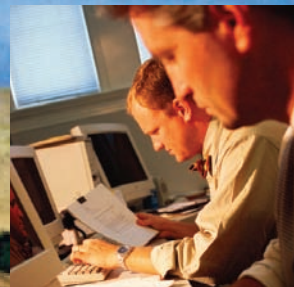


Comparative Performance Measurement



Pavement Smoothness

2008



Documents
Document Sharing Hub



American Association of State Highway
and Transportation Officials

Comparative Performance Measurement

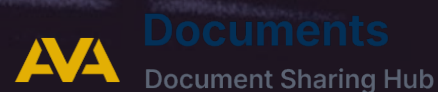
Pavement Smoothness

2008



American Association of State Highway
and Transportation Officials

444 North Capitol St, NW, Suite 249
Washington, DC 20001



© 2008 by the American Association of State Highway and Transportation Officials. All rights reserved. Printed in the United States of America. This book or parts thereof may not be reproduced in any form without written permission of the publishers.

ISBN: 978-1-56051-424-4

Photo of paver on front cover courtesy of Missouri Department of Transportation

AMERICAN ASSOCIATION OF STATE HIGHWAY AND TRANSPORTATION OFFICIALS EXECUTIVE COMMITTEE

2007–2008

President: Pete K. Rahn, Missouri

Vice President: Allen Biehler, Pennsylvania

Secretary/Treasurer: Carlos Braceras, Utah

Regional Representatives:

Region I David Cole, Maine, One-Year Term
 Kris Kolluri, New Jersey, Two-Year Term

Region II Stephanie Kopelousos, Florida, One-Year Term
 Butch Brown, Mississippi, Two-Year Term

Region III Debra Miller, Kansas, One-Year Term
 Kirk Steudle, Michigan, Two-Year Term

Region IV Gary Ridley, Oklahoma, One-Year Term
 Rhonda Faught, New Mexico, Two-Year Term

Immediate Past President: Victor M. Mendez, Arizona

Executive Director: John C. Horsley, Washington, DC

American Association of State Highway and Transportation Officials Standing Committee on Quality

Chair:	Rhonda G. Faught, P.E., Cabinet Secretary, New Mexico Department of Transportation
Vice Chair:	Douglas Rose, Deputy Administrator and Chief Engineer for Operations Maryland Department of Transportation, State Highway Administration
Secretary:	Joseph S. Toole, Associate Administrator for Professional and Corporate Development Federal Highway Administration
Liaison:	Anthony R. Kane, Director of Engineering and Technical Services American Association of State Highway and Transportation Officials

State Members

Alabama—Ronald L. Baldwin, P.E.
State Office Engineer

Alaska—Vacant

Arizona—James Young
Partnering Director

Arkansas—Ralph J. Hall
Assistant to the Director

California—Elizabeth A. Doohar
Chief, Office of Engineering Mgmt. and Acting
Assistant Division Chief of Construction

Colorado—Dennis Largent
Project Development Area Engineer

Connecticut—Vacant

Delaware—Kevin Canning
Quality Engineer

Dennis O'Shea
Assistant Director, Design

District of Columbia—William P. Carr
Director, Research and Technology Development

Wasi U. Khan, P.E.
Chief, Quality Assurance/Quality Control Division

Florida—Larry Ferguson III, CPM
Manager, Performance Management

Georgia—J. T. Rabun, P.E.
Assistant State Materials and Research Engineer

Hawaii—Leigh Pascua
Highways Division Staff Services Office

Glenn M. Yasui
Highways Administrator

Idaho—Jeff R. Miles, P.E.
Materials Engineer

Julie Pipal
Budget, Policy and Intergovernmental Relations Manager

Dave Tolman
Division Administrator

Illinois—John A. Webber
Assistant to the Secretary for Strategic Planning and
Special Projects

Indiana—Vacant

Iowa—Mitchell J. Dillavou, P.E.
Director, Engineering Bureau

David J. Putz, Ph.D.
Survey and Measurement Advisor

Kansas—Jim Kowach
Chief of Design

Kentucky—Katrina Bradley, P.E.
Chief District Engineer, District 9, Flemingsburg

Louisiana—Michael Bridges, P.E.
Undersecretary

Kirt A. Clement, P.E.
Deputy Undersecretary

Geralyn Penn
DOTD Management Consultant

Maine—Joyce N. Taylor
Assistant Director

Maryland—Becky Burk
Performance Excellence Manager

Normetha D. Goodrum
Deputy Administrator for Finance Information
Technology and Administration

