
AAA	AL0013	67.27	0.00	0.00	25.40	26%	0.00	0.00	30.43	31%
AAA	AL0013	67.28	0.00	0.00	51.40	53%	0.00	2.52	15.07	18%
AAA	AL0013	67.29	0.00	0.00	29.60	30%	0.00	0.00	0.71	1%
BBB	AL0012	56.00	2.00	0.00	0.00	1%	0.00	0.00	0.00	0%
BBB	AL0012	56.01	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
BBB	AL0012	56.02	2.70	0.00	0.00	1%	0.00	0.00	0.00	0%
BBB	AL0012	56.03	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
BBB	AL0012	56.04	2.00	0.00	0.00	1%	0.00	0.00	0.00	0%
BBB	AL0012	56.05	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
BBB	AL0012	56.06	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
BBB	AL0012	56.07	14.40	0.00	0.00	7%	0.00	0.00	0.00	0%
BBB	AL0012	56.08	3.00	0.00	0.00	2%	0.27	0.00	0.00	0%
BBB	AL0012	56.09	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
BBB	AL0012	56.10	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
BBB	AL0012	56.11	2.00	0.00	0.00	1%	0.00	0.00	0.00	0%
BBB	AL0012	56.12	0.00	0.00	0.00	0%	0.00	1.69	0.00	2%
BBB	AL0012	56.13	2.00	0.00	0.00	1%	0.00	0.00	0.00	0%
BBB	AL0012	56.14	2.00	0.00	0.00	1%	0.00	0.00	0.00	0%
BBB	AL0012	56.15	1.00	0.00	0.00	1%	0.00	0.00	0.00	0%
BBB	AL0012	56.16	1.00	0.00	0.00	1%	0.00	0.00	0.18	0%
BBB	AL0012	56.17	1.00	0.00	0.00	1%	0.68	0.00	0.00	0%
BBB	AL0012	56.18	1.50	0.00	0.00	1%	0.00	0.44	0.00	0%
BBB	AL0012	56.19	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%

Site	Route	MP	AW1	AW2	AW3	Agency HPMS	VW1	VW2	VW3	Vendor 4HPMS
BBB	AL0012	56.20	0.00	0.00	0.00	0%	0.44	0.33	0.00	1%
BBB	AL0012	56.21	3.00	0.00	0.00	2%	0.00	0.38	0.00	0%
BBB	AL0012	56.22	3.00	0.00	0.00	2%	0.00	0.33	0.00	0%
BBB	AL0012	56.23	2.00	0.00	0.00	1%	0.00	0.33	0.00	0%
BBB	AL0012	56.24	2.00	0.00	0.00	1%	0.00	0.00	0.00	0%
BBB	AL0012	56.25	2.00	0.00	0.00	1%	0.00	0.38	0.00	0%
BBB	AL0012	56.26	33.30	0.00	0.00	17%	0.33	0.00	0.00	0%
BBB	AL0012	56.27	0.00	0.00	0.00	0%	0.59	0.36	0.24	1%
BBB	AL0012	56.28	16.80	0.00	0.00	9%	0.00	0.62	0.00	1%
BBB	AL0012	56.29	9.30	0.00	0.00	5%	0.00	0.27	0.00	0%
CCC	AL0012	79.00	6.00	0.00	0.00	3%	2.43	1.36	0.00	3%
CCC	AL0012	79.01	11.60	0.00	0.00	6%	0.00	3.49	0.00	4%
CCC	AL0012	79.02	9.40	0.00	0.00	5%	0.00	0.50	0.00	1%
CCC	AL0012	79.03	5.50	0.00	0.00	3%	2.63	2.28	0.00	4%
CCC	AL0012	79.04	4.10	0.00	0.00	2%	2.10	1.10	0.00	2%
CCC	AL0012	79.05	2.00	0.00	0.00	1%	1.18	0.00	0.00	1%
CCC	AL0012	79.06	21.80	0.00	0.00	11%	2.93	9.18	0.00	11%
CCC	AL0012	79.07	21.90	0.00	0.00	11%	1.63	5.86	0.00	7%
CCC	AL0012	79.08	27.90	0.00	0.00	14%	0.00	4.41	0.00	5%
CCC	AL0012	79.09	14.40	0.00	0.00	7%	0.30	7.10	0.00	7%
CCC	AL0012	79.10	30.70	0.00	0.00	16%	1.10	15.87	0.00	17%
CCC	AL0012	79.11	47.20	0.00	0.00	24%	0.33	23.80	0.24	25%
CCC	AL0012	79.12	27.90	0.00	0.00	14%	0.00	26.97	0.00	28%
CCC	AL0012	79.13	37.50	0.00	0.00	19%	0.00	29.36	0.00	30%
CCC	AL0012	79.14	37.40	0.00	0.00	19%	5.03	8.44	0.00	11%
CCC	AL0012	79.15	52.20	0.00	0.00	27%	0.00	33.75	0.00	35%
CCC	AL0012	79.16	51.80	0.00	0.00	27%	0.00	36.97	0.00	38%
CCC	AL0012	79.17	50.10	0.00	0.00	26%	0.00	26.05	0.00	27%
CCC	AL0012	79.18	51.90	0.00	0.00	27%	0.00	15.57	0.00	16%
CCC	AL0012	79.19	52.80	0.00	0.00	27%	0.00	25.78	0.00	26%
CCC	AL0012	79.20	40.60	0.00	0.00	21%	0.00	12.76	1.33	14%
CCC	AL0012	79.21	29.60	0.00	0.00	15%	0.00	1.69	0.00	2%
CCC	AL0012	79.22	26.40	0.00	0.00	14%	7.46	5.65	0.00	10%
CCC	AL0012	79.23	29.40	0.00	0.00	15%	0.44	12.31	0.00	13%
CCC	AL0012	79.24	43.80	0.00	0.00	22%	8.17	23.21	3.91	32%
CCC	AL0012	79.25	38.90	0.00	0.00	20%	0.00	20.10	1.45	22%
CCC	AL0012	79.26	24.50	0.00	0.00	13%	17.26	0.95	0.00	10%
CCC	AL0012	79.27	46.80	0.00	0.00	24%	0.00	32.12	0.00	33%
CCC	AL0012	79.28	23.90	0.00	0.00	12%	8.73	13.71	0.00	19%
CCC	AL0012	79.29	15.30	0.00	0.00	8%	0.00	9.92	0.00	10%
DDD	AL0012	119.00	46.00	0.00	0.00	24%	0.00	20.99	0.00	22%
DDD	AL0012	119.01	35.70	0.00	0.00	18%	0.00	29.36	0.00	30%
DDD	AL0012	119.02	36.20	0.00	0.00	19%	5.03	9.47	0.00	12%
DDD	AL0012	119.03	40.70	0.00	0.00	21%	0.00	33.33	0.00	34%
DDD	AL0012	119.04	18.30	0.00	0.00	9%	0.00	33.89	0.00	35%
DDD	AL0012	119.05	51.30	0.00	0.00	26%	0.00	26.05	0.00	27%
DDD	AL0012	119.06	51.90	0.00	0.00	27%	0.00	15.57	0.00	16%
DDD	AL0012	119.07	47.60	0.00	0.00	24%	0.00	25.78	0.00	26%
DDD	AL0012	119.08	44.70	0.00	0.00	23%	0.00	11.87	1.33	14%
DDD	AL0012	119.09	45.40	0.00	0.00	23%	0.00	1.04	0.00	1%
DDD	AL0012	119.10	35.30	0.00	0.00	18%	7.46	11.07	0.00	15%

