Improving FHWA's Ability to Assess Highway Infrastructure Health

Phase I Results

final

report

U.S. Department of Transportation
Federal Highway Administration

March 22, 2011

report

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prepared for

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1.0 Project Background

1.1 OBJECTIVES

Over the past several years, the importance of preserving the existing transportation infrastructure has received increased focus. A fundamental element of the performance of a transportation system is the physical condition of the assets that comprise it. Consequently, the preservation of existing assets is a critical element of the nation's transportation programs and requires the identification of performance measures designed to capture and communicate the physical condition of pavement and bridges. The measures should also capture temporal changes in order to provide early indications of the efficacy of previous work and a basis for assessing options for future work.

The primary goals of this project are to define a consistent and reliable method of assessing infrastructure health with a focus on pavements and bridges on the Interstate Highway System, and to develop tools to provide FHWA and State DOTs ready access to key information that will allow for a better and more complete view of infrastructure health nationally. While initially focusing on the Interstate Highway System, it is the intent of this project to develop methodologies that can be expanded to the National Highway System or any other defined system of pavements or bridges, subject to data availability.

To meet these goals, the scope of this project includes two main tracks:

- Develop an approach for categorizing pavement and bridges as Good/Fair/Poor, which can be used consistently across the country. Performance in this context is based on condition information.
- Develop a methodology for determining the health of a corridor with respect to pavement and bridges. Health in this context is based on factors that go beyond condition.

These tracks are being coordinated with other Federal Highway Administration (FHWA), American Association of State Highway and Transportation Officials (AASHTO) and National Cooperative Highway Research Program (NCHRP) projects focused on performance-based transportation programs.

1.2 SUMMARY OF EXISTING PRACTICES AND DATA

This section summarizes the findings from a literature review conducted as part of Task 2 of this project. For more details, refer to the complete literature review report, dated December 13, 2010.

Data Collection

Although State DOTs collect and track a variety of measures of pavement and bridge condition today, the degree of coverage, consistency of measures, and method and frequency of data collection varies widely. Differences between State DOTs are typically more pronounced for pavements than bridges. Regardless, in order to develop a performance and health assessment approach that can be applied consistently across the U.S., the project team has focused on two national data sets – Highway Performance Monitoring System (HPMS) data and National Bridge Inventory (NBI) data.

HPMS is a national program that includes a sampling of inventory information for all of the nation's public road mileage as certified by the States' Governors on an annual basis. Each year, State DOTs are required to furnish data per the reporting requirements of the *HPMS Field Manual*. The HPMS requirements and field manual have recently been updated. The results are referred to as "HPMS 2010+".

All State DOTs are required to submit NBI data to the FHWA for all highway bridges on or over public roads, as well as on culverts greater than 20 feet in length. State DOTs and Federal agencies conduct periodic inspections of these structures, prepare and maintain a current inventory of these structures, and report the data to the FHWA using the procedures and format outlined in the *Recording and Coding Guide for the Structure Inventory and Appraisal of the Nation's Bridges*.

State DOTs have expressed a desire through direct feedback from AASHTO members to limit any additional data collection requirements.

Pavement Condition Data

Available systems of pavement condition evaluation and monitoring range from State-specific pavement management systems (PMS) to HPMS. Prior to the recent HPMS update, the main measure of pavement condition used in HPMS was International Roughness Index (IRI), which is an indicator of pavement roughness. In addition to IRI, HPMS 2010+ includes data on rutting, faulting, and cracking. Given that IRI is one component of pavement condition, but not condition in its entirety, HPMS 2010+ may allow for development of a combined distress and IRI scoring method.

Outside of the HPMS program, State DOTs collect a wide variety of additional pavement data elements, including longitudinal cracking, transverse cracking, fatigue cracking, rutting, and others. However comparisons between State DOTs are challenging because of differences in the specific items collected, data collection protocols, and methods/equipment used to collect data (e.g. manual versus automated methods, for example). A better understanding of the impacts of these differences will be a key output from the pilot study.

IRI, rutting, and cracking are primarily functional condition indicators. A key missing ingredient in determining pavement condition is to examine the structural response of the layered system. However, most State DOTs do not collect structural response information for PMS purposes.