Bridgid Seering
Statewide Partnering Coordinator

Massachusetts—Vacant

Michigan—Mark A. Chaput, P.E.
University Region Engineer

Myron G. Frierson, CPA
Bureau Director

Minnesota—Richard L. Arnebeck
Division Director

Mississippi—Vacant



Missouri—Mara Campbell
Director of Organizational Results

Rebecca J. Geyer
Organizational Results Specialist

Montana—James D. Currie
Deputy Director

Nebraska—Susan E. Larson
Administrator, Human Resources Division

Claude R. Oie
Engineer, Construction Division

Nevada—James R. Souba, P.E.
Assistant Director, Engineering

New Hampshire—Vacant

New Jersey—Walter McGrosky
Director, Capital Program Support

New Mexico—Nick Mandel
Chief, Quality Bureau

Gary Shubert
District 2 Engineer

New York—Daniel D'Angelo, P.E.
Director, Office of Design

Steven J. Hewitt
Director, Office of External Relations

Sue O'Connor
Office of External Relations

North Carolina—Julie A. Hunkins, P.E.
Director, Office of Environmental Quality

Walt Thompson
Director, Productivity Services

Jimmy Travis, P.E.
State Alternative Delivery Engineer

North Dakota—Tim Horner
Deputy Director for Business Support

David Leingang
North Dakota Department of Transportation

Ohio—Vacant

Oklahoma—Vacant

Oregon—Thomas J. Lauer, P.E.
Manager, Major Projects Branch

Pennsylvania—Jill Reeder
Chief Information Officer

Puerto Rico—Evelyn S. Colón-Berlingeri
Acting Director, Administration Area

Rhode Island—Colin A. Franco, P.E.
Managing Engineer, Research and Technology

South Carolina—Carl Chase
Assets Manager

South Dakota—Johna Leidholt
Cost Analyst

Tennessee—Diane E. Gusky, AICP
Director, Project Management Division

Texas—Bill Dickeson
Quality Management Branch Manager

Steven E. Simmons, P.E.
Deputy Executive Director

Utah—Wayne Rago
Productivity Coordinator

Vermont—Melvin E. Adams
Director of Policy and Planning

Virginia—Larry D. Jones
Management Services Division Administrator

Malcolm T. Kerley, P.E.
Chief Engineer

Washington—Daniela Bremmer
Director of Strategic Assessment

Paula J. Hammond, P.E.
Secretary of Transportation

West Virginia—Roy Capper, P.E.
Quality Assurance Section Unit Supervisor

Wisconsin—Rory L. Rhinesmith, P.E.
Division Operations Manager

Paul Trombino, III
Region Operations Manager
Wisconsin Department of Transportation

Wyoming—Mel Anderson
Performance Analyst

Janet Farrar
Strategic Performance Improvement Program Manager

U.S. DOT Member—FHWA—Daniel L. Fodera
CMQ/OE, Federal Highway Administration
Office of Professional and Corporate Development

Associate Member—International
New Brunswick—Stephen Blechschmidt
Senior Grading Technician

Dale A. Forster
Director, Construction

Ontario—Gerry Chaput
Chief Engineer/Director, Highway Standards Branch

Project Panel

Leonard Evans, Ohio DOT

Joe Beke, New Jersey DOT

Daniela Bremmer, Washington State DOT

Mara Campbell, MoDOT

Rick Miller, Kansas DOT

J. T. Rabun, Georgia DOT

Brian Schleppi, Ohio DOT

David Winter, FHWA

Nana Srinivasas, NCHRP Program Manager

Research Team: Spy Pond Partners with Applied Pavement Technology and University of Michigan

TABLE OF CONTENTS

Executive Summary	1
Analysis of Pavement Data Provided by 32 States	2
Identification of High-Performing States	2
Practices Contributing to Smooth Pavements	3
Improving Future Comparative Performance Measurement Using IRI	5
Introduction	7
Background	7
Research Objectives	8
Literature Review	8
Report Organization	11
Findings and Recommendations	13
Comparative Performance Analysis	13
Practices Affecting Pavement Smoothness	18
Findings Related to Measurement Consistency	27
Recommendations	29
Methodology	39
State Participation	40
Data Specification	40
Data Compilation	45
Data Analysis	49
References	53
Appendix A—Participant Questionnaire	55
Appendix B—Interview Guide for Smooth Pavements Practice Identification	61

