DEPARTMENT OF TRANSPORTATION

Pavement Data Quality Management Plan

As required by 23 CFR 490.319(c)

05/10/2018

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Data Collection Equipment

MnDOT currently owns three Pathrunner vans, built and sold by Pathway Services, Inc. located in Tulsa, Oklahoma. The current fleet of Pathway vans consists of a 2011 Ford Econoline van and two 2016/2017 Ford Transvans each equipped with two laser profiling systems (one in each wheel path) and a 3D laser/camera system for measuring rutting/faulting and capturing pavement distress.

2011 Pathrunner

2016/2017 Pathrunner

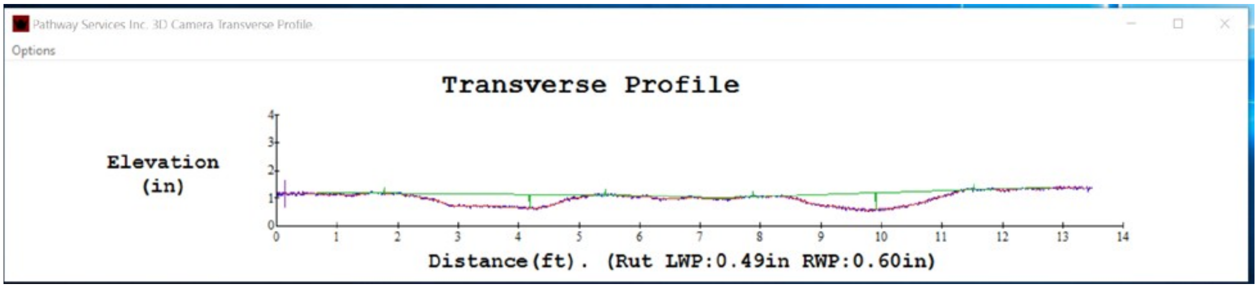
Inertial Profiler System

The vans meet the qualifications for an inertial profiler as described in AASHTO M328-14, "Standard Specifications for Inertial Profiler." Each wheel path is equipped with an accelerometer and laser height sensor. In addition, the vans have a Distance Measuring Instrument (DMI) for measuring the length of each section. The system measures the wheel path profile at roughly 0.12 inch intervals. The profile data is used to calculate the International Roughness Index (IRI) and subsequently Minnesota's Ride Quality Index (RQI).

Rutting

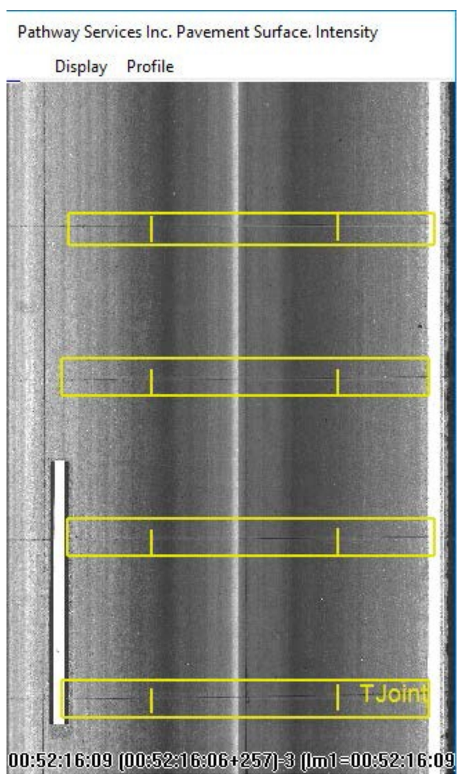
The vans use a 3D laser/camera system to measure pavement rutting. A laser beam is reflected off a rotating mirror and the 3D camera is used to process the resulting shape of the beam on the roadway. A simulated straight edge is then applied to the resulting transverse profile and the maximum rut depth is calculated. At highway speeds, a transverse profile is measured every 8mm. In addition, roughly 1500 measurements are taken across the lane to determine the profile. This process is the preferred method as stated in AASHTO R 48-10, section 5.3.7, "Determining Rut Depth in Pavements."

