QUALITY MANAGEMENT FOR PAVEMENT CONDITION DATA COLLECTION

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ABSTRACT
Within a pavement management system, pavement condition data are used for modeling pavement performance; to trigger maintenance, rehabilitation, and reconstruction; to evaluate program effectiveness; and to satisfy many other purposes. While there are many different methodologies used for assessing pavement condition (i.e., manual, semi- and fully automated surveys), the need for quality data remains the same. Agencies take a number of steps to ensure and verify data quality, including calibration of the data collection equipment or the inspection teams, incorporating quality control sections that are re-inspected to assess repeatability, verifying reasonableness and completeness of the pavement condition survey, and conducting audits of the pavement distress data.

As part of a Federal Highway Administration project, a *Practical Guide for Quality Management of Network-Level Pavement Condition Data* was developed based on agency procedures, practical examples, and case studies. This paper summarizes the components of a data quality management plan for pavement condition data collection and when applicable, provides examples of agency practices. The primary activities involved in developing a data quality management plan include identifying what data quality standards will be used, identifying what activities need to occur to achieve those standards, measuring the data, and reporting the results. Specifically related to pavement condition data collection, the key components of a data quality management plan include establishing data collection/rating protocols, defining data quality standards, determining personnel responsibilities, providing personnel training programs, establishing equipment calibration and method acceptance, conducting data inspection, applying corrective action, and reporting the results of the quality management process.

INTRODUCTION
Pavement condition data are a critical element to pavement management. Since the pavement condition data are used in a variety of agency functions (e.g., assessing current condition; developing performance prediction models; establishing the performance of different pavement designs, treatments, or materials; developing treatment recommendations, timing, and costs; allocating agency resources) ensuring that the results of the pavement condition survey are as reliable, accurate, and complete as possible will significantly enhance the use and effectiveness of the pavement management outcomes.

Pavement performance is dependent on a variety of factors, such as pavement type and thickness, climate and traffic loading, drainage conditions, subgrade type, and construction quality. The variability of pavement performance due to these types of factors can vary from one pavement segment to the next, from year to year, and are reflected in the pavement condition survey. Pavement performance is typically tracked through pavement condition surveys that include the type (e.g., cracking, faulting, rutting, and ride), severity (e.g., low, medium, and high), and extent (e.g., length, area, count) of pavement distress. Minimizing the variability in pavement condition assessment helps to ensure that the survey results reflect actual pavement performance and not variations in the survey results due to data quality issues.

Pavement condition data is often used to calculate condition indices for describing current condition. The level of data variability can impact the distress severity and extent, which may significantly affect the distress deduct values. Data variability not only impacts the pavement condition assessment, but can also lead to inaccuracies in performance prediction, which can impact treatment timing, treatment selection, and budget estimates. For example, in ASTM

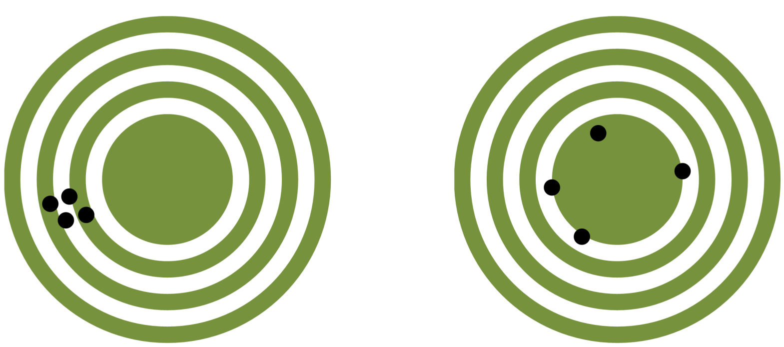
D6433, *Standard Practice for Roads and Parking Lots Pavement Condition Index Surveys* method, a one percent difference in low-severity fatigue cracking makes a 12 point difference in the pavement condition index (PCI) calculation. This 12 point difference may not only impact the treatment recommendation, but also the associated cost.