List of Tables

Table 1. Breakdown of Entire IRI Sample Dataset.	50
Table 2. Length by Peer Group.	51

List of Figures

Figure 1. Initial Smoothness by Pavement Type	14
Figure 2. Comparison of Interstate Pavement IRI Values in Participating States for Flexible Pavements in a Dry, Freeze Climate Zone	15
Figure 3. Comparison of Interstate Pavement IRI Values in Participating States for Rigid Pavements in a Dry, Freeze Climate Zone	15
Figure 4. Comparison of Interstate Pavement IRI Values in Participating States for Flexible Pavements in a Dry, No Freeze Climate Zone	15
Figure 5. Comparison of Interstate Pavement IRI Values in Participating States for Rigid Pavements in a Dry, No Freeze Climate Zone	16
Figure 6. Comparison of Interstate Pavement IRI Values in Participating States for Flexible Pavements in a Wet, Freeze Climate Zone	16
Figure 7. Comparison of Interstate Pavement IRI Values in Participating States for Rigid Pavements in a Wet, Freeze Climate Zone	16
Figure 8. Comparison of Interstate Pavement IRI Values in Participating States for Flexible Pavements in a Wet, No Freeze Climate Zone.	17
Figure 9. Comparison of Interstate Pavement IRI Values in Participating States for Rigid Pavements in a Wet, No Freeze Climate Zone.	17
Figure 10. Summary of Survey Results and Selection of States for Follow-Up	19
Figure 11. Timeline of NCHRP 20-24(37B) Project	39
Figure 12. Thirty-Two Participating States	40
Figure 13. Slope Profile PSD Plot.	49

List of Acronyms

AADT	Annual Average Daily Traffic
AASHTO	American Association of State Highway and Transportation Officials
AGC	Associated General Contractors of America
ARTBA	American Road and Transportation Builders Association
ASCE	American Society of Civil Engineers
CRC	Continually Reinforced Concrete
DOT	Department of Transportation
DMI	Distance Measurement Instrument
FHWA	Federal Highway Administration
FIPS	Federal Information Processing Standards
GAO	Government Accountability Office
GPS	Global Positioning System
GRIP	Governor Richardson's Investment Partnership
HMA	Hot Mix Asphalt
HPMS	Highway Performance Monitoring System
HRI	Half-Car Roughness Index
IRI	International Roughness Index
LTPP	Long-Term Pavement Performance
MEPDG	<i>Mechanistic Empirical Pavement Design Guide</i>
MRI	Mean Roughness Index
NHS	National Highway System
NCHRP	National Cooperative Highway Research Program
PCC	Portland Cement Concrete
PI	Profile Index
PSD	Power Spectral Density
QA/QC	Quality Assurance/Quality Control
SCOH	(AASHTO) Standing Committee on Highways
SCOP	(AASHTO) Standing Committee on Planning
SCOQ	(AASHTO) Standing Committee on Quality
SPS	Specific Pavement Studies



Photo courtesy of Indiana Department of Transportation.

Comparative Performance Measurement for Pavement Smoothness

Executive Summary

Today's transportation agencies need to find ways to improve service and demonstrate tangible results for their customers—while operating under increasingly tight resource constraints. Comparative performance measurement is a potentially powerful technique for motivating and facilitating changes that result in improved performance. It motivates organizations to pursue improvements by showing them what their peers have been able to achieve. It facilitates improvement by identifying specific best practices that have led to good results. Establishing comparable measures can take considerable effort, but pays off when participating organizations learn from practices employed by their peers to improve their own performance. Comparative performance measurement efforts also have the important effect of shining a spotlight on current approaches to how data is tracked, how performance is being measured, and how results are being used. Participating agencies have an opportunity to examine the consistency and accuracy of their measurement practices, learn about differences in measurement across agencies, and work toward a greater degree of commonality.

This report presents results of the second in a series of comparative performance measurement efforts sponsored by the American Association of State Highway and Transportation Officials (AASHTO) Standing Committee on Quality (SCOQ), Performance Measurement and Benchmarking Subcommittee. The purpose of these efforts is to identify states that have achieved exemplary performance, find out what practices have contributed to their success, and document these practices for the benefit of other states. This effort focuses on pavement smoothness, and was co-sponsored by the AASHTO Standing Committee on Planning (SCOP) Subcommittee on Transportation Asset Management.

