

**THE USE OF PERFORMANCE METRICS ON
THE PENNSYLVANIA TURNPIKE**

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ABSTRACT

The Pennsylvania Turnpike Commission opened the first 169 mile (270 km) portion of the Pennsylvania Turnpike between Carlisle, PA, and Irwin, PA, on October 1, 1940, making it the first Super Highway in the United States. Since that time the Commission has been dedicated to providing their users with a first class driving experience. As a part of the Turnpike's reconstruction and capacity expansion efforts, the Commission wants to ensure that their pavements continue to meet the goals for safety and user comfort.

In 2007 the Commission contracted for an annual evaluation program for its 550 centerline-mile (880 km) pavement network. In this program, the performance of the Turnpike system is evaluated on a 0.1-mile (160 m) interval basis in the travel lane for each travel direction. The specific performance metrics are designed to ensure a safe, comfortable experience for the Turnpike's users. These metrics are:

- Ride Quality – International Roughness Index, ASTM E-950 and E-1926
- Rutting – Rut depths, PennDOT Publication #336
- Skid Resistance – Friction Number, ASTM E-274 using both ribbed (E-501) and smooth (E-524) tires.

The Turnpike compares the results of the annual evaluations to the established performance metrics to ensure their patrons are receiving an enhanced driving experience. Performance comparisons are also used to identify areas needing improvement, to program projects for remediation, and to address unsafe conditions. This paper discusses how the annual monitoring program and its results are used to meet the high performance goals of the Turnpike and adequately distribute the available maintenance and repair funds to the proper projects.

BACKGROUND

With the opening of the first section on October 1, 1940, the Pennsylvania Turnpike was the nation's first super highway. The initial section stretched for 169 miles (270 km) from Carlisle, PA, to Irwin, PA. The Turnpike was constructed to a uniform standard as a limited access highway with four twelve foot (3.6 m) lanes, minimum 10 foot (3 m) median, and a 10 foot (3 m) berm. By 1957, the Turnpike stretched from Ohio to New Jersey, and Philadelphia to Scranton. In 1988 the Turnpike Commission began construction on the first of numerous extensions in the Pittsburgh area. The construction of these extensions continues. (1)

The Commission started collecting automated data on the entire Turnpike system in 1993 through a contract with the Pennsylvania Department of Transportation (PennDOT). In 1993 and 1995, the data collected by PennDOT included: roughness, rutting, and skid resistant for every tenth of mile. The roughness and rutting data were collected continuously and summarized for every tenth of mile. Starting in 1997, the system wide data collected every year was reduced to roughness and rutting. Friction data was collected at specific requested locations.

In order to continue providing their customers with a safe comfortable traveling experience, the Commission released a Request for Proposal in 2007 for automated, system-wide, data collection services. These data collection services included annual collection of pavement ride, rutting, and friction data on the primary travel lane throughout the entire 1050 directional miles (1680 km) of the Turnpike system. All data collected was processed in accordance with the applicable ASTM standards or PennDOT procedures.

DATA COLLECTION

The data for the Pennsylvania Turnpike is collected each fall (October/November) for one lane in each direction of travel on all the highways comprising the Turnpike system. The Turnpike system is comprised of six separate highways: Mainline, Northeast Extension, Amos Hutchinson Expressway, Beaver Valley Expressway, Mon-Fayette Expressway, and the Findlay Connector. Data collection is performed in the second lane from the left on each highway using two different pieces of equipment:

- Digital Survey Vehicle equipped with an ASTM E-950 (2) road profiler, 5-sensor rut bar, distance measuring equipment, differential GPS, and digital video camera systems, Figure 1
- ASTM E-274 (3) locked wheel skid resistance tester using both a ribbed (4) and a smooth (5) test tire, Figure 2



FIGURE 1 Digital Survey Vehicle.



FIGURE 2 Skid Resistance Tester.

