**KYTC Data Quality Management Plan**

**Introduction**

Since 1983, the Kentucky Transportation Cabinet (KYTC) has implemented and refined its pavement management system to provide the agency with an effective decision support tool for prioritizing pavement projects. KYTC annually collects network level data for pavement condition, geometry, and imagery. Data are processed through a combination of automated, semi-automated, and manual methods.

**Data Collection**

KYTC automated data collection is conducted annually on the Interstate, Other-NHS, and Non- NHS routes. All routes are collected in both directions, in the outer most lane. For this collection cycle, the average yearly collection is 35,000 lane miles. Collection is performed by technicians in the Operations and Pavement Management Branch currently using state owned vehicles and equipment. These collection vehicles are equipped with mapping grade GPS of 0.3-meter accuracy, an inertial measurement unit, three forward facing digital cameras, PavemetricsTM Laser Crack Measurement System, and a Dynatest Road Surface Profiler Mark IV. Data from all systems are configured with offsets such that reported data is positioned at one common location. This data collection equipment provides automated pavement distress, pavement rutting, pavement cross slope, pavement roughness (IRI), joint and crack faulting, roadway geometry (curve & grade), GPS data, and roadway images. In addition to network testing, KYTC also performs ride quality acceptance testing for new construction.

**Data Collection Protocols**

Pavement surface profile data is collected using a high-speed profiler (MK-IV RSP) in accordance with AASHTO R 56-14. Longitudinal profile, for IRI (International Roughness Index) calculation, is measured at least every 1 inch for both the left and right wheel paths. IRI is reported as Mean IRI, the average IRI of both wheel paths, for each 0.1 mile segment.

Pavement Cracking, Rutting, and Joint Faulting is summarized and reported for each 0.1-mile segment. Surface rutting is collected in both wheel paths every foot and reported separately for each wheel path to the nearest hundredth inch. Pavement cracking is reported to the nearest foot for each AASHTO pavement zone for Pattern Cracking, Longitudinal Cracking, and Transverse Cracking.

Digital images are made available for viewing on a web based application, http://maps.kytc.ky.gov/photolog/. The online Photolog is an internet application that allows the user to view roadway images per County, Route, Mile Point, and Direction. The application shows the most recent image by default, but earlier collections are available for selection.

Pavement distress data will be collected and reported in accordance with the following standards:

AASHTO R 36-13 - Evaluating Faulting of Concrete Pavements

AASHTO R 43-13 - Quantifying Roughness of Pavements

AASHTO R48-10- Determining Rut Depth in Pavements

AASHTO R 56-14 – Shall be used to certify the IRI collection equipment

AASHTO R 57-14 - Standard Practice for Operating Inertial Profilers and Evaluating Pavement Profiles

AASHTO PP 67-16 - Quantifying Cracks in Asphalt Pavement Surface from Collected Images Utilizing Automated Methods.

AASHTO PP 68-14 - Collecting Images of Pavement Surfaces for Distress Detection

AASHTO PP 69-14 - Determining Pavement Deformation Parameters and Cross Slope from Collected Transverse Profile

AASHTO PP 70-14 - Collecting the Transverse Pavement Profile

ASTM E950 - Standard Test Method for Measuring the Longitudinal Profile of Vehicular Traveled Surfaces with an Accelerometer Established Inertial Profiling Reference

ASTM E1926 - Standard Practice for Computing International Roughness Index of Roads from Longitudinal Profile Measurements.

Required accuracy and resolution of collected data are as follows:

Data Element Required Accuracy Required Resolution

IRI 5% 1 in/mi

Rut 0.08 in 0.01 in

Fault 0.08 in 0.01 in

Distress 10% 1 ft

GPS 0.00001 degrees 0.000001 degrees

**Vehicle (Equipment) Quality Control**

The following inspections/requirements shall be adhered to:

There must be no active precipitation during collection. If precipitation occurs after collection has begun, promptly close the route, shutdown the system, and replace the laser covers

No visible moisture or puddles should be present on the road surface during collection No testing prior to 30 min after sunup, and 30 min before sundown

Clean windshield and camera lenses

The operating temperature range for exterior systems is 40°F to 113°F (0°C to 45°C)

The operating temperature range for interior systems is 50°F to 95°F (10°C to 35°C). Use the vehicle’s heat and air conditioning to keep the interior temperature within the proper range.