Sample transverse profile from 3D laser/camera system:



Faulting

Faulting of concrete joints is also measured using the 3D laser/camera system. The method used to calculate the amount of faulting is consistent with the HPMS Field Manual and AASHTO R 36-13, Method B, for automated fault measurements with one difference; the location of the joints is determined using AutoCrack distress recognition software rather than the profile data. AutoCrack finds and classifies various types of cracks and defects based on the data from the 3D system. After locating all of the transverse cracks, a second step is performed on concrete pavements. The geometry of each transverse crack is examined and if it is predominantly straight, all the way across the lane, it is assumed to be a joint. Once the joints are identified, the 3D data on each side of the joint is analyzed to determine the amount of faulting in each wheel path. A sample 3D image showing the location of concrete joints, as determined by AutoCrack, shown below. The small vertical lines within the boxes indicate the position within the lane where the where the fault measurements are taken from the transverse profile data.



Cracking

Cracking is also determined from the 3D laser system. The data is collected consistent with AASHTO PP 68-14 "Collecting Images of Pavement Surfaces for Distress Detection." The 3D images are analyzed by the AutoCrack crack recognition software. AutoCrack analyzes each 3D image collected by the van and detects, classifies, and measures the presence of any pavement distress such as cracking, patching, potholes, etc.

Classification is done according to the MnDOT Pavement Distress Manual for network level data and according to the HPMS Field Manual for HPMS reporting.

Equipment Calibration

Each year, prior to beginning the testing season, several equipment calibrations/checks are performed, including the 3D laser system and profile lasers. Links to each procedure can be found on the pavement management website: MnDOT Pavement Management

Water Pan Test

A water pan test is done to calibrate the 3D laser system. This involves placing a 14 foot wide, 2 inch deep tray, on wheels, under the 3D lasers in the rear of the van. The tray is filled with water and a strip of special paper is placed on top of the water to prevent the laser from dispersing across the wet surface. The paper is then is sprayed with gray paint to ensure maximum reflectivity of the beam back to the 3D camera. Since water seeks its own level, the 3D lasers, when scanning the surface of the water pan, should be measuring no rutting and a horizontal surface. Special software in the van is used to display and adjust the resulting laser response and intensity.

Block Test

The block test involves placing metal blocks, machined to very exact thicknesses, on a base plate and turning on the laser profiling system. The blocks are then replaced and substituted with others and the difference in the measured elevation is recorded. The system takes the actual thickness of the blocks and the measured thickness and creates a calibration factor.

Bounce Test

The bounce test involves triggering the profile system and then rocking the vehicle from side to side, triggering the accelerometers. Since the van is stationary, the profile of the roadway is not changing and all of the movement is due to the van frame/suspension. The van's DMI is put in test mode, simulating driving down the road. The resulting profiles are exported and analyzed using ProVal. Since the van is not actually driving, the pavement profile is not changing, and should be constant with all movement being assigned to the accelerometers. If this is not the case, the accelerometer and/or laser likely needs to be replaced.

Distance Measuring Computer (DMI) calibration

The DMI is calibrated by driving the van over a known distance and comparing the distance measured by the vehicle's DMI. To ensure the van starts/stops at the exact point, traffic cones with reflective markers are placed at the beginning and ending of the calibration section. A photocell triggers the equipment to begin measuring the distance traveled. When the van reaches the end of the course, the photocell signals the equipment to stop measuring the distance. The user enters the actual distance of the calibration course. The system then uses the measured distance to create and store a calibration factor. For example, if the calibration course is 1000 feet and the vehicle DMI measures 995 feet the system is measuring less distance than is actually travelled. As a result, the calibration factor would be 1.005.