Site	Route	MP	AW1	AW2	AW3	Agency HPMS	VW1	VW2	VW3	Vendor 4HPMS
DDD	AL0012	119.11	29.50	0.00	0.00	15%	0.44	14.09	0.00	15%
DDD	AL0012	119.12	19.50	0.00	0.00	10%	8.17	17.58	3.91	26%
DDD	AL0012	119.13	45.40	0.00	0.00	23%	2.69	20.10	1.45	23%
DDD	AL0012	119.14	17.60	0.00	0.00	9%	17.52	0.95	0.00	10%
DDD	AL0012	119.15	36.10	0.00	0.00	19%	0.00	27.71	0.00	28%
DDD	AL0012	119.16	17.10	0.00	0.00	9%	8.73	14.42	0.00	19%
DDD	AL0012	119.17	36.70	0.00	0.00	19%	1.12	9.92	0.00	11%
DDD	AL0012	119.18	38.90	0.00	0.00	20%	0.41	9.71	0.00	10%
DDD	AL0012	119.19	16.50	0.00	0.00	8%	1.27	0.80	0.00	1%
DDD	AL0012	119.20	18.20	0.00	0.00	9%	0.00	2.69	0.00	3%
DDD	AL0012	119.21	9.90	0.00	0.00	5%	1.60	4.32	0.00	5%
DDD	AL0012	119.22	9.10	0.00	0.00	5%	0.36	4.88	13.08	19%
DDD	AL0012	119.23	0.00	0.00	0.00	0%	0.00	2.52	0.00	3%
DDD	AL0012	119.24	0.00	0.00	0.00	0%	0.00	27.11	0.18	28%
DDD	AL0012	119.25	9.60	0.00	0.00	5%	0.33	3.29	0.00	4%
DDD	AL0012	119.26	12.20	0.00	0.00	6%	0.00	10.09	0.00	10%
DDD	AL0012	119.27	33.30	0.00	0.00	17%	0.56	29.72	0.00	31%
DDD	AL0012	119.28	23.00	0.00	0.00	12%	0.44	49.64	0.00	51%
DDD	AL0012	119.29	30.30	0.00	0.00	16%	0.00	48.40	0.68	50%
EEE	AL0012	130.00	9.50	41.30	0.00	47%	0.00	27.65	24.36	53%
EEE	AL0012	130.01	30.60	22.20	0.00	38%	0.00	11.07	2.13	14%
EEE	AL0012	130.02	0.00	46.70	6.10	54%	0.00	47.72	0.00	49%
EEE	AL0012	130.03	32.30	20.50	0.00	38%	0.00	22.29	0.41	23%
EEE	AL0012	130.04	8.30	44.50	0.00	50%	0.00	5.21	0.00	5%
EEE	AL0012	130.05	3.10	49.70	0.00	53%	0.00	3.94	0.00	4%
EEE	AL0012	130.06	14.50	38.30	0.00	47%	0.00	0.74	0.00	1%
EEE	AL0012	130.07	21.30	31.50	0.00	43%	0.00	1.89	0.00	2%
EEE	AL0012	130.08	11.80	7.60	0.00	14%	0.00	8.67	0.00	9%
EEE	AL0012	130.09	11.50	26.30	2.60	36%	0.00	37.30	0.00	38%
EEE	AL0012	130.10	0.00	36.20	13.50	51%	0.00	7.79	0.00	8%
EEE	AL0012	130.11	0.00	41.80	11.00	54%	0.00	34.43	0.00	35%
EEE	AL0012	130.12	0.00	47.60	5.20	54%	0.00	31.32	19.24	52%
EEE	AL0012	130.13	6.30	46.50	0.00	51%	2.52	0.00	48.07	51%
EEE	AL0012	130.14	0.00	52.80	0.00	54%	0.00	25.13	25.49	52%
EEE	AL0012	130.15	0.00	49.10	0.00	50%	0.00	41.83	9.89	53%
EEE	AL0012	130.16	49.70	0.00	0.00	25%	0.00	30.05	0.00	31%
EEE	AL0012	130.17	0.00	43.60	9.20	54%	0.00	25.93	25.87	53%
EEE	AL0012	130.18	0.00	50.80	0.00	52%	0.00	47.01	0.00	48%
EEE	AL0012	130.19	8.80	44.00	0.00	50%	0.00	25.75	25.81	53%
EEE	AL0012	130.20	17.80	35.00	0.00	45%	0.00	46.15	5.48	53%
EEE	AL0012	130.21	0.00	31.40	21.40	54%	0.00	0.00	51.62	53%
EEE	AL0012	130.22	0.00	41.90	10.90	54%	0.30	51.06	0.00	53%
EEE	AL0012	130.23	0.00	52.80	0.00	54%	0.00	43.10	0.00	44%
EEE	AL0012	130.24	0.00	36.90	15.90	54%	0.00	40.35	10.33	52%
EEE	AL0012	130.25	0.00	52.80	0.00	54%	0.00	51.24	0.00	53%
EEE	AL0012	130.26	0.00	0.00	52.80	54%	0.00	8.85	42.57	53%
EEE	AL0012	130.27	0.00	0.00	52.80	54%	0.00	0.06	51.51	53%
EEE	AL0012	130.28	0.00	0.00	52.80	54%	0.00	25.28	26.02	53%
EEE	AL0012	130.29	0.00	0.00	52.80	54%	0.00	51.68	0.00	53%
FFF	AL0009	521.00	26.60	0.00	0.00	14%	0.00	4.06	16.96	22%
FFF	AL0009	520.99	19.00	0.00	0.00	10%	0.00	4.68	0.00	5%