Pavement smoothness is an important performance measure for all states—travelers and shippers place high value on it, and several studies (16, 21) have concluded that

smooth pavement reduces vehicle operating costs. Because of the Federal Highway Administration's (FHWA) Highway Performance Monitoring System (HPMS) requirements, all states collect and report International Roughness Index (IRI) data for their National Highway System (NHS) roads. Planned changes to HPMS will encourage greater accuracy and consistency in measurement and reporting of IRI. The importance of this measure to states and the availability of relatively consistent data across agencies made pavement smoothness a good candidate for comparative performance measurement.

Analysis of Pavement Data Provided by 32 States

There was strong interest in this effort—SCOQ enlisted participation from 32 states. Each state provided two years of IRI data covering their Interstate highway networks and completed a survey describing their IRI measurement and reporting methods. While several hurdles related to data consistency had to be addressed, a rich dataset was assembled that allows for comparisons of IRI across states by climate zone, pavement type, and functional class (urban vs. rural interstate). This dataset consists of over 1.2 million records of short (primarily 0.1 mi) highway sections. Assembling data for sections of uniform length made it possible to produce distributions of system length by IRI value. These distributions provided insights beyond what would have been possible through examination of average network IRI.

It should be noted that the analysis conducted within this project was performed with the understanding that current variations in IRI measurement practice make precise comparisons of IRI across states (or even across survey efforts within a state) difficult. It was assumed that measurement error on the order of 15 percent exists. That said, results showed substantial variation in pavement smoothness within the group of 32 states. Average length-weighted IRI ranged from 49 to 143 in./mi. The percentage of very smooth pavements (<40 in./mi) ranged from 43 percent to less than 1 percent.

Identification of High-Performing States

Based on ranking of states within peer groups, 12 states were identified as high performers with respect to pavement smoothness. A notable finding from this ranking exercise was that the states ranked highest for rigid pavements were often different from those ranked highest for flexible pavements. Similarly,



states that were ranked highest for their urban pavements were not necessarily the top performers for rural pavements. Five states were selected out of the 12 for detailed interviews; the remaining seven states were asked to provide supplemental information about their practices.

Practices Contributing to Smooth Pavements

The major conclusion from the investigation of the practices used by top-performing states is that achieving pavement smoothness does not just happen; it requires a clear focus by the agency, and policies and programs that support that focus. Most of the practices identified were related to achievement of initial smoothness for newly constructed pavements, with the major themes being (1) use of end-result ride specifications with financial incentives for good performance, and (2) establishment of close working relationships with the contractor community. However, one top-performing state had achieved results through a sustained pavement management program; another state had undertaken a smooth roads initiative involving management focus, commitment of resources, and public involvement.

Five agency practices and four contractor practices were identified as valuable for achievement of smooth pavements.

Agency Practices

Agency Practice No. 1: Strong Performance Management Orientation

Underlying the success of several of the top performing agencies was a strong performance management program including network-level pavement smoothness targets and deliberate investments, policies, and programs aligned with those targets. Establishment of network-wide pavement condition performance targets was important to provide a focus for improvement efforts within pavement construction and maintenance programs and a basis for funding requests. Utilizing pavement smoothness as one of the factors for triggering maintenance or rehabilitation projects is one mechanism for providing alignment between performance targets and programs.

Agency Practice No. 2: Use End-Result Pavement Construction Specifications with Incentive Bonuses

High-performing agencies attributed much of their success to use of end-result ride specifications. These specifications do not prescribe specific construction methods, but rather put responsibility on contractors to achieve target performance levels, providing them with the flexibility to decide how to meet these targets. In some cases, incentive bonuses are used to gain contractor acceptance for end-result specifications and provide motivation for improving practice. Some agencies set performance targets initially at values slightly smoother than what was currently being constructed, and then periodically tighten them as practice improves.

Agency Practice No. 3: Build Close Working Relationships with Paving Contractors

Establishment of close partnerships with contractors was cited by the high-performing agencies as important to achievement of good results. These partnerships included involvement of contractors in task forces to set end-result pavement construction specification performance targets, holding pre-construction kickoff meetings to provide “just-in-time” training prior to construction as well as scheduling periodic



Photo courtesy of Missouri Department of Transportation.

sessions to address pavement quality issues or jointly identify opportunities to enhance smoothness. Some agencies conducted education and outreach programs that were jointly attended by agency inspectors, construction supervisors, and crew members. Some established recognition programs, with annual smooth pavement awards for the contracting community.