Check each tire’s inflation to ensure it is at the pressure specified by the manufacturer on the label inside the driver’s side door frame (70 PSI)

Check for any unusual wear patterns and alert vehicle maintenance staff if necessary Check rack mount for any loose connections

Check wheel encoder for any loose connections

Check that the photoelectric sensor is securely fastened to the front bumper, the cables are secure, and the sensor is free of any dirt

Check that all flashing overhead lights, headlights, and tail lights are working properly

Check that the LCMS laser windows are free of any dirt. If the laser windows are dirty, use approved cleaning solution and wipes. Ensure the LCMS pods are securely fastened to the mounting structure of the van

Check that the RSP laser windows are free of any dirt. If the laser windows are dirty, use approved cleaning solution and wipes. Ensure the profiler is level and securely attached to the vehicle

Ensure the GPS antennas are not damaged and are securely attached to the vehicle. Check that any cables are properly sheltered from the elements

Check that the computer storage rack is secure to the mounting plate on the floor of the vehicle

Ensure that the components within the rack are not lose or missing. Make sure there are no obvious loose wires, open drawers, or other unsecured components

Check that all cameras are mounted securely and that the cables are properly connected

Check that the Inertial Measurement Unit is secured to the mounting plate on the floor of the vehicle and that there are no loose cables.

Check that the system battery is secure and that all cables are properly connected Check that the inverter is secure and that all cables are properly connected

Refer to the Mandli KY Van Manual to perform the following tests: Perform a Road Surface Profiler Block Check

Perform a Road Surface Profiler Bounce Test Perform an LCMS Height Check Calibration

Perform a Color Balance Calibration, Focus check, and polarizer check

Logging

The following check results will be logged using the FileMakerGo application:

RSP - Block height check

RSP - Accelerometer Check Morning cold tire pressure LCMS height check

RSP - bounce test average IRI

Digital Camera - focus check quality rating

Data checks occurring in vehicle prior to first daily production run:

Perform burn run with all systems collection

Check that all files exist in folder: .raw, .gps, .rsp, .log, .fea, .rdf

Open RSP file and ensure data covers the entire range of test compared to the LOG file Check that RSP file is in the correct direction of travel

Check that number of LCMS FIS files match expected number from LOG file Run Verifier software and view output for any warnings or errors

Maintain GPS resolution of less than one meter error

**Calibration and Certification Sites**

Each vehicle must pass DMI calibration, IRI cross correlation, and Distress validation every 15 days. Follow all guidance presented in the Mandli KY Van Manual for each test. Each KYTC Driver, Operator, and equipment must pass the tests before collection occurs.

The DMI calibration site should occur on a predetermined reference pavement section of known length, surveyed to the nearest inch accuracy. A typical course is 1.000 mile but can be as short as 1000 feet. This section should be free of horizontal curves. Each vehicle will make three successful passes on the DMI site. The difference in pulse count for these three tests must be within 0.2%. The average pulse count of the three runs is entered into the collection software.

Each vehicle and driver/operator must make 3 runs on each of the calibration sites every 15 days. These runs should be uploaded and immediately checked against the reference profile by the section supervisor. If any vehicle fails, equipment must be checked for faults. If no equipment faults are found, the tests must be repeated until passing results are achieved.

The Laser Crack Measurement System will also be checked using these calibration sites. The reported distress, including Rutting and Faulting, using the Crack Width Based Severity report must meet 90% repeatability.

Two certification sites, which will be used for driver certification, are chosen each year before testing begins; consisting of one PCC and one smooth Asphalt section of at least 0.1-mile length. KYTC staff will choose sites with no horizontal curves or vertical grade changes, and that are between 30 and 80 IRI having no severe localized roughness events. KYTC staff will provide traffic control and assist Kentucky Transportation Center (KTC) in site layout. KTC, under supervision of KYTC engineer, will test calibration sites using a reference profiling device, such as the SurPRO 4000. Site layout includes: Measure for distance using a survey grade tape, Mark left and right wheel paths using chalk as a guide for the equipment operator, Follow startup procedure for reference profile device, Walk both left and right wheel paths with the SurPRO 4000 or similar device, Complete a distance calibration and closed loop to calibrate the reference device. Once setup and reference device calibration are complete, KTC personnel will complete a minimum of five (5) profiler passes for each wheel path with the reference device.