Equipment Certification

Profiler

At the beginning of each season, all of the vans are taken up to MnROAD for certification. At MnROAD there are two certification sections, one asphalt and one concrete. The profile of each section is measured with a SurPro walking profile, which is considered the "reference" profile that the vans must match. The vans are driven over each section five times. The measured profiles are loaded into FHWA's ProVal software and a cross correlation is performed against the reference profile. Cross correlation involves comparing each point along the measured profile to that of the reference profile and summing the difference. In addition, the average IRI calculated by the van software must be within +/5% of the IRI as measured by the SurPro. Once the van passes, a sticker is affixed indicating it has passed certification for the year. This is the exact same process used to certify the inertial profilers used by paving contractors in Minnesota. The van will have to be re-certified during the year if any replacements or repairs are made to the lasers, accelerometers, or 3D camera system. This procedure complies with AASHTO R 56-14 "Standard Practice for Certification of Inertial Profiling Systems."

Rutting

To certify the rut measurement system on the van, the 3D laser system must first complete the water tray test (above). Once completed successfully, a 16 foot wide fabricated beam with 0.50" ruts is placed under the 3D lasers. The van's DMI is put into test mode and rut measurements are taken. The data is processed in the office and the resulting transverse profile and rut depths are compared to the shape of the beam and the maximum rut depth as measured with a straight edge laying on top of the beam. The equipment passes if the rut depth of each wheel path, as calculated by the van, is within 0.10" of the maximum rut depth as measured with micrometer underneath a 6 foot straightedge laying on the beam.

Faulting

Faulting is certified by running the van across a concrete cell at MnROAD and comparing the average fault height, as measured by the van, to that manually measured with a fault meter. To calculate faulting, AutoCrack is run to first identify all of the concrete joints. The 3D data is then processed to calculate the amount of faulting in each wheel path at each joint. To pass certification, the average faulting of the cell, as measured by the van, must be within 0.05” of the average faulting as measured by the fault meter.

Cracking

The AutoCrack system is certified by driving the van over a section of pavement that has been crack mapped by human raters. The 3D images are processed back in the office and the resulting cracks/distress are compared to the cracking identified on the crack map. The crack map shows the location, orientation, and length of all visible cracks. To pass certification, the 3D images must show 90% all of the cracks shown on the crack map.

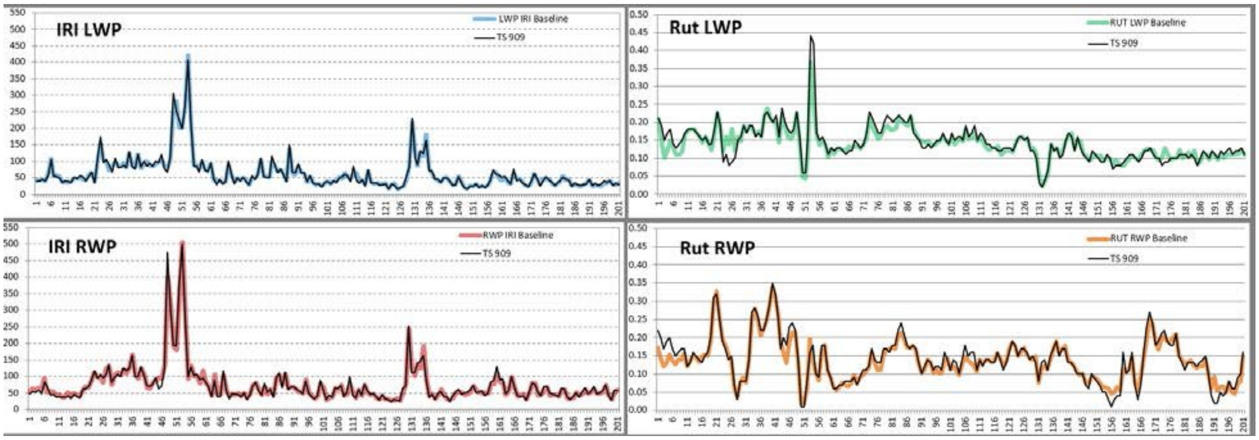
Operators

MnDOT also has an inertial profiler operator certification program. This ensures the operator understands the basics of measuring pavement profiles, the factors that affect the accuracy of data, using ProVal to analyze profiles, incentive pay tables, etc. The certification is done online and involves successful completion of MnDOT’s Pavement Surface Smoothness Specification training. This online course, which takes roughly 1.5 hours to finish, is free of charge and available to everyone. Since a majority of the online course deals with pay tables, deductions, corrective action, etc. it is not applicable to the PMU staff that operate our profiles. However, the first two modules of the class are valuable and serve as a good refresher. The PMU equipment operators are encouraged to review the first two modules of this course annually, prior to the testing season.