The Digital Survey Vehicle (DSV) collects its profile data in accordance with ASTM E-950 while traveling over the pavement at or near highway speeds. The DSV collects a longitudinal profile point and five transverse profile points at three inch (75 mm) intervals, and digital right-of-way images at a nominal 20-ft. (6 m) interval.

The pavement friction data is collected in accordance with ASTM E-274 using an International Cybernetics Corporation (ICC) Locked Wheel Skid Tester equipped with a 400 gallon (1515 l) water tank. Testing is performed while traveling at a speed of 40 MPH (65 KPH). The tester is setup with a ribbed test tire in the left wheel path and a smooth test tire in the right wheel path. The tester collects a minimum of five ribbed tire tests and five smooth tire tests for each signed mile of the Turnpike. The skid tester works in conjunction with a shadow vehicle to provide the traveling public with additional warning of the testing, and a water tanker truck used to refill the on-board water tank of the friction tester.

In addition to the contractor collected ride, rutting, and skid resistance data, the Turnpike engineering staff performs windshield condition surveys of the entire system determining a Pavement Condition Rating (PCR) for each 0.1-mile (160 m) interval of the Turnpike.

DATA PROCESSING AND REPORTING

The collected data are processed in accordance with the following standards/procedures and reported to the Turnpike for each 0.1-mile (160 meter) of the second lane from the left throughout the turnpike:

- Pavement Ride – International Roughness Index (IRI), ASTM E-1926 (6)
- Pavement Rut Depth – Pennsylvania Department of Transportation Publication Number 336 (7)
- Pavement Friction – Friction Number, ASTM E-274

The longitudinal profile points are processed through an industry standard Quarter Car computer model to produce the IRI for each 0.1 mile (160 m) interval in inches/mile. The transverse profile points are processed to determine the rut depth in each wheel path at 3-inch (75 mm) intervals. The rut depth is determined using computer models which simulate placing a 5-foot straightedge between the transverse profile point in the center of the vehicle and the outer most profile point for each transverse profile and measuring the vertical distance between the calculated straightedge elevation and the measured pavement elevation in each wheel path. The difference is the rut depth. The rut depth data is then summarized and reported out for each 0.1-mile (160 m) interval. The 0.1-mile (160 m) interval IRI and rutting data are then summarized and reported out as the average IRI and rutting for each of the Turnpike's highway sections. Highway section lengths are typically 6 to 8 miles (10 to 13 km). The section lengths are determined based on construction and rehabilitation/resurfacing history and can change over time.

The collected skid data are processed using industry standard computer models to produce a Friction Number (FN) for each skid test location. The FN for each skid test location within each 0.1-mile (160 meter) interval is reported. The FNs for each test location are also averaged to produce an average FN for each signed mile.

The processed data is reported to the Commission in Microsoft Office Excel format. A spreadsheet file is provided for each of the six highways comprising the Turnpike system. The spreadsheet files are named for each of the highways and contain the following data reports:

- Section Summary (IRI and Rutting)
- IRI and Rutting 0.1-mile (160 m)
- Friction Number by 0.1-mile (160 m)
- Friction Number by 1-mile (1.6 km)
- Original Data (IRI and Rutting)

All reports except the Original Data report are in centreline format showing the data on one line for both directions for the designated centreline interval. The Original Data report presents the 0.1-mile (160 m) IRI and rutting data in a directional format.

In addition to the IRI, rutting and Skid resistance data described above, the Commission's engineering staff also performs semi-annual windshield pavement condition rating (PCR) surveys of the entire Turnpike system. The PCR scale ranges from 0 to 100, with 100 being perfect condition. The PCR ratings were developed for the Commission's three primary pavement types (composite, flexible, and rigid) using the Long Term Pavement Performance Project, Strategic Highway Research Program protocols as a guide(8). The ranges in condition rating for each of the broad categories of distress, by pavement type, are provided in Table 1.