Site	Route	MP	AW1	AW2	AW3	Agency HPMS	VW1	VW2	VW3	Vendor 4HPMS
FFF	AL0009	520.98	12.60	0.00	0.00	6%	0.00	0.80	2.87	4%
FFF	AL0009	520.97	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
FFF	AL0009	520.96	28.20	0.00	0.00	14%	0.00	0.71	13.32	14%
FFF	AL0009	520.95	24.80	0.00	0.00	13%	0.00	0.00	24.78	25%
FFF	AL0009	520.94	36.30	0.00	0.00	19%	0.00	32.18	0.00	33%
FFF	AL0009	520.93	20.00	0.00	0.00	10%	0.00	1.75	1.57	3%
FFF	AL0009	520.92	25.90	0.00	0.00	13%	0.59	0.00	19.15	20%
FFF	AL0009	520.91	14.80	0.00	0.00	8%	0.00	0.00	2.31	2%
FFF	AL0009	520.90	3.40	0.00	0.00	2%	0.00	0.00	0.00	0%
FFF	AL0009	520.89	4.20	0.00	0.00	2%	0.00	0.62	5.65	6%
FFF	AL0009	520.88	1.10	0.00	0.00	1%	0.00	0.00	0.00	0%
FFF	AL0009	520.87	26.30	0.00	0.00	13%	0.00	0.00	24.60	25%
FFF	AL0009	520.86	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
FFF	AL0009	520.85	14.70	0.00	0.00	8%	0.00	0.71	9.80	11%
FFF	AL0009	520.84	21.00	0.00	0.00	11%	0.00	0.00	9.35	10%
FFF	AL0009	520.83	13.10	0.00	0.00	7%	0.00	0.00	10.21	10%
FFF	AL0009	520.82	22.00	0.00	0.00	11%	0.00	0.56	10.06	11%
FFF	AL0009	520.81	2.10	0.00	0.00	1%	0.00	1.75	0.00	2%
FFF	AL0009	520.80	17.80	0.00	0.00	9%	0.00	9.92	0.71	11%
FFF	AL0009	520.79	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
FFF	AL0009	520.78	5.10	0.00	0.00	3%	0.00	2.10	0.00	2%
FFF	AL0009	520.77	23.10	0.00	0.00	12%	0.00	5.57	10.36	16%
FFF	AL0009	520.76	10.50	0.00	0.00	5%	0.00	11.72	0.00	12%
FFF	AL0009	520.75	16.70	0.00	0.00	9%	0.00	2.28	7.02	10%
FFF	AL0009	520.74	0.00	0.00	0.00	0%	0.00	0.00	1.42	1%
FFF	AL0009	520.73	4.40	0.00	0.00	2%	0.00	1.78	4.14	6%
FFF	AL0009	520.72	5.20	0.00	0.00	3%	0.00	0.00	0.44	0%
FFF	AL0009	520.71	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
GGG	AL0009	524.00	24.80	9.00	19.00	41%	0.00	0.00	0.00	0%
GGG	AL0009	523.99	0.00	46.80	6.00	54%	0.00	0.00	0.00	0%
GGG	AL0009	523.98	51.10	0.00	0.00	26%	0.00	0.00	0.00	0%
GGG	AL0009	523.97	52.80	0.00	0.00	27%	0.00	0.00	0.00	0%
GGG	AL0009	523.96	52.80	0.00	0.00	27%	0.00	0.00	0.00	0%
GGG	AL0009	523.95	39.40	0.00	6.90	27%	0.00	20.19	0.00	21%
GGG	AL0009	523.94	52.80	0.00	0.00	27%	0.00	7.73	9.86	18%
GGG	AL0009	523.93	43.40	0.00	0.00	22%	0.00	4.08	20.87	26%
GGG	AL0009	523.92	51.60	0.00	0.00	26%	0.00	0.00	44.02	45%
GGG	AL0009	523.91	47.60	0.00	0.00	24%	0.00	7.28	12.88	21%
GGG	AL0009	523.90	35.00	0.00	12.00	30%	0.00	10.12	33.18	44%
GGG	AL0009	523.89	44.20	0.00	8.60	31%	0.80	3.97	24.84	30%
GGG	AL0009	523.88	50.00	0.00	0.00	26%	0.30	4.35	0.00	5%
GGG	AL0009	523.87	50.20	0.00	2.60	28%	0.00	21.76	0.00	22%
GGG	AL0009	523.86	52.80	0.00	0.00	27%	5.24	26.11	6.16	36%
GGG	AL0009	523.85	51.10	0.00	0.00	26%	0.00	13.91	18.65	33%
GGG	AL0009	523.84	32.30	20.50	0.00	38%	0.00	15.04	9.71	25%
GGG	AL0009	523.83	52.80	0.00	0.00	27%	0.00	36.97	6.33	44%
GGG	AL0009	523.82	52.80	0.00	0.00	27%	0.00	4.88	25.72	31%
GGG	AL0009	523.81	41.80	0.00	0.00	21%	0.00	3.46	40.23	45%
GGG	AL0009	523.80	49.10	0.00	0.00	25%	0.00	3.26	10.63	14%
GGG	AL0009	523.79	26.90	0.00	25.90	40%	0.00	12.52	2.93	16%
GGG	AL0009	523.78	16.90	0.00	35.90	45%	0.83	19.89	0.00	21%