The 5 reference device runs create road profiles for both the left and right wheel path. Supervising KYTC engineer evaluates each profile using road profiler analyzer software, such as ProVAL. The ProVAL software measures the repeatability and accuracy of the SurPRO roadway profiles. KYTC requires a minimum 95% repeatability between the five (5) profiler passes for each wheel path. These profiles are used as the reference for site calibration and driver certification.

The two sites used for IRI certification will also be used to certify collection for rutting, faulting, and cracking data. While each site is closed to traffic for certification setup, KYTC engineers will measure rutting and cracking on the asphalt site, and faulting and cracking on the PCC site.

Rutting will be measured every twenty-five (25) feet using a straightedge and digital depth gauge with a 5mm footprint for each wheel path. The average rutting reported by the testing vehicle must be within 2mm of the average for each manually measured rut for each wheel path.

Cracking will be measured and recorded manually by a KYTC team of pavement management engineers. Each crack will be recorded noting length, width, and position, creating a crack map. This crack map will then be used to produce a percent cracking value, as per HPMS requirements. The vehicle’s automated cracking results must be with 10% of the calculated percent cracking of the manual survey.

Faulting will be measured manually in the right wheel path for each slab in the 512 foot PCC certification site. The average manual faulting measurement will be compared with the automated result. The automated faulting measurement average must be within 2mm of the manual average.

Reference Profile Selection

If two or more profiles agree at greater than 98.0% correlation, discard the profiles below 98% and average any remaining profiles. SurPRO profile averaging is done by opening the .erd output from the SurPRO in Microsoft Excel, or similar, and removing the file header so that only the elevation data remains. Do this for each remaining profile, and combine these columns in one worksheet. Arranged each file’s data such that the zero start point is positioned in row 1.

Beginning at row 1, in any column right of the dataset, average all rows to create a new average elevation. Create a new .erd file using the header information from any of the original SurPRO files, then copy the new average elevation data below the header.

If no 2 profiles agree at 98% correlation or greater, but all meet the 95% correlation requirement, average all profiles using the method above.

The vehicle profiles must meet 90% repeatability and 88% accuracy (or 92% repeatability and 90% accuracy for Construction Acceptance drivers) when compared to the device reference profile.

**Personnel Training**

KYTC technicians are required to participate in yearly Driver Certification. Drivers will operate the collection vehicles on the Certification sites as detailed above. Drivers are required to meet 90% repeatability and 88% accuracy compared to the reference device profile for 10 consecutive passes for general network testing. Construction Acceptance drivers are required to meet 92% repeatability and 90% accuracy compared to the reference device profile for 10 consecutive passes.

KYTC pavement raters currently perform yearly windshield survey rating calibration at predetermined validation sites as a group to reassess the visual windshield survey skills of the rater staff. These calibration sites are established using locations expected to be encountered throughout the State. Distress ratings are given for; wheel path cracking, other cracking, raveling, joint separation, appearance, patching, and out of section for bituminous asphalt pavements and; joint deterioration, other cracking, faulting, appearance, patching, and out of section for portland cement concrete pavements. Pavement raters’ scores are compared and normalized against the group average to calibrate the visual survey of the individual raters to each other. A Pavement Distress Index (PDI) is calculated from these distresses as well as data from IRI values for each pavement section.

**Quality Control Process**

KYTC conducts quality control checks on all tests performed by the collection vehicles. The QC process is conducted on photo images, IRI, pavement distress, and rutting.

Data from each van will be transferred weekly via FTP to the storage server. Technicians will transfer files twice, correcting any failed transfers shown by FTP software, then check file size and file count for each test date folder to ensure that all data was transferred successfully.

Within 4 weeks of test date, the data processor will then review and report results of all tested sessions loaded to the server. Each session loaded to the storage server will be recorded in an excel workbook, sorted by test date and vehicle. Also recorded in this workbook for every session will be positive or negative results for Photo Quality, RSP file, LCMS .fis files, session log, and imported to database. If any issue is found in the 4 checks, the session will not be imported to the database. Sessions found with errors or quality issues will be copied to a separate workbook and technicians will be notified for review.