Verification Course

Once the vans get officially certified, the verification course is driven to establish a baseline. The verification course is an 8 mile long loop on various state highways located near the Office of Materials and Road Research in Maplewood, Minnesota. Measurements are taken on a 2 mile bituminous section of MN 36 and 2 mile concrete section on I-694. The newly certified van is driven over the course five times, to establish a baseline for each section. The data is processed at 52.8 foot intervals. An Excel spreadsheet, with imbedded macros, is used to generate a plot of IRI and rutting in each wheel path, and GPS compass heading. Approximately every two weeks, the vans drive over the verification course and the resulting plots of IRI, rutting and compass heading are overlaid on top of the baseline plot. While no statistical analysis is done, the user ensures that the data from the current run is consistent with the baseline data. The data will never be exactly the same as the baseline due to vehicle wander, changes in pavement condition, temperature/weather effects, etc. However, if any of the lasers, accelerometers, or DMI were malfunctioning or out of calibration, it would be easily detected by the plots. All runs over the course of the season are saved in the annual verification spreadsheets. A separate verification file is kept for each van.

Example of graphs comparing a verification run to a baseline on 52.8 foot intervals:



Data Collection

Once the equipment has been calibrated and certified the actual testing season begins. Since the vans are driven at highway speeds, it is difficult for the operator to monitor everything that is being measured in real time. For this reason, the van is equipped with several internal warnings and flags to inform the operator of any issues with equipment. An audible computer voice is used by the system to inform the operator of issues with the lasers, DMI, GPS or computers. In addition, the operator monitors the screens on the van to ensure the lasers and accelerometers are working correctly. Certain fields will change color when data is being collected or is out of tolerance.

Daily Checks

The following steps are done each morning, before the van begins data collection:

- Do a visual inspection of the tires; measure the cold tire air pressure if it appears to be low.
- Clean camera window, if needed.
- Clean laser lenses, if needed.
- After equipment startup, ensure all components are operating normally and are ready for testing.

During data collection, the following steps are done:

- Monitor the quality of the cameras/images
- Monitor DMI unit, make sure it’s within the certification measurements
- Take note of road closures, construction and any other reason the road cannot be tested fully

At the end of the day, view the data that was collected during the day, including:

- View 3D images
- View right shoulder images
- View perspective images
- Review records in the database file from the day's testing.
- Copy all information from the profiler computer to a portable hard drive.

Periodic Checks

- Measure the cold tire air pressure with a tire gage on a weekly basis to ensure it meets the manufacturer's recommendations.

- Roughly every two weeks, the verification course will be run to and compare IRI, rutting and faulting results against the baseline data. The metrics will be calculated on 52.8 foot intervals and plotted against the baseline data. In addition, the DMI will be checked by comparing the measured distance against the verification course distance.

- The Block and Bounce Tests, as described in AASHTO R57-14, will be run monthly to ensure the accuracy of the vertical measurements.

Examples of the forms used for the daily and periodic checks are included in the Appendix.

Data Processing and Review

Once the van returns from testing a district or county, the removable hard drives in the van computers are removed and the data is transferred to one of three computer work stations. To ensure no data is lost, a minimum of two copies of all the data is maintained. Initially, only one copy exists, in the van. The data on the van's removable hard drives is transferred to the hard drives in the work station, creating a second copy. The data is then transferred to a server at the Maplewood Lab, creating a third copy. Once all data has been fully processed and checked, the removable drives are reformatted and returned to the van.

Using software provided by the vendor, checks are made for any missing images, bad laser data or other problems. If none exist, further processing is done to calculate the IRI and rut depth of each section.