As part of a Federal Highway Administration (FHWA) project, a *Practical Guide for Quality Management of Network-Level Pavement Condition Data* (*Practical Guide*) was developed based on agency procedures, practical examples, and case studies *(1)*. Agency procedures and practices were identified through a literature search, agency survey, and follow up interviews (as needed). The results of the literature search, agency survey, and follow up interviews indicated that while several highway agencies have documented quality management processes, such as British Columbia, Louisiana, Oklahoma, and Pennsylvania; however, the majority of agencies do not.

The *Practical Guide* was developed in an effort to aid highway agencies in developing and implementing a quality management plan for network-level pavement condition data collection and processing. Although specifically targeting highway agencies, the contents of the *Practical Guide* are also applicable to local agencies, and are useful regardless of the pavement network size, the type of pavement distress/condition collected (e.g., smoothness, rut depth, faulting, cracking), the method of data collection (e.g., manual or automated), or the method of condition data processing (e.g., fully automated, semi-automated).

DATA QUALITY MANAGEMENT

Traditional data quality management is based on the approach that there is a single "true" or reference value (i.e., ground truth) and that the measured data is as close as possible to this true value *(1)*. Data quality is then described as the deviation from the true value due to random (e.g., unknown and unpredictable changes in measurement) and systematic (e.g., measuring equipment or process) errors. Random errors tend to result in lower precision, while systematic errors tend to result in lower accuracy in relation to the ground truth. Figure 1 illustrates examples of accuracy and precision. Accuracy is the closeness of the measurement to the ground truth value, while precision is the variation of multiple measurements of the same condition (e.g., variation of results from multiple profile runs for determining IRI, faulting, or rut depth).



a. High precision, low accuracy   b. High accuracy, low precision

FIGURE 1 Examples of precision and accuracy (*1*).

Pavement management systems are more reliable, accurate, and complete when higher quality data is used. Substandard data can result in poor decisions, resulting in wasted money or a reduction in the viewed worthiness of a pavement management system. However, there is also a balance between quality data and the cost and time required to collect it. A study conducted by the Virginia Department of Transportation (DOT) identified the following benefits of implementing a quality management plan for pavement condition data collection *(2)*:

- Improved accuracy and consistency of data.
- Better credibility within the organization.
- Better compliance with external data requirements.
- Better integration with other internal agency data.
- Cost-savings from more appropriate treatment recommendations.
- Improved decision support for managers.

DATA QUALITY PLAN

A data quality management plan documents the methods for measuring data, the required level of data quality, the personnel responsible for ensuring quality data, the required personnel training programs, the type and frequency of data, database, and video checks, the corrective actions in the event the data quality standards are not being met, and the reporting of the data quality management results. The data quality plan should include all aspects of the data collection process, prior to and during data collection and through data acceptance. Each component of the data quality plan is further described in the following sections.

Data Collection and Rating Protocols

Whether the pavement condition survey is conducted using windshield, automated, or semi-automated surveys, the data collection process should be well-documented to ensure proper procedures are being followed by personnel associated with the condition survey (both pavement rating and equipment operation). There are a number of methods and test procedures for conducting pavement condition surveys. For example, pavement condition assessments can be conducted in accordance with FHWA *Distress Identification Manual for the Long-Term Pavement Performance Program (3)*, ASTM D6433, *Standard Practice for Roads and Parking Lots Pavement Condition Index Surveys*, or agency-developed methods. In addition, there are a number of applicable standards and test procedures from the American Society for Testing and Materials (ASTM) and the American Association of State Highway and Transportation Officials (AASHTO), such as, AASHTO R 43-13, *Standard Practice for Quantifying Roughness of Pavements*, AASHTO PP 70-10, *Standard Practice for Collecting the Transverse Pavement Profile*, AASHTO R 36-13, *Standard Practice for Evaluating Faulting of Concrete Pavements*, and AASHTO PP 67-10, *Standard Practice for Quantifying Cracks in Asphalt Pavement Surfaces from Collected Images Utilizing Automated Methods.* Data items typically collected during the pavement condition survey are shown in table 1.