Photo quality is check at the beginning, middle, and end of every run. Pictures must be of sufficient brightness that highway features are visible, and free of rain or other defects. The RSP data file is checked to ensure it contains data for the entire tested route, and that the direction is correct. LCMS files, from which pavement distress and rutting are derived, are checked to ensure data is available for the entire tested section. If any of these conditions are not acceptable, the run is flagged for additional checks and is not imported to the database.

Data flagged as unacceptable through this process is reviewed in detail. If the issue can be corrected, the run is fixed and imported. Otherwise, the affected highway section is scheduled for re-shoot. Technicians will recollect any road section flagged as unacceptable within 8 weeks of original test date.

Photo Quality

Images are accepted based on Clarity, Brightness, and Completeness. Image review includes the following:

Image Clarity - All images should be clear and highway signs easily readable. Most highway distresses should be evident in all views. There should be minimal or no debris in the cameras' viewing path.

Image Brightness/Darkness - Images are not to be collected during hours when lighting is insufficient. No collection prior to 30 min after sunup, and 30 min before sundown. In addition, a good indicator of insufficient light is activation of automatic street lights or vehicle headlights.

Dry Pavement - Test sections should not have any visible water. Pavement surface saturation should be less than 10%. Data collection should be halted immediately during a rain storm.

Pavement Clear of Debris - Test sections should be clear of debris. Pavement surface should have less than 10% of vegetation, litter, or animal remains covering the pavement.

Image Replay - Images should play sequentially and in the correct order. Data collection should give the impression that the viewer is traveling in the forward direction

Missing Images - There should be less than 5 missing images in any given test section, and no more than 3 consecutive missing images

Data Processing and Reporting

Sessions imported to the database are processed to create the LCMS .xml files for reporting. XML files contain: van position data; roadway cracking depth, width, and location; rut depth, width, and location; cross section data; and macrotexture information. Processing is completed using the Mandli LCMS Route Process, a batch Mandli LCMSRoadInspect analyzer which writes the .xml files and downward imaging files for Intensity and Range.

Sessions are then checked using Mandli Roadview 7.0, or similar, for quality of downward images, missing frames, and accurate pavement type and, if necessary, reprocessed for areas of PCC pavements.

Sessions with greater that 5% missing or poor quality frame images due to LCMS errors are marked for retesting, if other processing corrections cannot be made.

Sessions with PCC pavements visible within the downward images and greater than 50% of the image frame are reprocessed with Mandli LCMS Route Process with the pavement setting set to Concrete instead of the default Asphalt.

Reporting of sessions is completed with Mandli Roadview Workstation. Reporting of sessions must take place within 12 weeks of the testing date. This ensures that problems discovered during the reporting process can be corrected in a timely manner. Errors discovered during the reporting; missing processed .xml files, missing IRI data, etc. will be corrected for the appropriate error and reporting rerun within two weeks.

Quality Control Checks for Reported Sessions

Reported sessions are checked for completeness, accuracy, and consistency; looking for numbers outside of the appropriate or expected range. The following ranges are considered valid:

IRI – 20 to 200 for Interstate and Parkway routes, 20 to 400 for all other routes

Rutting – 0 to 0.75 inch for Interstate and Parkway routes, 0 to 1 inch for all other routes

Percent Cracking – 0 to 50%

Faulting – 0 to 1 inch

Temporal analyses will be used to detect unexpected condition changes given the criteria below. These changes will be compared to construction or maintenance activity locations. Any changes outside the expected range which do not match expected results from work will be checked for accuracy.

IRI Change – +/- 10 MRI

Rut Change – +/- 0.1

Percent Cracking Change – +/- 10%

Faulting Change – +/- 0.08

The reported sections are mapped using ArcGIS to spot routes that are missing from the compiled statewide report. These missing routes are researched or located, determinations for why they did not report are formulated, necessary changes made, and re-reported (if possible).

KYTC pavement rating team will visually survey 10% of pavement sections as quality control to verify the LCMS data and the expected deterioration model of the collected LCMS data is accurate. Cracking percentage of automated collection vs KYTC rating team should be within +/- 30%.