Distress Measurements

Once the database has been fully error checked, and processed for IRI and rutting, it is ready for distress analysis. Prior to 2017, distress surveys were done using a semi-automated method where a technician in the Pavement Management Unit would view pavement images collected by the van and determine the type, severity and length of the various distresses. In 2017, MnDOT switched to an automated system, called AutoCrack. Before AutoCrack is run, each record in the database is first checked to ensure the pavement type is correct. In addition, the beginning of the record is adjusted if there is a bridge at or near the beginning of the section. This is done to avoid AutoCrack doing crack assessments on the bridge deck as if it were a pavement. All of the long bridges on the network (Mendota, Lafayette, etc.) are isolated as individual sections so the AutoCrack analysis can be omitted prior to loading into the pavement management system.

Once the pavement type has been validated/corrected, the database is loaded into AutoCrack and the analysis begins. On undivided, 2-lane, roads only the right lane in either the northbound or eastbound (increasing) direction is rated by AutoCrack. On divided, multi-lane, roads the rightmost through lane is rated in both directions. A typical MnDOT district will consist of roughly 1,800 roadway miles of pavement (360,000 images) to be rated. It will take AutoCrack 10-14 days to finish analyzing all of the images. AutoCrack assigns each distress into one of four severity categories and any or all of 5 locations across the lane:

- Low, Medium, High, and Severe
- Left Edge, Left Wheel Path, Center of the Lane, Right Wheel Path, and Right Edge

Once this is finished, a second step, called AutoClass is performed to convert AutoCrack's perceived distress types and severities to MnDOT's distress types and severities. The AutoClass process converts each of the distresses into MnDOT distresses using a series of forms that also define the minimum size for each distress type. For example, the agency might designate 3 feet as the minimum longitudinal crack length. If AutoCrack identifies any longitudinal crack shorter than this it will ignore it and not convert it to an agency distress.

For HPMS reporting, the AutoClass process is modified to classify cracking consistent with the HPMS Field Manual for Percent Cracking.

Once the AutoClass process is completed, the database is updated for the final time. It will now contain all pertinent condition data, include IRI, rutting, faulting and cracking for each record in the database, typically a mile long section. The database file is then saved, both to the workstation and the server.

As a quality check, approximately 10% of the segments are reviewed for accuracy. This is done by a human rater viewing the 3D pavement images and comparing the visible cracks/defects to the automated results. In particular, the review focuses on any visible distress not classified by AutoCrack and/or any distress classified incorrectly. Adjustments to the AutoClass set up may be necessary if differences get to be too frequent.

Final Error Checks and Data Formatting

The completed database is then loaded into a Macro enabled Excel spreadsheet. The spreadsheet has three macros which are run:

- Error Check
- Roughness
- Distress

The Error Check macro goes through each line in the database and checks for the following:

- IRI values = 0 in/mile or more than 600 in/mile.
- Any pavement distress that is = 100%
- Mismatched distress (concrete distresses on an asphalt road, etc.)
- Unusually high rutting or faulting values
- Sections with no length
- Concrete pavements with joints spaced at 6 feet or less

The errors do not necessarily mean the data is bad, just that it needs to be checked. If errors indicate missing or bad data the database may need editing and reprocessing. Once the errors are resolved and/or validated, the Roughness and Distress macros are run. These macros format the data so it is ready for importing into the pavement management system.

The finished data is then loaded into the Highway Pavement Management Application (HPMA). As a final check, each segment is reviewed using HPMA's Section Performance Plot. For each section the current year's data is plotted along with past year's data. The plots are reviewed to ensure the trend seems reasonable. If the is a sudden jump/drop in either the SR or RQI, and no indication of any work being done, the video-log system is launched to see if:

- Maintenance work, such as patching or crack sealing was done.
- Issues with the pavement condition (wet, debris on the road, etc.)
- Construction activity (lane changes, bypasses, etc.)
- Incorrectly classified/categorized distress

If maintenance work was done, it is added to the pavement history database in HPMA and the section's decay curve is recalculated. Sometimes the video does not indicate any work done despite the change in condition. This could be caused by vehicle wander in the lane from one year to the next, differences in travel speed from year to year, particularly in heavily travelled urban areas or segments with stop lights or signs.