Bridge Condition Data

The NBI dataset contains condition data by bridge component – deck, superstructure, substructure, channel/channel protection, and culvert. It also contains data on a bridge's functionality, such as underclearances and posting information. Data standards, collection procedures, quality control processes, and calculation methods related to the NBI data set are well established and have been used by State DOTs and the FHWA for several years. The measures currently under consideration by FHWA and AASHTO for national deployment focus on NBI data. Under consideration are good/fair/poor measures based on NBI component ratings, and a measure based on Structural Deficiency status.

Looking beyond the NBI, data required for AASHTO's Pontis bridge management system provide the most potential in terms of national bridge performance measurement. Most State DOTs (over 40) license Pontis. The Pontis database contains all NBI data items, as well as more detailed element-level inspection details. For example, the NBI file contains a single condition rating for a bridge's superstructure. The Pontis database contains additional data on the distribution of conditions by condition state for each structural element of the superstructure, including elements such as girders, stringers, floor beams, etc. Despite the number of DOTs using Pontis, there are still differences in the underlying data. For example, some DOTs do not collect element-level data. Rather, they use Pontis for NBI reporting. Others have modified the bridge element definitions. In addition, The AASHTO Subcommittee on Bridges and Structures has recently updated the definitions of the AASHTO Commonly Recognized (CoRe) Bridge Elements. These new definitions are not currently reflected in Pontis.

Despite the differences highlighted above, bridge condition data collection protocols are considered to be less variable than those for pavement condition data, providing greater opportunities for a national comparison of State datasets.

Overall Health

In many cases, the term "health" is used synonymously with "condition." For this research effort, it is anticipated that "health" will incorporate condition data, but also include additional asset characteristics.

The literature review found two examples of this broader type of health index – one developed by the U.S. Chamber of Commerce[1], and one developed by a group of European Nations through the European Cooperation in Science and Technology (COST) initiative.[2] The Chamber of Commerce approach considers aspects of supply (e.g., highway and transit density), quality of service (e.g., travel time index and fatalities), and utilization (e.g., percent of uncongested lane miles). The COST approach considers safety, comfort, structural adequacy, and environmental factors. In addition, the California DOT has developed a bridge health index that combines condition data from several individual bridge elements into a single, overall index. These efforts help to illustrate the potential and application of the health index approach. They also help to define a general model for developing a health index that can be summarized as follows:

1. Determine which asset characteristics (e.g., condition, traffic, safety, etc.) to include in the health index;
2. Determine which indicator(s) (e.g., IRI, structural adequacy, vehicle miles travelled, accidents, etc) to use for each characteristic;
3. Determine the relative weight of each indicator;
4. Normalize the indicators (e.g., on a 1 to 100 scale); and
5. Calculate the health index as a weighted average of the indicators.

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[1] Michael Gallis & Associates, et. al., Transportation Performance Index: Complete Technical Report - Measuring and Benchmarking Infrastructure Performance. Prepared for the U.S. Department of Commerce. September 19, 2010.

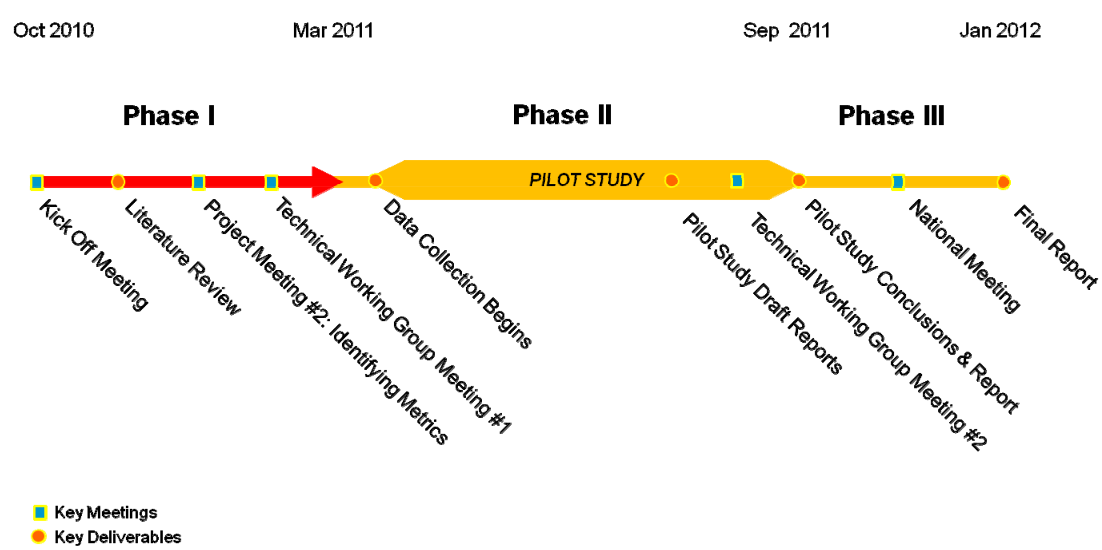
[2] European Cooperation in Science and Technology, *Transport and Urban Development*, Cost Action (354), Performance Indicators for Road Pavement, Final Evaluation Report.