Agency Practice No. 4: Integrate Customer Input

One high-performing state involved the public in order to gauge acceptable levels of pavement roughness. This input was used to strengthen the basis for pavement smoothness target setting.

Agency Practice No. 5: Pavement Management

One high-performing state emphasized the importance of a sustained commitment to investment in strong pavement bases, preventive maintenance, and rehabilitation of pavements well before they become noticeably rough. These good pavement management practices lead both to smooth pavements and lower life cycle costs.

Contractor Practices

Contractor Practice No. 1: Materials, Placement, and Finishing Techniques

Materials selection, materials placement, and finishing techniques that contribute to achievement of smooth asphalt pavements include use of polymer- or rubber-modified Hot Mix Asphalt (HMA) mixes, and minimizing mix segregation. For PCC pavements, techniques included minimizing hand finishing and timely application of the curing compound and joint sawing.

Contractor Practice No. 2: Equipment Deployment

Techniques noted in this category included use of material transfer devices to reduce risk of bumps to pavers, use of mobile hot plants, use of dedicated trucks to maintain high production rates, and ensuring a consistent paver speed.

Contractor Practice No. 3: Daily Testing and Adjustment

Daily testing of results using light-weight profilers can identify the need for immediate adjustments to improve smoothness.

Contractor Practice No. 4: Cultivating a “Quality Mindset”

Contractors interviewed as part of this effort emphasized the importance of cultivating a quality mindset within their organizations, communicating the importance of quality, and making necessary investments in equipment to achieve pavement smoothness targets. Some contractors provide bonuses to their crews to reward them for quality results.

Improving Future Comparative Performance Measurement Using IRI

Improving IRI Measurement Accuracy and Consistency

The ability of agencies to use IRI-based performance measures and targets as a tool for improving their practices is currently limited by inconsistencies and inaccuracies in the measurement data. Improvements in accuracy and consistency have already been occurring, but further progress is needed. Six recommendations were developed to make IRI data more compatible across different agencies, thereby enabling an improved ability to discern practices leading to smooth pavements. These recommendations also aim to raise the accuracy of each agency’s database, allowing for more valid trending analyses and comparison of IRI values across the network within individual states. The six recommendations included the following:

1. Encourage adherence to the AASHTO MP 11 Standard Equipment Specification for Inertial Profilers. Use of a recording interval less than two inches is a key element of this specification that is not yet standard practice because it can require expensive modification of existing profiler components.
2. Encourage rigorous application of regular calibration procedures and system checks, as documented in the AASHTO PP 50 Standard Practice for Operating Inertial Profilers and Evaluating Pavement Profiles. Most importantly, use regular equipment calibration and daily system checks to ensure integrity of network IRI surveys.
3. Further develop AASHTO MP 11 and PP 50 for network profilers. These standards were written with construction quality assurance in mind, and can be improved based on current experience with network profiler application. Consideration should be given to adding specifications for real-time data quality checks.
4. Spot check profile data on control sections to ensure that profilers are functioning properly.
5. Verify IRI calculation software—Wherever software is used to generate IRI values, they should be verified using a reference program. This is best accomplished via a collective effort involving profiler manufacturers.

6. Require profiler accuracy and repeatability testing as a condition of procurement contracts. Certify existing profilers against a defensible reference measurement, and upgrade them as needed.

Addressing Data Gaps That Limit Comparative Performance Analyses

One notable observation from this effort was that there was wide variation in states' ability to assemble the data that was requested: IRI data in 0.1-mi sections, along with pavement type, last treatment type and date, presence of a bridge, Annual Average Daily Traffic (AADT), Percent Trucks, County (for assignment of Climate Zone), and Functional Class. While some states faced data gaps—particularly for pavement types and treatment histories, the most common challenge faced was the lack of a convenient capability to join disparate linearly referenced datasets. This is a fundamental need that is being addressed by states within a much larger context than this comparative performance initiative. Nevertheless, making progress in this area is important to the future success of comparative performance measurement for pavement smoothness. The following recommendations should be considered by states wishing to get their “data house” in order to enable effective analysis, comparison, and diagnosis of pavement smoothness results and identification of areas to target for improvement.