Site	Route	MP	AW1	AW2	AW3	Agency HPMS	VW1	VW2	VW3	Vendor 4HPMS
GGG	AL0009	523.77	0.00	0.00	52.80	54%	0.00	6.54	9.95	17%
GGG	AL0009	523.76	0.00	52.80	0.00	54%	0.00	13.02	16.99	31%
GGG	AL0009	523.75	0.00	52.80	0.00	54%	0.00	6.99	36.82	45%
GGG	AL0009	523.74	0.00	52.80	0.00	54%	0.00	19.21	0.00	20%
GGG	AL0009	523.73	48.30	0.00	0.00	25%	0.00	25.58	21.46	48%
GGG	AL0009	523.72	52.80	0.00	0.00	27%	0.00	50.50	0.00	52%
GGG	AL0009	523.71	52.80	0.00	0.00	27%	0.00	25.52	25.72	53%
HHH	AL0012	170.00	24.30	0.00	2.00	15%	0.00	20.19	0.00	21%
HHH	AL0012	170.01	35.60	3.00	3.00	24%	0.00	7.73	9.86	18%
HHH	AL0012	170.02	9.20	4.90	10.90	21%	0.00	4.08	20.87	26%
HHH	AL0012	170.03	5.00	13.40	6.00	22%	0.00	0.00	44.02	45%
HHH	AL0012	170.04	0.00	0.00	46.30	47%	0.00	7.28	12.88	21%
HHH	AL0012	170.05	12.50	0.00	10.20	17%	0.00	10.12	33.18	44%
HHH	AL0012	170.06	0.00	18.60	13.50	33%	0.80	3.97	24.84	30%
HHH	AL0012	170.07	4.20	7.00	23.10	33%	0.30	4.35	0.00	5%
HHH	AL0012	170.08	14.10	0.00	3.00	10%	0.00	21.76	0.00	22%
HHH	AL0012	170.09	19.30	7.10	0.00	17%	5.24	26.11	6.16	36%
HHH	AL0012	170.10	0.00	23.50	11.50	36%	0.00	13.91	18.65	33%
HHH	AL0012	170.11	28.40	0.00	13.30	28%	0.00	15.04	9.71	25%
HHH	AL0012	170.12	21.70	0.00	12.60	24%	0.00	36.97	6.33	44%
HHH	AL0012	170.13	30.60	0.00	10.70	27%	0.00	4.88	25.72	31%
HHH	AL0012	170.14	11.50	28.20	0.00	35%	0.00	3.46	40.23	45%
HHH	AL0012	170.15	6.60	36.90	0.00	41%	0.00	3.26	10.63	14%
HHH	AL0012	170.16	8.60	0.00	11.20	16%	0.00	12.52	2.93	16%
HHH	AL0012	170.17	7.10	4.00	5.00	13%	0.83	19.89	0.00	21%
HHH	AL0012	170.18	25.10	9.70	2.80	26%	0.00	6.54	9.95	17%
HHH	AL0012	170.19	18.10	0.00	12.50	22%	0.00	13.02	16.99	31%
HHH	AL0012	170.20	7.30	0.00	24.70	29%	0.00	6.99	36.82	45%
HHH	AL0012	170.21	13.70	0.00	25.10	33%	0.00	19.21	0.00	20%
HHH	AL0012	170.22	33.90	0.00	7.00	25%	0.00	25.58	21.46	48%
HHH	AL0012	170.23	8.70	0.00	29.30	35%	0.00	50.50	0.00	52%
HHH	AL0012	170.24	7.40	45.40	0.00	50%	0.00	25.52	25.72	53%
HHH	AL0012	170.25	0.00	31.10	21.70	54%	0.00	1.24	46.89	49%
HHH	AL0012	170.26	0.00	4.40	48.40	54%	0.00	48.81	0.00	50%
HHH	AL0012	170.27	0.00	17.40	35.40	54%	0.00	0.00	50.59	52%
HHH	AL0012	170.28	7.00	0.00	45.80	51%	0.00	0.00	50.50	52%
HHH	AL0012	170.29	0.00	0.00	52.80	54%	0.00	29.78	0.00	31%
III	AL0012	573.00	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
III	AL0012	573.01	6.00	0.00	0.00	3%	0.00	0.00	0.00	0%
III	AL0012	573.02	1.00	0.00	0.00	1%	0.00	0.00	0.00	0%
III	AL0012	573.03	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
III	AL0012	573.04	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
III	AL0012	573.05	2.30	0.00	0.00	1%	0.00	0.00	0.00	0%
III	AL0012	573.06	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
III	AL0012	573.07	8.80	0.00	0.00	5%	0.00	0.00	0.00	0%
III	AL0012	573.08	1.50	0.00	0.00	1%	0.00	0.00	0.00	0%
III	AL0012	573.09	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
III	AL0012	573.10	2.70	0.00	0.00	1%	0.00	0.00	0.00	0%
III	AL0012	573.11	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
III	AL0012	573.12	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
III	AL0012	573.13	2.40	0.00	0.00	1%	0.00	0.00	0.00	0%

Site	Route	MP	AW1	AW2	AW3	Agency HPMS	VW1	VW2	VW3	Vendor 4HPMS
III	AL0012	573.14	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
III	AL0012	573.15	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
III	AL0012	573.16	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
III	AL0012	573.17	0.80	0.00	0.00	0%	0.00	0.00	0.00	0%
III	AL0012	573.18	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
III	AL0012	573.19	1.00	0.00	0.00	1%	0.00	0.00	0.00	0%
III	AL0012	573.20	2.00	0.00	0.00	1%	0.00	0.00	0.00	0%
III	AL0012	573.21	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
III	AL0012	573.22	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
III	AL0012	573.23	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
III	AL0012	573.24	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
III	AL0012	573.25	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
III	AL0012	573.26	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
III	AL0012	573.27	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
III	AL0012	573.28	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
III	AL0012	573.29	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%
JJJ	AL0012	197.00	51.50	0.00	0.00	26%	0.00	34.19	0.00	35%
JJJ	AL0012	197.01	15.90	36.90	0.00	46%	0.00	33.54	0.00	34%
JJJ	AL0012	197.02	24.90	27.90	0.00	41%	0.00	51.65	0.00	53%
JJJ	AL0012	197.03	0.00	52.80	0.00	54%	0.00	51.24	0.00	53%
JJJ	AL0012	197.04	3.20	49.60	0.00	53%	0.74	47.21	0.00	49%
JJJ	AL0012	197.05	6.20	46.60	0.00	51%	25.04	24.36	0.00	38%
JJJ	AL0012	197.06	52.80	0.00	0.00	27%	0.00	48.75	0.00	50%
JJJ	AL0012	197.07	28.50	22.30	2.00	40%	0.00	46.36	0.00	48%
JJJ	AL0012	197.08	39.60	13.20	0.00	34%	0.00	48.19	0.00	49%
JJJ	AL0012	197.09	50.80	1.00	1.00	28%	0.00	41.09	0.00	42%
JJJ	AL0012	197.10	5.80	47.00	0.00	51%	0.00	19.80	22.17	43%
JJJ	AL0012	197.11	45.30	7.50	0.00	31%	0.00	30.10	18.94	50%
JJJ	AL0012	197.12	10.80	13.70	27.30	48%	0.00	34.84	12.08	48%
JJJ	AL0012	197.13	6.40	30.70	15.70	51%	0.00	49.37	0.00	51%
JJJ	AL0012	197.14	29.70	22.10	1.00	39%	0.00	41.65	0.00	43%
JJJ	AL0012	197.15	0.00	5.30	47.50	54%	0.00	50.68	0.00	52%
JJJ	AL0012	197.16	0.00	52.80	0.00	54%	0.00	48.37	0.00	50%
JJJ	AL0012	197.17	3.80	41.60	7.40	52%	0.00	48.75	0.00	50%
JJJ	AL0012	197.18	3.60	49.20	0.00	52%	8.20	43.13	0.00	48%
JJJ	AL0012	197.19	27.70	25.10	0.00	40%	0.00	50.32	0.00	52%
JJJ	AL0012	197.20	0.00	46.40	6.40	54%	0.00	50.38	0.00	52%
JJJ	AL0012	197.21	0.00	52.60	0.00	54%	0.00	34.01	14.09	49%
JJJ	AL0012	197.22	48.90	0.00	0.00	25%	0.00	31.38	0.00	32%
JJJ	AL0012	197.23	31.50	21.30	0.00	38%	0.00	34.96	0.00	36%
JJJ	AL0012	197.24	2.90	49.90	0.00	53%	0.00	50.88	0.00	52%
JJJ	AL0012	197.25	42.80	0.00	10.00	32%	0.00	33.98	0.00	35%
JJJ	AL0012	197.26	8.30	44.50	0.00	50%	0.00	40.32	0.00	41%
JJJ	AL0012	197.27	0.00	31.40	21.40	54%	0.00	10.63	40.23	52%
JJJ	AL0012	197.28	0.00	25.70	27.10	54%	0.00	25.93	25.99	53%
JJJ	AL0012	197.29	0.00	31.90	20.90	54%	0.00	50.41	0.00	52%