2.0 Phase I Highlights and Recommendations

2.1 PHASE I MILESTONES

In order to achieve the objectives of this project, it has been divided into three phases, shown in Figure 2.1. Phase I focused on defining an approach for assessing infrastructure health, with a focus on pavements and bridges. In Phase II the approach will be finalized and tested via a pilot study on a sample corridor. Phase III is centered on a national meeting to review the project results and discuss the preferred methodology and next steps. This report marks the completion of Phase I (as illustrated by the red arrow in Figure 2.1).

Figure 2.1 Project Milestones



As part of Phase I, three formal project meetings were held. On October 14, 2010, a Project Kick-off Meeting was held at FHWA Headquarters in Washington D.C. Discussion focused on the project scope and expectations. On December 14, 2010, Project Meeting #2 was held with a focus on preparation for Technical Working Group (TWG) Meeting #1, which occurred on February 4, 2011. Discussions at all three of these meetings shaped the results and direction of Phase I (Sections 2.2 and 2.3 respectively). For more detailed notes on the discussions of each meeting, refer to the meeting minutes.

It is anticipated that the TWG will provide input throughout this project. In many cases, personnel responsible for pavement and bridge management are the best source of information regarding the health and performance of these assets. The TWG members will be asked to identify data that they consider in assessing the overall health of pavements and bridges. The TWG also will provide input regarding the criteria for classifying asset condition as good, fair or poor and information they use to make this determination. The recognition and inclusion of the types of information practitioners use to make assessments of health will be vital to establishing credibility and buy-in for this effort.

FHWA has worked with AASHTO to assemble the TWG to:

- Provide input on the assessment methodologies;
- Provide necessary data and support for the pilot; and
- Meet with the project team to review pilot results.

The TWG includes the following representatives from six State DOTs and AASHTO:

- Ms. Judith Corley-Lay, North Carolina DOT;
- Ms. Joneete Kreideweis, Minnesota DOT;
- Ms. Mara Campbell, Missouri DOT;
- Mr. David Huft, South Dakota DOT;
- Mr. Steven Krebes, Wisconsin DOT;
- Ms. Daniela Bremmer, Washington State DOT; and
- Mr. Matt Hardy, AASHTO.

Three of the DOTs (Wisconsin, Minnesota, and South Dakota) maintain a portion of the I-90 corridor selected for the pilot study, which is described below.

2.2 KEY FINDINGS FROM PHASE I

Based on the project understanding, literature review, guidance from FHWA, and input from the TWG, several findings regarding asset condition and health have emerged. These findings are summarized below, organized by the two parallel tracks of the project – categorizing asset condition as good/fair/poor, and assessing overall health.

Defining Good/Fair/Poor

The approach being implemented through this project for categorizing asset condition as good/fair/poor requires two separate steps:

1. Define **definitions** for good/fair/poor. By design, these definitions relate solely to the condition of a pavement or bridge, and do not consider other factors such as safety, capacity, etc. In addition, they are metric-neutral, meaning that the definitions will remain constant regardless of the metrics selected in step 2.
2. Define **condition metrics and thresholds** that can be used to systematically categorize assets based on these definitions. It is anticipated that as new data and modeling capabilities become available, these metrics will evolve.