Regardless of the method(s) used, the pavement condition and rating protocol should clearly state what types of distress are to be collected, how the distress is quantified (e.g., number of cracks, total length, percent area), what are the applicable severity levels, what is the reporting interval, and when applicable, how the distress is computed (e.g., quarter-car for determining the International Roughness Index [IRI], 5-point stringline method for determining rut depth).

TABLE 1 Data typically collected during the pavement condition survey (*1*)

Data Items Typically Collected	Other Items Collected Concurrently[2]
International Roughness Index (IRI)	Video images
Rut depth	GPS coordinates
Cracking	Geometrics (e.g., curve, grade, cross-slope, elevation)
Faulting (JPCP)[1]	Other assets (e.g., structures, signals, signs, guardrail)
Punchouts (CRCP)[1]	Events (e.g., construction zones, railroad crossings)
Patching	
Joint condition (JPCP, CRCP)	
Raveling	
Bleeding	
Surface texture	

[1] JPCP = jointed plain concrete pavement; CRCP = continuously reinforced concrete pavement.
[2] Typically collected as part of an automated data collection survey.

Data Quality Standards

Data quality standards are used to determine how well the results of the pavement condition survey match the actual conditions. Actual conditions are measured at control, verification, and blind sites and compared to the results of the pavement condition survey according to agency-determined accuracy and precision statements. The following sections further describe establishing ground truth values, agency values for accuracy and precision statements, and a brief summary of agency statistical methods for data evaluation.

Establishing the Ground Truth

The methods used to determine the ground truth should result in values that are equal to or better in accuracy than what will be used during the production survey. Ground truth values for IRI are typically measured using a Face Dipstick®, walking profiler, or other types of Class 1 profilers. Rut depth is commonly measured using a straightedge, a walking profiler, or a Dipstick®. Manual methods for measuring crack and joint faulting commonly include a straightedge or a fault meter (e.g., Georgia fault meter). Finally, manual ratings for other types of surface distress (e.g., cracking, potholes, raveling, joint deterioration) are usually evaluated using a walking survey or by reviewing video images and noting the presence of distress (when automated surveys are used).

Control, Verification, and Blind Site Testing

Control, verification, and blind sites are used during the quality control, acceptance, and independent assurance process. Prior to the production survey, control sites are used to verify equipment calibration, to accept the rating method, to provide rater training, and to establish the pavement condition ground truth. During the production survey, control sites are used to check rater repeatability (repeated measurements of the same section under the same or similar conditions) and reproducibility (degree of variation among results obtained by different raters of the same pavement segment), and to check the accuracy and precision of the data collection equipment *(1)*. The criteria and measurements for ground truth at the control site are established by the agency (or third-party) prior to the production survey. Control sites are typically centrally located and range in length from 0.5 to 1.0 miles (0.8 to 1.6 km).

Verification sites are typically geographically located and are used to verify data collection during the production survey. Prior to the production survey, verification sites are rated by the agency using the same rating practices and methods that will be used during the production survey (ground truth is typically not measured). Multiple runs/passes are conducted on the verification site(s) to determine the accuracy and repeatability of the sensor data and the distress rating.

Blind sites are similar to verification sites in that they are used by agencies to verify data collection equipment and pavement rating procedures during the production survey; however, the data collection team is unaware of the blind site location. The agency determines the condition of the blind site (may include ground truth testing) prior to the production survey. After the data collection team has completed testing and submitted the data for a blind site, the agency checks the results against the quality standards.

Tables 2 and 3 provide examples of agency control and verification site requirements, respectively.