TABLE 1 Pavement Condition Rating Methodology

Composite Pavement	
Condition Factor	Maximum Rating
Ride Quality	40
Transverse & Longitudinal Cracks/Joints	15
Surface Defects	15
Surface Deformation	15
Surface Cracking	15
Total	100
Flexible Pavement	
Condition Factor	Maximum Rating
Ride Quality	40
Surface Defects	10
Surface Deformation	25
Surface Cracking	25
Total	100
Rigid Pavement	
Condition Factor	Maximum Rating
Ride Quality	40
Transverse & Longitudinal Cracks	15
Structural Defects	15
Surface Deformation	15
Cracking	15
Total	100

The PCR surveys are usually conducted in the spring (April/May) so that damage by winter conditions are promptly noted and work scheduled accordingly, and in the fall (October/November), so that recently paved projects can be evaluated separate from the contract and so that damage by summer heat conditions can be corrected prior to the winter season. The surveyors are separated into two different cars so that each person has an unobstructed view of the pavement. The cars typically contain one representative from the Engineering General Consultant and one from the Commission's Engineering-Design Division in one car, and a representative from the Commission's Maintenance and Engineering-Construction Divisions in another car. The surveyors rate each section independently, then the ratings are averaged to provide the final PCR for each section.

CONDITION DATA ANALYSIS

The Commission uses a combination of PCR, IRI, Rutting and Skid Resistance to identify projects for planned rehabilitation (PCR and IRI) and safety (Rutting and Skid Resistance) projects. To this end, the Commission has established the condition thresholds shown in Table 2 to be used in analyzing the pavement condition data.

TABLE 2 Pavement Condition Data Thresholds

Condition Data	Threshold Value	Condition Data	Threshold Value
PCR	70	Rutting	0.5 inch (13 mm)
IRI	130 inches/mile	FN (Smooth Tire)	20
		FN (Ribbed Tire)	35

The Commission performs a regression analysis for each section of the Turnpike using the PCR and IRI data from several years of data to determine their deterioration rates, see Figure 3. The deterioration rates are calculated separately then averaged together for each section. Utilizing the deterioration rates and threshold values, the year of expected section failure is determined for each section. The expected years of section failure are used to help create the Commission’s ten year capital plan.

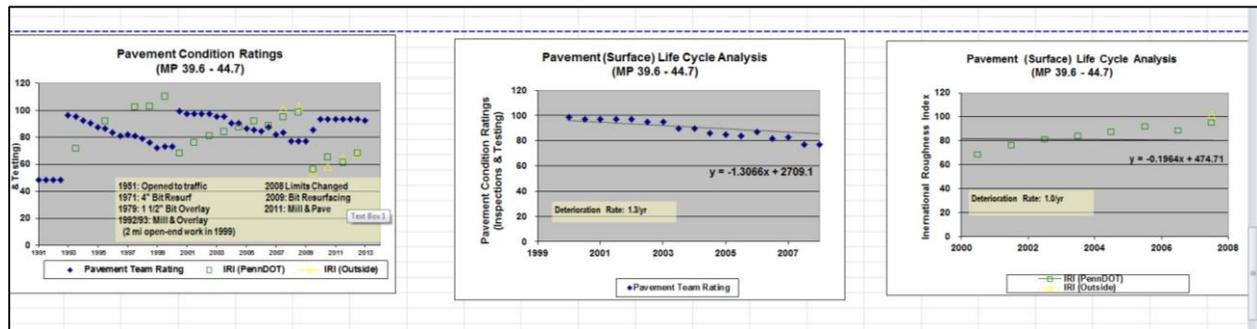


FIGURE 3 Example of Highway Section Deterioration Rates.