Based on proposed FHWA definitions and input provided by the TWG, the following definitions have been advanced as part of this project:

- **Good condition** – Pavement and bridge infrastructure that is free of significant defects, and has a condition that does not adversely affect its performance. This level of condition typically only requires preventive maintenance activities.
- **Fair condition** – Pavement and bridge infrastructure that has isolated surface defects or functional deficiencies on pavements; or minor deterioration of bridge elements. This level of condition typically could be addressed through minor rehabilitation, such as overlays and patching of pavements that do not require full depth structural improvements; and crack sealing, patching of spalls, and corrosion mitigation on bridges.
- **Poor condition** – Pavement and bridge infrastructure that is exhibiting advanced deterioration and conditions that impact structural capacity. This level of condition typically requires structural repair, replacement or reconstruction.

These definitions can also be presented in a tabular form, as shown in Table 2.1.

Table 2.1 Defining Good/Fair/Poor

	Condition	Typical Work Required
Good condition	• Free of significant defects • Condition does not adversely affect its performance	• Preservation activities
Fair condition	• Isolated surface defects or functional deficiencies on pavements • Minor deterioration on bridge elements	• Minor rehabilitation - Pavement overlays and patching - Bridge crack sealing, patching of spalls, and corrosion mitigation
Poor condition	• Advanced deterioration • Conditions impact structural capacity	• Structural repair, replacement, or reconstruction

These definitions are intended for use by FHWA and State DOTs. They provide a single scale for subsequent measure and threshold discussions. Ultimately, they may need to be simplified for public consumption. In addition, if they are presented to the public, care should be taken to consider potential legal consequences of certain terms.

Ideally, the overall use of these definitions would be considered when finalizing them. For example, if the objective is to hold DOT's accountable for achieving good/fair/poor targets, then there may need to be more technical scrutiny and consensus building than if the main objective is to provide a nationwide reporting mechanism. However, it is unclear at this time how the good/fair/poor definitions may be used by Congress in the next reauthorization, and the focus at this time is on providing a national reporting mechanism.

The definitions and metric thresholds (discussed below) are not meant to vary by functional class. These differences would be addressed during a subsequent target setting process, e.g., where a target could be defined as the percent of a network (or portion of a network) that is in good condition.

Pavement Condition Metrics

Based on the work conducted in Phase I of this study, it is recommended that the following three options for pavement condition metrics be explored during the pilot in Phase II.

Pavement metric option #1 - IRI. There is momentum for IRI to be the initial basis for a national pavement performance measure. For example, IRI thresholds for good/fair/poor are currently being developed as part of NCHRP 20-24(37) G. (At this time, NCHRP 20-24(37) G is still ongoing. Therefore, all references to that work in this document should be considered to be in a draft stage.) These thresholds (which are presented in Table 2.2.) are consistent with the thresholds recommended in a recent FWHA report called, *Baseline Performance Data for Federal-Aid Performance Framework*, and with the thresholds used in the FHWA's *Condition and Performance (C&P) Report*.

Table 2.2 Potential IRI Thresholds

Threshold in C&P Report	Category	Draft Threshold from NCHRP 20-24(37) G	Category
≤95	Good	< 95	Good
≤170	Acceptable	95 ≤ IRI ≤ 170	Fair
>170	Not Acceptable	> 170	Poor

Pavement metric option #2 - New Metric Based on HPMS 2010+ Data. Although there is interest in IRI as an initial national indicator, there are recognized limitations with using a single indicator to measure pavement condition. IRI is a measure of pavement roughness not of overall condition. Many States DOTs combine ride/roughness data with distress data to represent overall pavement condition. However the details of this approach vary considerably across the country. As part of the pilot study, the project team will investigate using the distress elements required as part of HPMS 2010+ to develop a similar type of combined measure. For example, the new metric could involve a combination of IRI, rutting, faulting, and cracking. Potential issues on using this type of HPMS-based measure include:

- HPMS 2010+ pavement distress data is reported only for HPMS sample sections.
- HPMS data are only collected in one direction (e.g., east and south).
- Some DOTs are investigating the use of transfer functions to convert their existing data into the required HPMS 2010+ format. However, the validity of this approach has not been widely studied.
- It is anticipated that there is a significant range in how DOTs are collecting HPMS 2010+ condition data. IRI and rutting may be the most consistently collected across agencies.