Maintain historical IRI data for 0.1-mi sections, and make this data easily accessible and easy to aggregate. While maintaining actual profile information provides maximum flexibility for processing to suit various needs that may arise, it would be beneficial for continued cross-state comparative performance measurement if states maintained their data in 0.1-mi sections.

Maintain information about pavement types with accurate spatial referencing. Pavement type breakdowns should at a minimum distinguish flexible, rigid, and composite pavements, with finer breakdowns recommended. National support for standard pavement type classification schemes (with specific definitions and crosswalks across existing classification methods) should be considered through an AASHTO initiative.

Maintain accurate pavement treatment history (both maintenance and rehabilitation) records, including both in-house and contractor work, accurate dates of last treatment, classification of treatment type, and accurate spatial referencing of the treatment limits.

Maintain accurate information on bridge locations to enable analysis of IRI datasets with and without bridges.

Provide data integration capabilities that are accessible to end users, allowing for dynamic segmentation permitting analysis of IRI data together with pavement type, treatment history, bridge location, traffic, and functional classification.

Introduction

Background

In 2004, the AASHTO Standing Committee on Quality (SCOQ) Performance Measures and Benchmarking Subcommittee initiated NCHRP 20-24(37)—Measuring Performance Among State DOTs. This initiative aims to establish a handful of comparative performance measures in key strategic focus areas—for example, project delivery, system condition, congestion, and safety; facilitate comparisons of these measures across a group of volunteer agencies; and use these comparisons as a way to identify and share best practices and lessons learned. On-time, on-budget project delivery was selected as the initial performance area. The final report for this initial comparative performance measures effort—NCHRP Project 20-24(37A)—presents data for 20 states and provides a synthesis of 28 best practices from the nine top-performing states.

NCHRP Project 20-24(37B) continues the comparative performance initiative, focusing this time on pavement smoothness. The IRI was selected as the performance measure for comparison because all states must report IRI to the FHWA as part of their HPMS submittals, and considerable effort has been made in recent years to establish clear standards and protocols to improve IRI measurement and reporting consistency.

This effort is timely, considering both the recent HPMS Reassessment and the adoption of the new *Mechanistic–Empirical Pavement Design Guide* (MEPDG). The individuals working on the HPMS Reassessment have envisioned a broader use of the pavement condition information than in the past. As a result, there will be several changes in the type and frequency of data that will be requested of state highway agencies. Reliable IRI data will be essential for the success of this effort.

The MEPDG considers both structural and functional pavement performance characteristics in the analysis of estimated damage to a pavement over time. The IRI is the functional performance indicator used in the analysis. The roughness models are based on the initial as-constructed pavement smoothness and changes in smoothness

due to the propagation of distress, site factors (such as subgrade), and maintenance activities. The default models incorporated into the design software have been calibrated at the national level using data from the Long-Term Pavement Performance (LTPP) program. However, they are not representative of all conditions and regions of the country. For that reason, it is important that the models be calibrated and validated to conditions in each state or region. The use of more consistent data collection practices will lend itself better to regional calibration activities.

Research Objectives

The objectives of this research project were to facilitate the process of comparing the performance of peer state DOTs using the IRI; prepare, analyze, and evaluate the performance data; and identify and document good practices related to achievement of smooth pavement. In addition to identifying causal links which may exist between network-level pavement smoothness and best practices, an important objective of this project was to facilitate future use of comparative analysis of pavement smoothness performance, by identifying analysis approaches and measurement techniques that can, over time, achieve a greater degree of consistency and comparability. While states measure pavement conditions in various ways, often using multiple indicators, this project was limited to comparisons of pavement smoothness on the Interstate System. This focus on the Interstate System eliminates much of the variability in IRI measurement that is related to measurement speed and speed changes, short segment lengths, and the presence of traffic signals. It is important to note that some states employ different pavement construction and management practices on Interstates than for other roadways, so the results of this research should be considered valid for Interstates only.

Literature Review

A focused review of literature relevant to this project was conducted to establish an appropriate set of expectations for what can be achieved. The results of this review are organized into the following five observations about IRI and its variations across individual pavement sections and different states.

1. Network-level IRI data from different states contain baseline measurement error on the order of 15 percent due to differences in equipment, calibration practices, and variations across operators.