TABLE 2 Examples of agency control site requirements (*1*)

Agency	Number of Sites	Site Length	Details
British Columbia	4 asphalt	0.5 mi (0.8 km)	Selected using prior year's survey data or control sections
Louisiana	4 asphalt 4 JCP[1] 4 CRCP[2]	0.5 mi (0.8 km)	Service provider is required to evaluate prior to proceeding to the next district
Oklahoma	2 asphalt 2 JCP	0.5 mi (0.8 km)	Used as part of the scoring of the service provider's proposal
Pennsylvania	4 asphalt 2 JCP	~0.5 mi (0.8 km)	Service provider must run each vehicle prior to proceeding to production testing
Virginia	8 asphalt 2 JCP 2 CRCP	Variable	Calibrate distress rating process Establish precision and bias for roughness, rut depth, and distress

[1] JCP – jointed concrete pavement
[2] CRCP – continuously reinforced concrete pavement

TABLE 3 Examples of agency verification site requirements (*1*)

Agency	Details
British Columbia	• One site every 3 days • For long contracts (> 30 days) also verify repeatability
Colorado	• Virtual review of eight asphalt and two concrete segments from the first 500 mi (selected randomly) • Each region reviews an additional three to six sites
Louisiana	• Review 5 percent of collected sections
Maryland	• IRI and rut depth each month (> 3 times during survey) • Compare cracking index with previous year
Nebraska	• 10 percent of pavement segments spot checked in field
Oklahoma	• Weekly evaluation of verification or control site (6 to 10 per survey year)
Pennsylvania	• 125 blind sites • Random sample of 2.5 percent of all segments surveyed

Data Accuracy and Precision Statements

Accuracy and precision statements are used to determine the acceptable level of variability between the ground truth distress/condition measurements as compared to the results achieved by the pavement rating team(s) during the production survey. As noted previously, accuracy and precision values are typically based on multiple runs/surveys of the control sites. Examples of agency accuracy and precision criteria are shown in table 4.

TABLE 4 Example of agency accuracy and precision requirements (*1*)

Agency	Data Element[1]	Accuracy	Precision
Alabama	IRI	± 5% of control section	± 1 in/mi (0.02 m/km)[2]
	Rutting	±0.1 in (2.5 mm) of manual survey	± 0.01 in (0.25 mm)[2]
	Faulting	± 0.1 in (2.5 mm) of manual survey	± 0.01 in (0.25 mm)[2]
British Columbia	IRI	± 10% of Class I profile survey	± 6.3 in/mi (0.1 m/km)[3]
	Rutting	± 0.12 in (3 mm) of manual survey	± 0.12 in (3 mm)[3]
	PDI[4]	± 1 PDI[2] (0 to 10 scale)	± 1 standard deviation[3]
Oklahoma	IRI	± 5% of dipstick or Class I profiler	1 in/mi (0.02 m/km)
	Rutting	± 0.08 in (2.0 mm) of manual survey	0.01 in (0.25 mm)
	Faulting	± 0.08 in (2.0 mm) of manual survey	0.01 in (0.25 mm)
Virginia	IRI	±5% of agency reference value	< 5% of 10 runs
	Rutting	± 0.08 in (2.0 mm) of reference value	< 5% of 10 runs

[1] *All agencies collect pavement condition using automated data collection vehicles.*
[2] *Average of 5 runs.*
[3] *Standard deviation of 5 runs.*
[4] *Pavement distress index.*

Sample Size

In order to ensure a statistically valid assessment, an appropriate number of samples should be determined for evaluating data quality. For pavement condition assessment, a sample is considered to be a pavement segment that represents conditions typically found on the pavement network for each pavement type. The sample size can be determined by equation 1.

$$n = \left[\frac{z*_{\alpha/2}\ \sigma^2}{Margin\ of\ Error}\right]^2 \qquad \text{(Equation 1)}$$

where,

n = sample size.

$z^*_{\alpha/2}$ = critical z-value (two-tailed test).

σ = population standard deviation (or sample standard deviation for $n \geq 30$).

The margin of error is defined, in percent, as the maximum expected difference between the population and the sample parameter (i.e., how much error you can tolerate, if unknown, 5 percent is often assumed).