APPENDIX B

Example Calculation of Power and Significance Testing Using TOST and Paired Two-sided Student's t-test (Paired Data)

This example was conducted based on pavement cracking data collected by XDOT in 2015. The agency ratings were considered as ground reference and the ratings from vendor 4 were considered as the testing data. The rating data values are presented in Table 36.

Table 36. HPMS ratings from XDOT collected in 2015 rated by the state agency and vendor 4.

Site	Agency HPMS%	Vendor HPMS%
AAA	8.31	3.81
AAA	6.33	8.71
AAA	0.34	1.79
AAA	0.00	0.75
AAA	1.85	4.63
AAA	41.72	42.44
AAA	12.45	16.53
AAA	17.68	33.88
AAA	29.00	33.68
AAA	36.38	16.66

STEP 1 - DETERMINATION OF BASIC STATISTICS OF THE REFERENCE (AGENCY) GROUP AND THE TESTING GROUP (VENDOR 4)

Mean

$$mean = \frac{\sum_1^n x_i}{N}$$

Where x_i are the HPMS ratings from either agency or vendor; N is the number of samples in each group, which also can be regarded as number of paired samples in this case (N=10).

$$mean\ of\ agency\ ratings\ (Mean\ 1) = 15.41\%$$
$$mean\ of\ vendor\ ratings\ (Mean\ 2) = 16.29\%$$

Mean difference

$$Mean\ difference = Mean1 - Mean2$$
$$Mean\ difference = -0.88\%$$

Standard deviation

$$Standard\ deviation = \sqrt{\frac{\sum_1^n (x_i - mean)^2}{N}}$$
$$Standard\ deviation\ of\ agency\ ratings\ (SD1) = 15.32\%$$
$$Standard\ deviationof\ vendor\ ratings\ (SD2) = 15.26\%$$

Correlation coefficient

$$\rho = \frac{\sum_1^N (y_i - \bar{y})(z_i - \bar{z})}{\sqrt{\sum_1^N (y_i - \bar{y})^2 \sum_1^N (z_i - \bar{z})^2}}$$

$$\rho = 0.829$$

Where y_i are the HPMS ratings from agency and z_i are the HPMS ratings from vendor.

Standard deviation of paired difference

$$Standard\ deviation\ of\ paired\ difference\ (SD\ diff) = \sqrt{SD1^2 + SD2^2 - 2 * \rho * SD1 * SD2}$$
$$SD\ diff = 8.94\%$$

Standard error

$$Standard\ error = \sqrt{\frac{SD\ diff}{N}}$$
$$Standard\ error = 2.83\%$$

STEP 2 - PAIRED TWO-SIDED STUDENT'S T-TEST RESULTS

Degrees of freedom

$$Degrees\ of\ freedom\ (dof) = N - 1$$

$$dof = 9$$

T statistic

$$t = \frac{mean\ difference}{\frac{SD\ diff}{\sqrt{N}}}$$
$$t = -0.31$$

P-value

The p-value is based on the t statistic and degrees of freedom. It can be determined by checking the t table or software packages (Excel, Matlab, R, etc.) that have statistical analysis functions.

$$P = 0.76\ (two - sided)$$

STEP 3 - TOST EQUIVALENCE TEST RESULTS

Degrees of freedom

$$Degrees\ of\ freedom\ (dof) = N - 1$$

$$dof = 9$$

Equivalence limits

Since the mean difference is less than 30%, the equivalence limits of +/- 4 apply (Morian 2020).

T statistic

$$t_1 = \frac{lower\ limit - mean\ difference}{standard\ error}$$

$$t1 = 1.1$$

$$t_2 = \frac{upper\ limit - mean\ difference}{standard\ error}$$

$$t1 = -1.73$$

P-value

$$P_1 = 0.15\ (one - sided)$$
$$P_2 = 0.06\ (one - sided)$$
$$P = Max(P_1, P_2) = P_1 = 0.15$$

STEP 4 - POWER ANALYSIS

The power values were calculated mainly using the formular approach except for Application 3: Statistical Testing for TSDD Data Sampled under Different Frequencies. The SCI300 values from the Greenwood Beam model were selected for statistical testing with different sampling frequencies. The raw reported deflection data in the LTPP InfoMaterials database has an interval of 0.01 mi and a sampling speed of approximately 37 mph; the reported sampling frequency is approximately 1 Hz. The reported data in the LTPP InfoMaterials database was already processed; the common TSDD sampling frequency is approximately 1 kHz, but different TSDD equipment may have different sampling frequencies. Even for the same equipment, the reporting interval might change depending on the storage capacity of the disk. Thus, it is necessary to examine if the data sampled using TSDD with relatively low frequency are significantly equivalent to or significantly different from the data sampled using TSDD with high frequency.

In this case, the SCI300 values from the Greenwood Beam model were selected for statistical testing with different sampling frequencies. The raw data from the Greenwood Beam model at 0.01 mi are considered as a reference (high frequency). Then one data record (segment) was selected for every two data records (segments) from the Greenwood Beam model to mimic a lower sampling frequency of 0.5 Hz (0.02 mi). Since the sample size of the high-frequency dataset (0.01-mi interval) and the low-frequency dataset (0.02-mi interval) are not the same, the TOST procedure was formulated to test the equivalency of the unpaired groups. Also, the difference-based Welch's t-test was adopted to examine the difference between the independent (unpaired) datasets.