Issues related to comparability of IRI measurements from state to state have been the subject of many prior studies and reports. The 2000 Government Accountability Office (GAO) Report, "Managing for Results—Challenges in Producing Credible Performance Information," noted their 1999 finding that "IRI data were not comparable between states because states differed in the devices, procedures, and mathematical simulations they used to calculate the index." Since then, as noted above, progress has been made to understand variations in protocols and methods and to achieve a greater degree of consistency. A 2004 survey of 38 states, conducted by California to identify other states with which they might benchmark IRI, showed that most states reported IRI for the average of right and left wheelpaths in the outer lane, but there was less consistency with respect to inclusion of bridges, calibration frequency, section length reported, and collection frequency. Efforts to standardize data collection procedures have resulted in the increased use of the provisional AASHTO protocols, which are included as guidelines in the HPMS *Field Guide*.

A 2004 HPMS/IRI experiment conducted by Ohio DOT (ODOT) collected IRI data on Interstate sections in Kentucky, Pennsylvania, Maryland, Virginia, and West Virginia and compared these data to the IRI statistics for the same sections that were reported by those states for the 2002 HPMS submittal. Sections on bridges and sections affected by construction zones were removed. All of the ODOT-collected IRI values were higher than those that the states had reported to HPMS. Differences between the ODOT-measured value and the HPMS-reported value ranged from 1 percent to 15 percent.

percent (MD)—though the MD data were based on less than 12 centerline miles. The conclusions of the experiment were that there were too many variables and unknowns to fairly compare HPMS IRI data state to state, and the standard deviations of differences in IRI across the different samples and the relatively small number of samples precluded factoring the data to allow for valid comparisons.

The 2004 FHWA “profiler roundup” included high-speed profilers from 14 different state DOTs, most of which were in use for measurement of IRI in pavement management. They measured nine test sections of diverse surface texture. On seven of the nine sections, the average IRI values from this group of profilers covered a total range of 10–15 percent from each other. This effort also showed that not only was there “scatter” in the measurements, but there was also systematic upward bias in measurements for pavement sections with rougher surface textures. Other studies as part of the LTPP have indicated that profilometer measurements are less repeatable for longitudinally tined surfaces than transverse tined surfaces. Steve Karamihas, a member of the research team, has authored several studies on the topic of profiler repeatability that confirm problems with repeatability of profilers with small height sensor footprint on tined and diamond ground surfaces (8, 9).

One notable finding of the 2004 roundup was that there was not better agreement in measurements across profilers of the same make and model than across profilers of different makes and models. This suggests a strong operator influence, even under well-defined conditions. Operators can affect IRI very easily, and most often in ways that bias the values upward: (1) poor speed control can add artificial roughness to the profile; (2) wander within a lane affects the IRI, and favoring the outside of the lane usually causes an upward bias; (3) improper tire pressure or lack of Distance Measuring Instrument (DMI) calibration can cause a shift in section boundaries; (4) failure to observe calibration and recommended field procedures can cause poor data collection to go on for days without detection (e.g., forgetting to do the bounce test puts you at risk of collecting data with a malfunctioning sensor, but the numbers may not be off by enough to alert an operator). Adoption of strict standardized equipment and operator certification processes have been suggested to address these issues.

2. Some differences in measurement and index calculation methods can be accounted for based on the existing body of research.

Removal of bridges from the datasets is one important adjustment that is typically straightforward to do, so long as pavement sections with bridges are clearly identified. A second is adjustments to datasets that utilize the half-car roughness index (HRI) rather than the mean roughness index (MRI). Such adjustments can be made for different pavement types based on regression equations developed from studies that have compared these two measures for individual sections. This adjustment was made as part of the Ohio experiment mentioned earlier. Other differences—for example, use of the “worst” lane rather than the outer lane, use of only the left or right wheelpath, etc.—cannot be as easily accounted for, yet can introduce systematic biases that impede cross-state comparisons.

3. Differences in weather conditions are another major source of variation in IRI measurements that needs to be acknowledged.

Studies have also shown that IRI measurements are sensitive to temperature and moisture conditions. Moisture can cause the pavement subgrade to swell or shrink, which affects the profile and therefore the roughness. Frost heaves of subgrade and base layers can also cause variations in the pavement profile. NCHRP Report 434 (Project 10-47) included examples of this in seasonal measurements from the LTPP database (13). Jointed Portland Cement Concrete (PCC) can change by up to 40 in./mi throughout a 24-hour cycle (12). Thin asphalt on expansive clay can be much rougher when the ground freezes. Given that HPMS IRI data are based on a single pass (rather than an average of multiple observations), documentation of environmental conditions at the time of IRI data collection is extremely important.