Table 5 represents the sample size estimates for confidence levels of 90, 95, and 99 percent and a margin of error of 2.5 and 5 percent. The confidence level is defined as the probability that the estimated value is in the population (95 percent is commonly used). In table 5, the population size can be considered to be, for example, the number of pavement segments by pavement type, or the number of miles/segments by region and pavement type. Table 5 also indicates that as the population size increases, the confidence level increases, and the margin of error decreases, the sample size increases.

TABLE 5 Sample size estimates

Population Size	CL-90% MOE-5%	CL-90% MOE-2.5%	CL-95% MOE-5%	CL-95% MOE-2.5%	CL-99% MOE-5%	CL-99% MOE 2.5%
500	176	343	218	378	286	421
1,000	214	520	278	607	400	727
2,500	245	756	334	952	525	1,288
5,000	257	890	357	1,176	586	1,734
10,000	264	977	370	1,333	623	2,098
25,000	268	1,038	379	1,448	647	2,400
50,000	270	1,060	382	1,491	655	2,521
75,000	270	1,067	383	1,506	658	2,564
100,000	270	1,071	383	1,514	660	2,586

Note: CL – confidence level; MOE – Margin of Error; calculations are based on http://www.raosoft.com/samplesize.html.

Statistical Evaluation

The most common statistical methods used by highway agencies for quality management include the paired t-test, the Cohen's kappa statistic, and percent within limits. Each of these methods is briefly described in the following *(1)*:

Paired t-test is used to evaluate a sample of matched pairs or similar units, or one group of units that has been tested twice (e.g., comparing the ground truth to the pavement condition survey results, comparing two raters evaluating the same pavement segment). The assumptions for the paired t-test include that each of the two populations being compared follow a normal distribution, have the same variance, and the samples have been selected randomly and independently from the population. The paired t-test statistic is calculated by:

$$t_0 = \frac{\bar{d}}{s_d/\sqrt{n}} \quad \text{(Equation 2)}$$

where,

t_0 = t-test statistic
$\bar{d}$ = average of the n differences
s_d = standard deviation of the differences
n = number of matched pairs

Prior to calculating the t-test statistic, the hypothesis to be evaluated should be identified. Common null and alternate hypotheses include:

$$\text{Null hypothesis: } H_0\text{: } \bar{x}_1 - \bar{x}_2 = 0 \quad \text{(Equation 3)}$$
$$\text{Alternate hypothesis: } H_a\text{: } \bar{x}_1 - \bar{x}_2 \neq 0$$

where,

$\bar{x}_1$ = average of population 1
$\bar{x}_2$ = average of population 2

If t_0 > critical t-value ($t_{1-\alpha/2,df}$), the null hypothesis is rejected, indicating that the population means are likely different. However, if $t_0 < t_{1-\alpha/2,df}$, the null hypothesis cannot be rejected, indicating that the population means are likely the same. The critical t-value ($t_{1-\alpha/2,df}$) is determined using the standard normal distribution table which is found in the majority of statistical textbooks.

Cohen's kappa statistic can be used to measure the level of agreement between raters. A score is calculated that quantifies how much consensus exists among the different raters, as well as the possibility of raters agreeing or disagreeing simply by chance. The Cohen's kappa statistic is determined by:

$$K = \frac{n_a - n_c}{n - n_c} \quad \text{(Equation 4)}$$

where,

K = kappa statistic
n = total number of observations
n_a = number of observations in agreement
n_c = number of agreements due to chance

The Cohen's kappa statistic ranges from -1 to 1 (0 to 1 is typical). A value of 1 indicates that there is perfect agreement between the ratings (every distress is measured the same), while a value of 0 indicates no agreement than that expected by chance (e.g., raters guessed at the distress). Table 6 provides an example of the kappa statistic values.