In Figure 16, three sections were removed due to insufficient segments in each section. A p-value of the TOST smaller than or equal to the significance level (0.05 in this study) indicates that the two groups are significantly equivalent, while it states that the two groups are significantly different for a difference-based Welch's t-test. It can be summarized from Figure 16 that 20 out of 54 sections were found to be significantly equivalent using TOST, while all sections were concluded as not significantly different using Welch's t-test. This re-emphasizes that the formulation and testing of the correct hypothesis is essential, which adopted the simulation approach to demonstrate the difference between the two approaches. The formular approach uses the following formula:

$$Power = \mathcal{T}_{n-1}\left(-t_\alpha, n-1 \middle| \frac{\sqrt{n}\,(\delta - |\epsilon|)}{\sigma}\right) - \mathcal{T}_{n-1}\left(t_\alpha, n-1 \middle| \frac{\sqrt{n}\,(\delta + |\epsilon|)}{\sigma}\right)$$

Where $\mathcal{T}_{n-1}(.\,|\theta)$ is the cumulative distribution function of the noncentral t-distribution with n-1 degrees of freedom and the noncentrality parameter θ; n is number of data pairs; ϵ is the true mean difference between the test and reference populations; δ is the upper limit of a symmetric equivalence limits; σ is the standard deviation of paired difference.

The MINITAB has the capability to calculate the power values by providing equivalence limits, sample size, Sd diff, and mean difference.

$$Power = 0.00$$

STEP 5 - SUMMARIZING THE ANALYSIS RESULTS

The TOST, student's t-test, and power results are summarized in Table 37.

Table 37. TOST and power analysis results for reference sites using XDOT 2015 reference site data from one state agency and vendor 4 (SD and mean values are in %).

Site	SD (Agency)	SD (Vendor)	Mean (Agency)	Mean (Vendor)	SD diff	Mean diff	Paired Student's t-test	TOST (±4)	Power (±4, a=0.05)
AAA	15.32	15.26	15.41	16.29	8.94	-0.88	0.76	0.15	0.00

APPENDIX C

MATLAB Code For TOST and Power

A spreadsheet for paired TOST equivalency testing was developed based on previous research (Lakens 2017). Moreover, MATLAB code was developed for TOST equivalency testing and power analysis for paired data by the authors of this report.

MATLAB CODE FOR PAIRED TOST

```
function [P] = TOST(A,B,LL,UL)

R = corrcoef(A,B); % data sets A annd B
r=R(1,2);
if isnan(r) % check if r (correlation) is not avaliable, if not avaliable then assign 0 to r.
   r=0;
else
   r;
end
[J,K]=size(A);

SD1=std(A);
SD2=std(B);

t1 = (mean(A)-mean(B)-LL)./(sqrt((SD1.^2+SD2.^2-2*r*SD1*SD2)/J));
t2 = (mean(A)-mean(B)-UL)./(sqrt((SD1.^2+SD2.^2-2*r*SD1*SD2)/J));

if t1>0
   P1=1-tcdf(abs(t1),J-1);
else
   P1=tcdf(abs(t1),J-1);
end

if t2<0
   P2=1-tcdf(abs(t2),J-1);
else
   P2=tcdf(abs(t2),J-1);
end

P=max(P1,P2);


end
```

MATLAB CODE FOR UNPAIRED TOST

```
function [P] = IndependentTOST(A,B,LL,UL)

[J1,K1]=size(A);
[J2,K2]=size(B);

SD1=std(A);
SD2=std(B);

t1 = (mean(A)-mean(B)-LL)./(sqrt((SD1.^2)./J1+(SD2.^2)./J2));
t2 = (mean(A)-mean(B)-UL)./(sqrt((SD1.^2)./J1+(SD2.^2)./J2));

dof=(((SD1.^2)./J1+(SD2.^2)./J2).^2)./(((((SD1.^2)./J1).^2)./(J1-1))+((((SD2.^2)./J2).^2)./(J2-1)));

if t1<0
   P1=1-tcdf(abs(t1),dof,'upper');
else
   P1=tcdf(abs(t1),dof,'upper');
end

if t2>0
   P2=1-tcdf(abs(t2),dof,'upper');
else
   P2=tcdf(abs(t2),dof,'upper');
end

P=max(P1,P2);
end
```

MATLAB CODE FOR PAIRED POWER

```
function [POWER] = MINITABPOWER(samplemean1,samplemean2,meanSDdiff,LL,UL,sig,N)

D=samplemean1 - samplemean2; % D= mean of data set 1 - mean of data set 2

lamda1=((D-LL)./meanSDdiff)*sqrt(N);
lamda2=((D-UL)./meanSDdiff)*sqrt(N);

x = tinv(1-sig,N-1);

POWER1= nctcdf(-x,N-1,lamda2); % can be found in the T table
POWER2= nctcdf(x,N-1,lamda1);

if abs(D)<=abs(UL)
   POWER=POWER1-POWER2;
   if POWER<0
      POWER=0;
   end
else
   POWER=nan;
end
```

APPENDIX D

Example of Determination of Alpha (Agency's Risk) for AC Pavement Cracking Verification

STEP 1 - DETERMINATION OF NUMBER OF SUBSECTIONS (N) AND SUBSECTION LENGTH

In this example, the number of subsections (N) and subsection length are set as 10 and 0.03 mi, respectively, which follows the minimum recommendation proposed by (Morian 2020). In order to investigate the impact of alpha on power results, the XDOT cracking data were averaged to obtain a subsection length of 0.03 mi, and 10 samples were taken from each site. The inspected length is thus exactly the total length of the sites. The TOST and power statistics at different alpha (agency's risk) and recommended equivalence limits were calculated. Note that, the N and subsection length are minimum recommended values; the agency can always increase them to achieve higher power. The N of 10 and subsection length of 0.03 mi were adopted to examine if the minimum recommended values can achieve sufficient power and to what value of alpha sufficient power can be achieved. If not, the minimum recommended N and subsection length should be reconsidered.

STEP 2 - POWER ANALYSIS AT DIFFERENT LEVELS OF ALPHA

It was discussed that the power is related to alpha, standard deviation of the paired difference, equivalence limits, number of subsections (N), and the population mean difference. The standard deviation of the paired difference is dependent on N and subsection length, so as the population mean difference. The XDOT cracking data were used in this example and adopted the recommended minimum N of 10 and subsection length of 0.03 mi, and thus the population mean difference and standard deviation of the paired difference are considered as fixed for each site. The equivalence limits were determined based on HPMS Cracking Percent criteria to reduce the probability of misclassification. Thus, equivalence limits are considered as fixed once the mean reference ratings are determined.

The only factor that remained that can affect the power is alpha, namely agency's risk. A small alpha value might lead to insufficient power, and an alpha value greater than 0.2 is considered too much risk for the agency. In order to investigate the influence of alpha, the power under different combinations of alpha and equivalence limits were calculated. Note that the different equivalence limits in Table 38 are just for demonstrating the effect of alpha on power results at different equivalence limits; the actual adopted equivalence limits for cracking verification are still fixed.

Table 38. Examination of the impact of alpha on power at different equivalence limits using XDOT 2015 reference site data from one state agency and vendor 4.