The Commission uses the rutting and skid resistance data to manage the road network in such a way that safety is maintained. The 0.1-mile (160 m) rutting data for each wheel path is analyzed to determine the severity of rutting in each wheel path for that 0.1-mile (160 m) section. The rutting severity levels are determined using the following scale (7):

- Low Severity = Less than 0.5-inch (13 mm) (< 0.5-inch (13 mm))
- Medium Severity = 0.5-inch (13 mm) to less than 1.0-inch (25 mm) (\geq 0.5-inch (13 mm) to < 1.0-inch (25 mm))
- High Severity = 1.0-inch (25 mm) or greater (\geq 1.0-inch (25 mm))

The Commission uses the 0.1-mile (160 m) data points to determine if there are any sections with rutting equal to, or greater than, 0.5-inch (13 mm) for three tenths of a mile (0.3-mile) (0.5 km) in length. If sections do occur, the Commission uses their Open End Contracts to correct these areas.

The Commission uses the 0.1-mile (160 m) ASTM E-274 skid resistance data, both smooth and ribbed tire, to help it maintain safe pavements. The friction data is evaluated against the established thresholds to verify that no section of roadway greater than three tenth of a mile (0.3-mile) (0.5 km) in length has an FN_{smooth} less than 20, or an FN_{ribbed} less than 35. If a section falls below the threshold values, the Commission utilizes its Open End Contractor to fix the area.

CONCLUSION

The types and methods of pavement condition data collection used by the Pennsylvania Turnpike Commission have been described. The Commission uses the current and projected future values of PCR and IRI to determine a year of projected pavement section failure (in terms of established threshold values) and to program capital projects to avoid sections reaching failure. Additionally, safety improvements are promptly programmed for pavement sections exceeding thresholds for rutting and friction. The collection of objective pavement data and use of established decision criteria help the Commission to proactively manage their network of roads in such a way that safety and driver comfort goals are met.

REFERENCES

1. Cupper, Dan, "The Pennsylvania Turnpike: A History", ISBN 0-911410-90-1, Applied Arts Publishers, Lancaster, PA, Fourth Revised Edition, 2012
2. Annual Book of ASTM Standards, Volume 04.03, Roads and Paving Materials; Vehicle-Pavement Systems, ASTM E-950, "Standard Test Method for Measuring the Longitudinal Profile of Traveled Surfaces with an Accelerometer Established Inertial Profiling Reference", ASTM International, West Conshohocken, PA, 2013, pp. 1156-1161
3. Annual Book of ASTM Standards, Volume 04.03, Roads and Paving Materials; Vehicle-Pavement Systems, ASTM E-274, "Standard Test Method for Skid Resistance of Paved Surfaces Using a Full-Scale Tire", ASTM International, West Conshohocken, PA, 2013, pp. 1100-1105
4. Annual Book of ASTM Standards, Volume 04.03, Roads and Paving Materials; Vehicle-Pavement Systems, ASTM E-501, "Standard Specification for Standard Rib Tire for Pavement Skid-Resistance Tests", ASTM International, West Conshohocken, PA, 2013, pp. 1115-1118
5. Annual Book of ASTM Standards, Volume 04.03, Roads and Paving Materials; Vehicle-Pavement Systems, ASTM E-524, "Standard Specification for Standard Smooth Tire for Pavement Skid-Resistance Tests", ASTM International, West Conshohocken, PA, 2013, pp. 1120-1122
6. Annual Book of ASTM Standards, Volume 04.03, Roads and Paving Materials; Vehicle-Pavement Systems, ASTM E-1926, "Standard Practice for Computing INTERNATIONAL Roughness Index of Roads from Longitudinal Profile Measurements", ASTM International, West Conshohocken, PA, 2013, pp. 1295-1310
7. Pennsylvania Department of Transportation Publication No. 336, "Automated Pavement Condition Surveying Field Manual", Pennsylvania Department of Transportation, Harrisburg, PA, 2012, pp. 20-21
8. Strategic Highway Research Program, National Research Council, SHRP-P-338 "Distress Identification Manual for the Long-Term Pavement Performance Project". Washington, D.C., 1993