4. **True differences in IRI across individual pavement sections and changes in IRI over time are attributable to numerous factors, including pavement type, pavement design and material properties, construction methods, traffic loadings, and environmental conditions.**

Numerous LTPP analyses have indicated that multiple interacting factors impact both initial pavement roughness and changes over time: pavement type, construction methods, layer materials and thicknesses, soil conditions, freeze-thaw cycles, and traffic loadings. Variations in roughness across new pavements can be significant—for example, a 2004 panel analysis published in the American Society of Civil Engineers (ASCE) *Journal of Transportation Engineering* showed variations in as-built IRI measurements for asphalt concrete pavements in Wisconsin from 0.4 to 1.6 m/km (25 to 102 in./mi) (15). These results indicate that complex interactions across variables can confound diagnosis of explanations for differences in roughness. They also indicate that it will be difficult to distinguish best practices in pavement preservation from best practices in new surface construction using a snapshot of system-wide roughness.

5. **IRI does not tell the whole story about pavement condition and performance.**

IRI is generally seen as a lagging indicator of pavement condition. IRI values can be quite good on pavements that have had obvious surface fatigue for years. Good examples of this can be found on many of the LTPP Specific Pavement Studies (SPS)-9 sites, where visible surface fatigue often appears before the IRI values suffer a commensurate penalty (11). At some point, the pavement finally starts to get potholes, and the IRI may increase suddenly and dramatically. It is also important to note that IRI can be temporarily boosted with relatively low-cost overlays which may not be the best strategy from a life-cycle cost perspective. Best practices for short- and even medium-term smoothness are not always best practices to achieve long-term smoothness or maximize pavement life. Therefore, while

DOTs may use IRI as a comparative measure of pavement performance for pavement smoothness, as best practices considered, it must be recognized that IRI tells only part of the real story about pavement performance.

Given the above observations, while it may be difficult to say that state X with an average IRI value of 110 is higher performing than state Y with an average IRI value of 120, it is reasonable to conclude that when states are ranked by average IRI, the highest ranked states probably do have smoother pavements than the lowest ranked states and are likely to have pavement management, design, and construction practices in place that are contributing to their results.

Report Organization

The findings and recommendations of this effort are presented in Section 3. Details on the overall timeline for the effort, and the methodology for data requirements specification, data gathering, and compilation are provided in Section 4.





Findings and Recommendations

Comparative Performance Analysis

Analysis Results

Figures 1–9 present results of the comparison of Interstate pavement IRI values across participating states. IRI comparisons were made within peer groups. Peer groups were defined as combinations of pavement type (flexible or rigid), functional class (urban or rural interstate), and LTPP climate zone (Dry, No Freeze; Dry, Freeze; Wet, No Freeze; and Wet, Freeze). Generally speaking, the Wet, Freeze climate zone encompasses the northeast quadrant of the United States (extending as far west as Minnesota, Iowa, and Missouri, and as far south as Kentucky and Virginia); the Dry, Freeze climate zone covers the Northwest (extending as far south as Kansas, Colorado, Utah, and Nevada and including northernmost portions of Arizona and New Mexico); the Dry, No Freeze climate zone covers the Southwest (excluding coastal areas); and the Wet, No Freeze climate zone covers the Southeast United States as well as western coastal areas.)

In order to maintain anonymity, each state was assigned a number between 1 and 32.¹ The charts shown in the figures include one bar for each grouping of segments. In Figure 1, each bar represents a single pavement type within a state. In Figures 2–9, each bar represents a single functional class (urban or rural interstate) within a state for the pavement type and climate zone shown in the figure title.

Only the most recent year of data is shown on the charts. The left y-axis indicates the percentage of mileage falling below IRI cutoff values of 60, 94, and 170 in./mi.

These cutoffs are represented by the dark blue, yellow, and light blue portions of the bars respectively. The right y-axis is the length-weighted average IRI corresponding to the red line that is superimposed on the bars.²

¹ Assignments of numbers to states were not made alphabetically.

² The bars on these figures only show IRI values below 170 in./mi; the partial bars indicate that the remaining mileage had IRI of 170 or greater.