Finally, once the data has been loaded into HPMA and all of the above checks done, the overall percent Good and Poor (based on RQI) is calculated and compared to what it was predicted to be based on the previous year's condition and planned work. This is outlined in the Annual Pavement Condition report.

Error Resolution

Any data errors discovered during verification, processing, and/or checking can be attributed to one of two causes:

1) Errors during data collection
2) Errors during data processing/analysis

An investigation is needed to determine where the data error occurred and how to best resolve it and avoid it in the future.

Errors attributed to problems during data collection will likely result in the van needing to return to the location and re-collecting the data. Errors related to data processing will result in the data being reprocessed to correct any errors/deficiencies.

HPMS Data

All data submitted to FHWA as part of the annual HPMS submittal will comply with the requirements of the HPMS Field Manual. This includes, but is not limited to:

- Analyzing and reporting data in 0.1 mile intervals
- Reporting all condition data based on 100% coverage (no sampling) of the segment
- Reporting IRI, Rutting, Faulting and Cracking according to the Field Manual requirements

Contact Information

Further, more detailed information can be found in the appendices or on the pavement management website: http://www.dot.state.mn.us/materials/pvmtmgmt.html

Inquiries can also be made to the pavement management engineer:

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Maplewood, MN 55109
651-366-5567
dave.janisch@state.mn.us

Approvals:

Curtis Turgeon

Digitally signed by Curtis Turgeon
DN: cn=Curtis Turgeon
Date: 2018.05.15 09:31:30 -05'00'

Date

Curt Turgeon, Pavement Engineer

Arline K Kocher

ARLENE K KOCHER
2018.05.18 08:41:27 -05'00'

Date

Arlene Kocher, FHWA-MN Division Adiminstator

Appendix – Sample Forms

Verification and DMI Calibration Form

VERIFICATION DMI CALIBRATION

*Date:*_______________________

*Vehicle #*___________________

*Mileage:*___________________

Tape Set:____________________

Time:_______________________

Weather: Sunny Partly Cloudy Cloudy

Tire Pressure

Left-Front:_______________ 65 psi +/- 3 psi Right-front:_______________

Left-rear:________________ 80 psi +/- 3 psi Right-Rear:________________

DMI Check

Use Tape Set # (999) 850' +/- 1.5'

DMI Course Distance: ____________________________________

Distance Measured: ______________________________________ 848.5' – 851.5' OK

New Calibration#____

Distance Measured After Calibration:_______________________________

Course: HWY 36/I-694 Enter EB MN 36 @ English Street. Collect data between RP 8 and 10. Head north on MN 120. Enter WB I-694 @ MN 120. Collect data between RP 51 and 49. Exit on US 61. Head south on US 61 back to the Maplewood lab. Drive in right lane @ 55 mph

Technicians Signature:_____________________________________

Vehicle Certification Form

2018 Pathway Van Certification Form

Vehicle Number: ______________________

IRI Certification (MnROAD): PASSED on Date: _______________

Rutting Certification (Rutting frame) Date: _______________

	Left Wheel Path	Right Wheel Path
Rut Frame (inches)		
Van Measured Rut (inches)		
Difference (inches)		

Van must be +/- 0.10" of measured rut depth using a 6 foot straightedge on rut frame.

Faulting Certification Date: _______________

	Left Wheel Path	Right Wheel Path
Faultmeter Average (inches)		
Van Average (inches)		
Difference (inches)		

Van average must be +/- 0.05" of Faultmeter Average

Cracking Certification Date: _______________

	Right Wheel Path
# of Cracks on Crack Map	
# identified by 3D System	
Percent Identified	

Van must be able to identify 90% of cracks shown on crack map

Daily Equipment Check Form

210333 DAILY CHECK LIST

DATE	Operator Initials	Check Tires (daily)	Check/Clean Lasers (daily)	Check/Clean Cameras (daily)	Measure Tire Pressure (weekly)	NOTES

Driver Notes Form

VEHICLE / EQUIPMENT ISSUES

Name: ______________________

Date: ______________________

Van #: ______________________

NOTES

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Notes: Record problems and solutions, database errors, Pathways calls, and other important information.