These issues have been flagged for consideration during the pilot.

Pavement metric option #3 – New Metric Which Incorporates Structural Response. A significant benefit of Options #1 and #2 is that they are possible with existing data, or data that is expected to be available shortly through HPMS 2010+. However, neither option provides a comprehensive view of pavement condition. A more comprehensive pavement metric would also consider the structural response of the layered system. Therefore, as part of this study, the project team will explore opportunities and potential challenges of using state collected falling weight deflectometer data (if available) and deflection data collected with a Rolling Wheel Deflectometer as part of the good/fair/poor assessment in combination with options 1 and 2, presented above.

Bridge Condition Metrics

Three options for bridge condition metrics have been identified for consideration during the pilot.

Bridge metric option #1 - Structural Deficient (SD) Status. SD status is determined by FHWA based on NBI data submitted by State DOTs. A bridge is classified as SD if:

- The condition of its deck, superstructure, substructure, and/or culvert is rated 4 or less (on a ten-point scale), OR
- Its structural condition or waterway adequacy is rated 2 or less.[3]

[3] FHWA Non-regulatory supplement for 23 CFR 650.409, http://www.fhwa.dot.gov/legsregs/directives/fapg/0650dsup.htm

SD status is being explored as a potential national performance measure through NCHRP 20-24(37) G, and will be evaluated as part of the pilot for this study.

Bridge metric option #2 - NBI Ratings. While SD status is a widely used measure of bridge condition, it is binary (a bridge is either SD or it is not). The ideal metric for bridge condition would be a numeric index that allows for specifying different levels of urgency for addressing a bridge need. For example, the NBI dataset includes ratings for deck, culvert, superstructure, and substructure. These ratings range from 1 to 9. Previous FHWA efforts and a recent comparative analysis study of bridge conditions conducted though NCHRP 20-24(37) E used the following thresholds to categorize bridges as good/fair/poor:

- Good – Minimum rating ≥ 7;
- Fair – Minimum rating is 5 or 6; and
- Poor – Minimum rating < 5.

This approach will be explored during the pilot study.

Bridge metric option #3 - New Measure Based on NBI Ratings. Another option for combining the NBI ratings described above is to include additional ratings in the calculation (e.g., inventory load rating and water adequacy rating) and to calculate a weighted average. Each rating would be weighted by its perceived importance to overall bridge condition. This approach is similar to the bridge Health Index metric used by the Pontis bridge management system. During the pilot, the study team will explore options for a new bridge metric that is based on the weighted average of NBI ratings for deck, superstructure, substructure and culvert, inventory load rating, and water adequacy rating. This new metric could be reported on a 1-100 scale, with thresholds established for categorizing bridges as good/fair/poor.

Overall Health

The health assessment is intended to provide a means for FHWA to examine the overall health of specific corridors and respond to requests for information. It will enable FHWA to examine health across States in a consistent manner. State DOT’s may also be interested in the health assessment if they would like to know the condition of pavements and bridges in adjacent States, or if they would like to use the data to augment their agency-specific pavement and bridge data.

Several DOTs already compile and report information related to infrastructure health. While the FHWA can learn from these by reviewing existing reports and dashboards, the overall intent of this effort is to develop an approach that can be applied across States. Therefore the approach must be feasible solely with national data sets.

The vision for the health assessment has two components. The first is the ability to develop reports that summarize overall health and identify potential warning signs. The second component is a tool that enables users to review metrics and examine detailed data.

In developing the project approach, the FHWA and the project team narrowed down several options, coming to the following conclusions about the details of the health assessment:

- Scope – The pilot study will be conducted on an Interstate corridor, but the methodology should be applicable for the entire National Highway System or any other defined roadway network for which the required data is available.
- Scale - Data should be available by highway segment and flexible for analysis purposes. For example, FHWA would like the option to look at a segment of highway through an urban area, look at a segment of highway across an entire State, look at a segment of highway across multiple States, or examine overall network conditions of several (or all) States.
- Timing – The methodology will focus on a current snapshot of conditions/health, and where possible anticipate near term issues.
- Issues to address - The initial effort will focus on system condition, building on the pavement and bridge metrics used to categorize assets as good/fair/poor. It will include other data and metrics where available. For example, asset characteristics and usage may help to provide context and identify red flags. Specific factors identified for consideration include truck weight or truck type, age, output from the FHWA's Pavement Health Track Tool, and the financial demands of maintaining the asset. The health assessment methodology will enable future consideration of additional factors such as operational performance and transportation impacts.