TABLE 6 Cohen's kappa statistic values (*1*)

Cohen's Kappa Statistic	Strength of Agreement
< 0.00	Disagreement
0.00	Chance of agreement
0.01 to 0.20	Slight Agreement
0.21 to 0.40	Fair Agreement
0.41 to 0.60	Moderate Agreement
0.61 to 0.80	Substantial Agreement
0.80 to 0.99	Almost Perfect Agreement
1.00	Perfect Agreement

Percent within limits (PWL) is used by most highway agencies to evaluate construction material quality. This concept has been applied to evaluate pavement condition data by the Pennsylvania DOT. PWL is defined as the "percentage of the lot falling above the lower specification limit (LSL), beneath the upper specification limit (USL), or between the USL and LSL" *(4)*. The PWL calculation uses the sample mean and standard deviation to estimate the percent of the data that is within the specification limits. The percent within limits is determined using:

$$\bar{x} - \frac{z*_{\alpha/2}\sigma}{\sqrt{n}} \quad \text{to} \quad \bar{x} + \frac{z*_{\alpha/2}\sigma}{\sqrt{n}} \quad \text{(Equation 5)}$$

where,

$z*_{\alpha/2}$ = critical value (two-tailed test).
σ = population standard deviation.

n = sample size.

Personnel Roles and Responsibilities
An effective quality management plan depends on the personnel responsible for managing, updating, and implementing the plan. In addition, the personnel involved in the plan should be included in developing the plan to improve the level of buy-in from the participating staff. With that in mind, the quality management plan should also include clearly defined roles and responsibilities for each feature of the data quality process. For example, the quality management plan should clearly identify the staffing, roles, and responsibilities for data quality control and acceptance criteria, scheduling, problem reporting, documentation, and tracking. For example, the team collecting the data should also be responsible for conducting the quality control activities; alternatively, the agency pavement management division should assess the acceptability of the data since they are the ultimate owner of the survey results.

Personnel Training Programs
Personnel training should be conducted for all phases of the data collection, rating, and data reduction. For automated systems, data collection personnel must learn how to conduct startup, daily, and end of day data and systems checks, calibrate the sensors, operate the equipment, monitor data collection in real time, and troubleshoot hardware, software, video, and automotive systems of the complex data collection equipment. For a pavement condition rating (semi-automated or manual), raters must learn the proper protocols and should pass competency tests to ensure the proper procedures are being followed. Rater evaluation may include comparison to the lead rater (single-rater repeatability) and cross-rater checks (reproducibility). Finally, data reduction personnel must learn how to compile the data in the proper format and check for errors.

Equipment Calibration and Method Acceptance
Equipment calibration and rating method acceptance are verified prior to data collection and periodically during the production survey to ensure the equipment operates and functions appropriately, and that the pavement condition analysis methods are being followed. Equipment calibration/verification should be conducted in accordance with applicable ASTM/AASHTO standards and manufacturers' recommendations. These generally include *(1)*:

- Calibrate equipment prior to and periodically during data collection. Use control sites with known length and condition values. Distance measuring instrument (DMI) can be calibrated in the field, while equipment laser sensors will require laboratory calibration.
- Automated vehicle checks: check that computer systems are properly functioning; tire pressure checks; real-time monitoring of data collection; and at the end of the day check data files for irregularities, and sample video images for completeness and clarity.
- Laser profiling system calibration includes laser sensor checks and block tests; accelerometer calibration; bounce tests to verify sensors and accelerometers; accelerometer checks; and block tests to check the vertical height sensor.
- Video camera checks include image quality; image resolution; proper camera angle; camera enclosures; and remove lens debris.

Data, Database, and Video Image Checks
Typically, data inspection checks are performed by the agency as it is submitted. Conducting data checks as the data arrives will aid in minimizing the potential of repeat errors in subsequent data sets. Typical agency data, database, and video image checks include:

- Distress rating checks include expected number of railroad crossings and bridge segments; incorrect distress type or severity; maximum patch length; missing 5 or more low/medium severity distresses; missing high severity distresses; non-matching distress types to pavement type; over-rating (identifying a distress when one is not present); ranges of individual and combinations of distress; and comparison to distress data from previous years.
- Database checks include bridge segments that were not rated as bridges; data file structure; deviation of pavement type and pavement texture from previous year; duplicate records; highway not in network; incomplete data; incorrect highway limits; incorrect pavement type; location description (route, direction, section begin and end milepost); minimum and maximum tolerance parameters; non-numeric data in a numeric field; null and negative values; number of missing consecutive segments; sections with longer lengths than specified; sudden change in roughness and rut depth; and zero slab/joint counts for concrete pavements.
- Video checks include image clarity; image resolution; brightness/lighting; proper camera angle (aim); camera focus; missed images; and stitching of images.