Site	Power (±4, a=0.05)	Power (±4, a=0.1)	Power (±4, a=0.15)	Power (±4, a=0.2)	Power (±7.5, a=0.05)	Power (±7.5, a=0.1)	Power (±7.5, a=0.15)	Power (±7.5, a=0.2)	Power (±10, a=0.05)	Power (±10, a=0.1)	Power (±10, a=0.15)	Power (±10, a=0.2)
AAA	0.00	0.05	0.25	0.40	0.56	0.77	0.86	0.91	0.88	0.95	0.98	0.99
BBB	0.96	0.99	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
CCC	0.51	0.74	0.84	0.90	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00
DDD					0.11	0.27	0.38	0.46	0.37	0.55	0.65	0.73
EEE									0.05	0.10	0.16	0.21
FFF	0.93	0.98	0.99	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
GGG									0.00	0.10	0.21	0.29
HHH	0.00	0.25	0.40	0.51	0.75	0.87	0.93	0.95	0.96	0.99	0.99	1.00
III	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
JJJ	0.13	0.36	0.50	0.59	0.85	0.93	0.96	0.98	0.99	1.00	1.00	1.00

As seen from Table 38, power is positively related with equivalence limits and alpha. The wider the equivalence limits the higher the power, the higher the alpha, the higher the power. For pavement cracking verification, as for many applications, it is recommended that the power should be kept above 0.8 (80% chance of correctly determining equivalence). Note that in real pavement cracking verification, the agency can increase N to achieve higher power. In this example, we adopted the minimum N and subsection length to examine if these specific recommended values are feasible so that a sufficient power could be achieved.

The power was calculated for each site only when the population mean difference was within the equivalence limits. For example, the power values of site DDD were not available at all levels of equivalence limits (±4%, ±7.5%, and ±10%) because the population mean difference was 11.38, which was outside of the widest equivalence limits (±10%).

STEP 3 - SUMMARIZE POWER ANALYSIS RESULTS FOR ALL SITES AND ALL YEARS

In order to investigate if the minimum recommended values of N and subsection length can achieve sufficient power and to what value of alpha sufficient power can be achieved, the above power analysis was conducted on three years (2013, 2014, and 2015) of cracking data from XDOT DOT. The results are summarized in Table 39.

In Table 39, the denominator is the number of sites where the agency and vendor HPMS Cracking Percent ratings were within the corresponding equivalence limits (± 4 for agency HMPS ratings ≤ 30% and ± 10 for agency HMPS ratings > 30%), while the numerator is the number of sites where a power no less than 0.8 was achieved. The higher the value, the higher the probability that the state agency has sufficient power to conclude a qualified vendor as equivalent when the vendor is in fact qualified. As seen from the values that they are all less than or equal to 1, indicating that "power no less than 0.8" is a stricter constraint than "mean difference within equivalence limits," it can be observed that when increasing alpha, the number of sites that concluded "equivalent" increases as well at the same equivalence limits. It is because the increase of alpha allows a higher value of TOST P-value to be concluded as "equivalent." Moreover, the higher the alpha, the higher the power, and thus a greater number of sites had power no less than 0.8.

Table 39. Impact of alpha on number of sites where the power greater than 0.8 was achieved / number of sites where "equivalent" was concluded using XDOT 2013, 2014, and 2015 reference site data.

Agency Ratings	Limits, alpha	2013	2014	2015-1	2015-2	2015-3	2015-4	Sum
HPMS < 30	±4, a=0.05	0/0	1/2	2/2	2/2	2/2	3/4	10/12
HPMS < 30	±4, a=0.10	0/1	1/2	2/2	2/3	2/2	3/4	10/14
HPMS < 30	±4, a=0.15	0/2	2/2	2/2	2/3	2/2	4/5	12/16
HPMS < 30	±4, a=0.20	0/3	2/2	2/2	2/3	2/2	4/5	12/17
HPMS < 30	±7.5, a=0.05	3/4	3/4	2/3	5/6	2/3	4/5	19/25
HPMS < 30	±7.5, a=0.10	4/5	3/4	2/4	5/6	3/3	4/5	21/27
HPMS < 30	±7.5, a=0.15	4/5	3/4	3/5	6/6	3/4	5/5	24/29
HPMS < 30	±7.5, a=0.20	4/5	4/4	3/5	6/6	3/4	5/5	25/29
HPMS > 30	±10, a=0.05	0/0	2/3	1/1	3/3	1/2	2/2	9/11
HPMS > 30	±10, a=0.10	0/0	2/3	1/1	3/3	1/2	2/2	9/11
HPMS > 30	±10, a=0.15	0/0	2/3	1/2	3/3	1/2	2/2	9/12
HPMS > 30	±10, a=0.20	0/0	3/3	1/2	3/3	2/3	2/2	9/12
HPMS > 30	±12.5, a=0.05	0/0	3/3	1/2	3/3	2/3	2/2	11/13
HPMS > 30	±12.5, a=0.10	0/0	3/3	1/2	3/3	2/3	2/2	11/13
HPMS > 30	±12.5, a=0.15	0/0	3/3	2/2	3/3	3/3	2/2	13/13
HPMS > 30	±12.5, a=0.20	0/0	3/3	2/2	3/3	3/3	2/2	13/13

STEP 4 - INTERPRETING THE RESULTS

For pavement cracking verification or vendor selection, we are more interested in how many sites have sufficient power given the conclusion of "equivalent" was drawn. From the last column of the table, it was seen that increasing the equivalence limits from ± 4 to ± 7.5 and from ± 10 to ± 12.5 doesn't necessarily increase the percentage of sites that had power no less than 0.8. With the recommended equivalence limits of ± 4 and ± 10, the percentage is already high. In terms of the alpha values, it should be noted that as alpha is the agency's risk, a large alpha will be a disadvantage to the state agencies. Moreover, increasing the alpha doesn't necessarily increase the percentage but put more risk on the state agencies.

Statistically speaking, large alpha and wider equivalence limits are preferable, since they come with higher values in the table. However, wide equivalence limits may cause ratings with large difference to be regarded as equivalent and high alpha will increase the agency's risk of accepting an unqualified vendor. After considering all the mentioned factors, alpha of 0.05 are recommended for sites with agency HPMS Cracking Percent ratings less than and greater than 30%.

APPENDIX E

Paired IRI from LTPP and Vendor-collected State Agency Data

Table 40. Paired IRI data from LTPP and vendor-collected state agency data in 2011.