Although potentially useful for DOT's, one concern with the proposed health approach is that they may be put in a position where they have to explain the differences between the results from FHWA's health assessment approach and their own. This issue will be explored further in Phase II of this project.

In addition to finalizing the metrics and data used for the health assessment, a key step in Phase II will be the development of an algorithm for combining these elements. For example, one option is to develop an index which assigns relative weights to each included metric. Another option is to base the assessment on independent thresholds, where any individual threshold could result in a lower overall health.

The display of the health assessment will also be critical to its success. Figures 2.2 and 2.3 represent two sample displays developed for illustrative purposes as part of Phase I.

Figure 2.2 Sample Health Display, Part 1

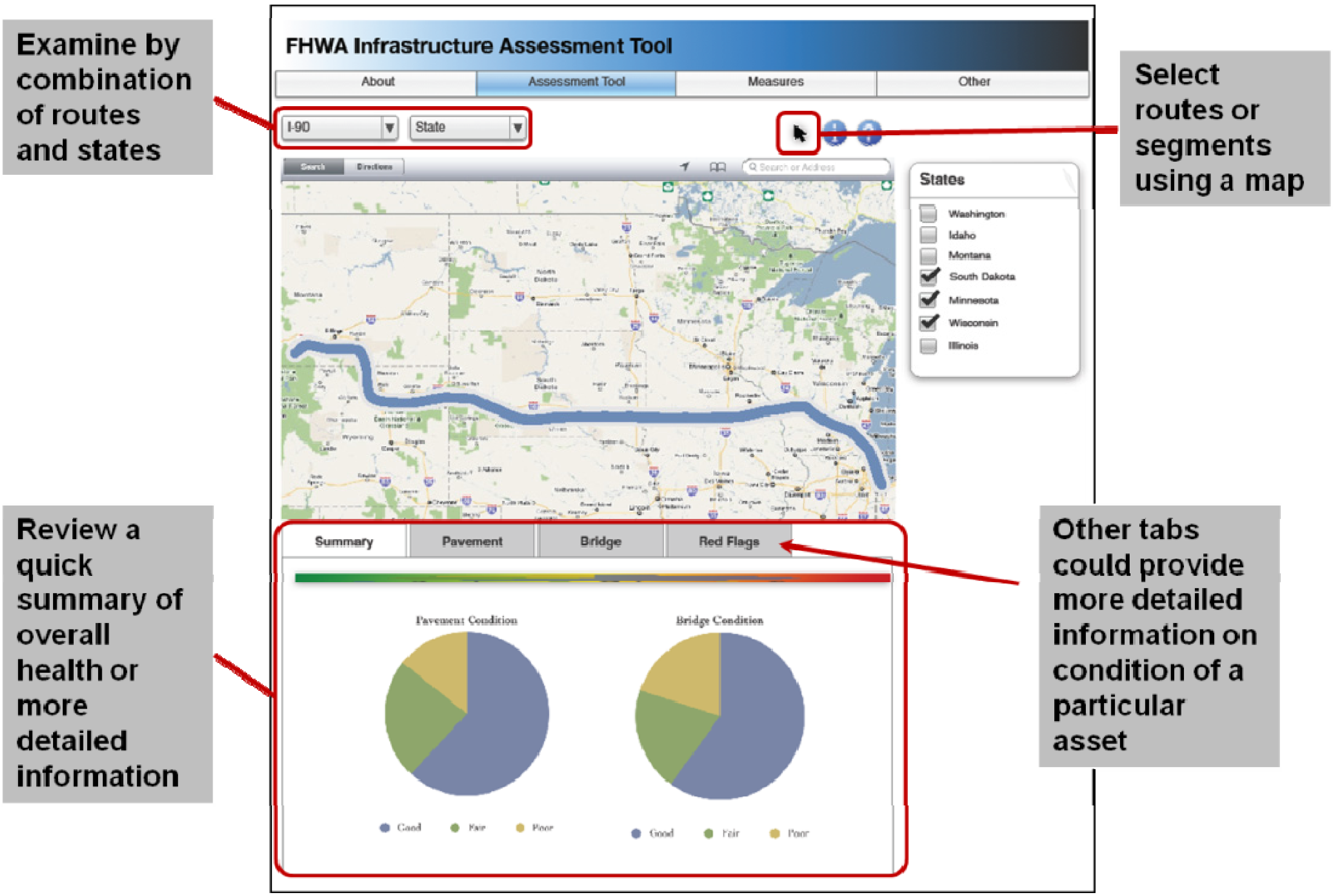
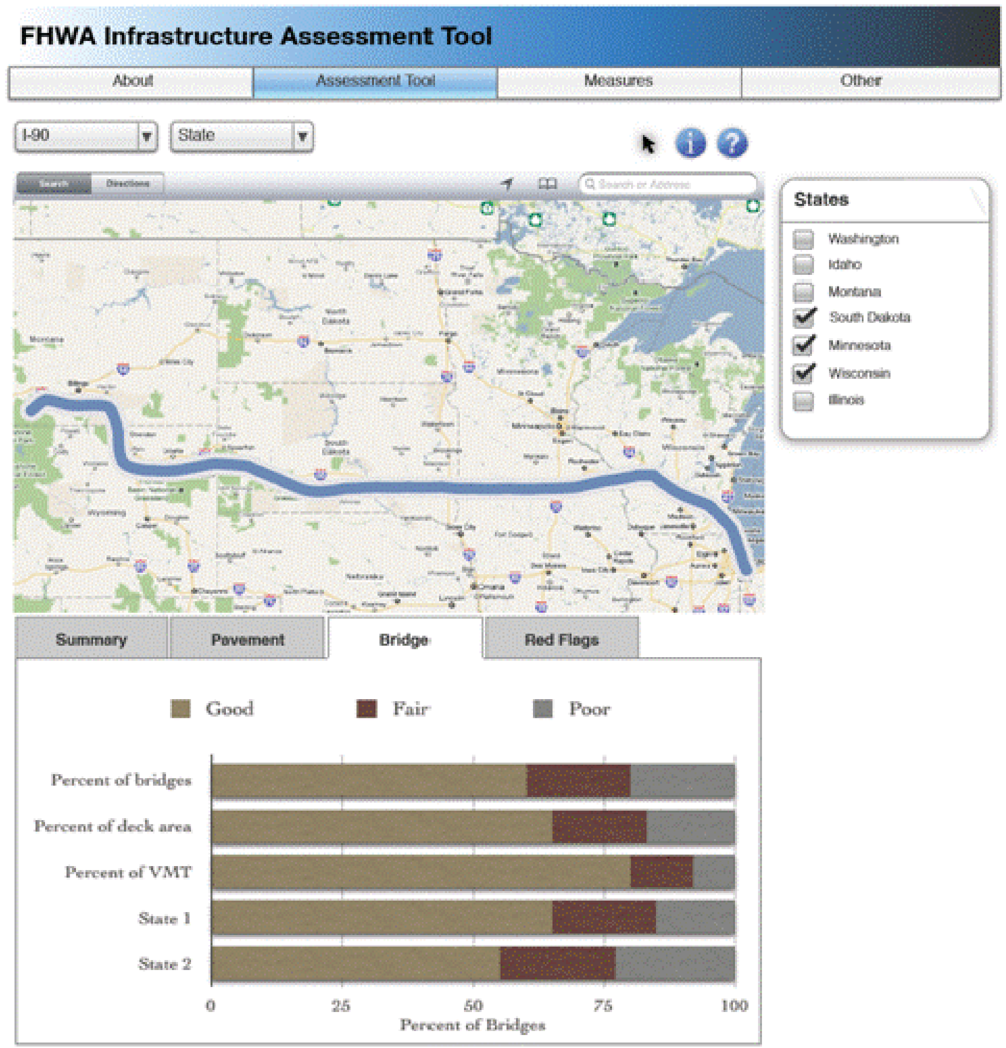