Corrective Action
In the event that the data does not meet the quality requirements, corrective action should be applied. For agencies that conduct the pavement condition survey using a service provider, it is important to discuss and agree upon the corrective actions prior to data collection rather than waiting until a problem is discovered. The type of corrective action to be taken depends on the type of problem encountered. Corrective action typically includes re-collecting or rerating pavement segments, retraining the data collection team or pavement raters, recalibrating equipment, and replacing defective equipment.

Reporting
Reporting of the quality management process is an important component of the overall quality management program. Documenting the quality management process enables the agency to track problems, identify issues to be resolved, and enable the continuous improvement of the process. The quality management document should include the following details *(1)*:

- Equipment and personnel used during data collection.
- Equipment calibration, maintenance, problems and corrective actions taken.
- Schedule and the reasons for any changes.
- Collection procedures and protocols used.
- Daily operator logs with results from system checks, bounce tests, and so on.
- Variances in procedures or changes in collection methods.
- Guidance documents.
- Control, verification, and blind site testing and results.
- Quality control activities.
- Rater checks and intra- or inter-rater comparisons.
- Quality control and acceptance issues and corrective actions taken.
- Copies of all correspondences.

APPLICATION OF THE QUALITY MANAGEMENT PLAN

As documented in the National Cooperative Highway Research Program (NCHRP) Synthesis 401, *Quality Management of Pavement Condition Data*, Quality Control (QC) plans for pavement condition data incorporate three phases *(5)*:

- Pre-production phase—aspects include training of personnel, calibration of measurement equipment, identification of verification sites, and establishing pavement condition criteria.
- Production phase—activities include measurement equipment verification, testing of verification sites, real-time data checks, daily verification of pavement condition data completeness and reasonableness, periodic checks of processed pavement condition data (e.g., smoothness, rutting, and faulting), and distress ratings.
- Post-production phase—checks of the transferred pavement condition data (e.g., missing sections, out-of-range data, and verification of distress ratings).

Implementation of the quality management procedures that include all three phases will assist in providing acceptable data quality criteria, acceptable levels of variability, and procedures that will help to minimize data variability. Table 7 provides a summary of the quality management plan activities for each of the three phases.

TABLE 7 Pavement condition survey activities

Pre-Production	Production	Post-Production
Data collection: a. Rating protocols b. Deliverables, data format, and schedule c. Data quality requirements and acceptance plan Quality control plan a. Equipment calibration and verification b. Personnel training c. Control and verification sites	Field collection: a. Equipment checks b. Real-time monitoring c. End of day data checks d. Control and verification site testing Data checks a. Sensor data and video images b. Distress rating Agency checks a. Monitor control and verification site testing b. Check data and video image samples	Data quality checks a. Segmentation and location b. Format c. Completeness d. Expected range e. Consistency f. Time-series or other comparisons Acceptance sampling a. Sample size b. Compare sample and batch ratings Additional tools a. Automated checks b. Independent assurance c. Data quality reports

SUMMARY

This paper documents the features of the data quality management plan which will assist highway and local agencies in developing, refining, and maintaining a quality management process for pavement condition data collection. To be effective, the data quality management plan should be updated periodically to reflect equipment changes, pavement condition assessment method updates and modifications, and improvements in the data collection process.

Benefits of a data quality management process for pavement condition data collection include improved data accuracy and consistency, better credibility in the pavement management system, better compliance with external data requirements, better integration with other agency data, more appropriate and timely treatment recommendations, and improved decision support for managers *(1)*.

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