Pavement Type AC	Most Recent Matched Year	LTPP Data (in./mi) Avg. L IRI	LTPP Data (in./mi) Avg. R IRI	Agency Data (in./mi) Avg. L IRI	Agency Data (in./mi) Avg. R IRI
51-0114	2011	89.03	71.80	80.00	82.00
51-0115	2011	50.78	54.96	73.00	67.00
51-0116	2011	58.06	58.85	81.00	67.00
51-0117	2011	50.09	51.19	67.00	70.00
51-0118	2011	46.01	46.98	85.00	75.00
51-0119	2011	71.15	71.79	85.00	71.00
51-0120	2011	64.74	62.50	95.00	111.00
51-0121	2011	66.62	57.65	128.00	115.00
51-0122	2011	56.90	55.96	73.00	64.00
51-0123	2011	47.32	51.51	80.00	77.00
51-0124	2011	45.37	56.18	78.00	68.00
51-0159	2011	65.15	58.37	86.00	91.00
51-1417	2011	70.13	78.69	92.00	82.00
40-0114	2011	72.76	66.26	76.45	81.25
40-0115	2011	71.84	83.15	82.85	78.65
40-0116	2011	77.98	63.90	88.50	64.55
40-0117	2011	79.26	75.66	76.45	69.35
40-0118	2011	70.61	60.45	95.00	67.45
40-0119	2011	60.43	54.36	63.10	55.05
40-0120	2011	68.62	67.73	77.27	66.33
40-0121	2011	81.34	91.35	96.35	94.35
40-0123	2011	73.04	54.78	78.40	67.20
40-0124	2011	73.11	63.12	82.00	72.75
40-0160	2011	75.70	93.66	75.80	86.75
54-1640	2011	48.19	45.43	60.35	66.50

Table 41. Paired IRI data from LTPP and vendor-collected state agency data in 2012.

Pavement Type	Most Recent Matched Year	LTPP Data (in./mi)	LTPP Data (in./mi)	Agency Data (in./mi)	Agency Data (in./mi)
AC		Avg. L IRI	Avg. R IRI	Avg. L IRI	Avg. R IRI
22-0113	2012	84.03	85.11	87.00	75.00
22-0114	2012	45.39	43.40	84.00	76.33
22-0115	2012	48.32	43.98	56.00	50.00
22-0116	2012	50.26	46.34	51.00	50.50
22-0117	2012	45.71	45.66	57.50	49.00
22-0118	2012	55.35	50.16	64.00	61.00
22-0119	2012	42.55	41.23	57.00	58.50
22-0120	2012	43.47	40.33	51.50	57.00
22-0121	2012	47.91	54.68	60.00	61.50
22-0122	2012	45.68	37.59	62.00	58.50
22-0123	2012	39.50	36.19	57.00	54.00
22-0124	2012	45.77	47.53	55.50	60.50

Table 42. Paired IRI data from LTPP and vendor-collected state agency data in 2013.

Pavement Type	Most Recent Matched Year	LTPP Data (in./mi)	LTPP Data (in./mi)	Agency Data (in./mi)	Agency Data (in./mi)
AC		Avg. L IRI	Avg. R IRI	Avg. L IRI	Avg. R IRI
40-0114	2013	90.86	60.22	105.10	80.00
40-0115	2013	80.11	73.51	92.35	85.50
40-0116	2013	84.16	64.08	89.30	69.60
40-0117	2013	88.34	68.77	91.05	77.90
40-0118	2013	80.57	56.57	93.35	73.75
40-0119	2013	74.75	52.25	80.35	63.55
40-0120	2013	110.61	73.88	102.37	80.73
40-0121	2013	142.26	90.53	151.35	108.10
40-0123	2013	80.75	64.39	96.65	75.45
40-0124	2013	74.71	68.91	94.90	84.10
40-0160	2013	71.08	77.89	86.70	87.55

Table 43. Paired IRI data from LTPP and vendor-collected state agency data in 2014.

Pavement Type	Most Recent Matched Year	LTPP Data (in./mi)	LTPP Data (in./mi)	Agency Data (in./mi)	Agency Data (in./mi)
AC		Avg. L IRI	Avg. R IRI	Avg. L IRI	Avg. R IRI
19-1044	2014	51.45	80.59	66.94	87.73
51-0114	2014	94.44	77.45	113.00	105.00
51-0115	2014	57.97	57.86	52.00	54.00
51-0116	2014	62.07	64.08	62.00	58.00
51-0117	2014	56.11	53.02	47.00	50.00
51-0118	2014	53.02	50.69	49.00	48.00
51-0119	2014	74.97	79.23	85.00	91.00
51-0120	2014	66.17	66.93	76.00	69.00
51-0121	2014	71.27	64.22	56.00	57.00
51-0122	2014	58.05	61.97	61.00	67.00
51-0123	2014	54.44	55.69	63.00	64.00
51-0124	2014	52.49	59.48	64.00	67.00
51-0159	2014	71.19	60.75	69.00	58.00
51-1417	2014	67.48	90.36	100.00	103.00
22-0113	2014	89.52	104.62	106.00	104.50
22-0114	2014	48.51	45.75	77.00	67.50
22-0115	2014	49.00	46.05	52.50	47.50
22-0116	2014	50.21	49.48	50.00	49.00
22-0117	2014	49.21	48.29	54.50	49.00
22-0118	2014	55.39	49.04	55.50	52.00
22-0119	2014	43.03	42.25	51.50	51.50
22-0120	2014	46.08	47.09	52.50	54.00
22-0121	2014	50.05	62.38	63.00	70.00
22-0122	2014	44.42	39.21	55.50	49.50
22-0123	2014	44.11	36.04	52.00	49.00
22-0124	2014	46.46	49.38	56.50	62.00
41-2002	2014	80.75	125.06	89.32	116.61
54-1640	2014	55.24	73.24	50.85	58.00

Table 44. Paired IRI data from LTPP and vendor-collected state agency data in 2013.

Pavement Type	Most Recent Matched Year	LTPP Data (in./mi)	LTPP Data (in./mi)	Agency Data (in./mi)	Agency Data (in./mi)
PCC		Avg. L IRI	Avg. R IRI	Avg. L IRI	Avg. R IRI
19-0213	2013	73.61	75.91	75.01	82.59
19-0214	2013	137.63	138.23	150.12	166.09
19-0215	2013	102.01	136.45	124.34	158.50
19-0216	2013	122.75	130.24	141.42	148.88
19-0217	2013	141.32	122.41	164.09	170.93
19-0218	2013	157.67	174.35	161.10	184.94
19-0220	2013	107.83	115.42	123.05	127.12
19-0221	2013	93.27	94.80	101.80	104.91
19-0222	2013	107.95	137.10	113.05	153.84
19-0223	2013	114.87	135.82	116.39	145.76
19-0224	2013	73.21	86.18	85.45	94.62
19-0259	2013	66.03	94.19	78.09	89.37
19-3033	2013	97.37	118.41	104.10	136.72
40-4157	2013	53.43	56.07	62.75	66.85