Figure 2.3 Sample Health Display, Part 2



2.3 PILOT PROGRAM

The objective of the pilot program that will be conducted in Phase II of this study is to test the methodologies described above for categorizing assets as good/fair/poor and assessing overall health. As part of the pilot, the study team will compile and compare three data sets for a multi-state, Interstate corridor: 1) data from State DOT databases, 2) HPMS and NBI data submitted to FHWA, and 3) data collected in the field as part of this effort. These data will be analyzed in order to address the following issues:

- Consistency between the three data sets listed above. Table 2.3 illustrates how these comparisons could be reported.
- Consistency in data between State DOTs.
- Implications of the use of automated data collection techniques.
- The validity of proposed methodologies, including algorithms for calculating the new measures, good/fair/poor thresholds, and the health assessment approach.

Table 2.3 Example of Testing Consistency Between Data Sources and Metrics

	State DOT Data			Data Submitted to FWHA			Data Collected in the Field by Project Team		
Data Set	**Good**	**Fair**	**Poor**	**Good**	**Fair**	**Poor**	**Good**	**Fair**	**Poor**
Metric Option #1	X			X				X	
Metric Option #2		X			X		X		
Metric Option #3			X		X				X

Pilot Corridor Selection

As part of Phase I, potential pilot corridors were evaluated based on consideration of a number of criteria, including the following (more details of the corridor selection process are available in a Phase I project memorandum, dated December 29, 2010):

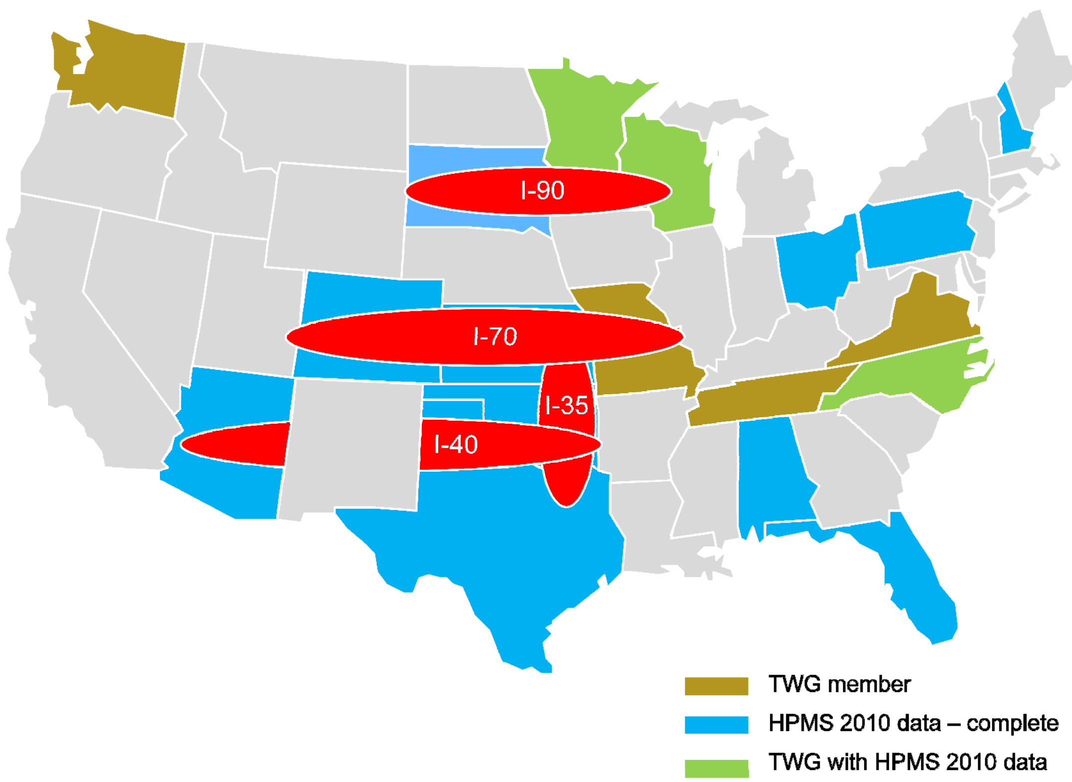
1. **Do not consider I-95.** The FHWA has conducted a previous data compilation pilot on the I-95 corridor.
2. **Adjacency.** Ideally, the three States would be adjacent. However, this was not mandatory.
3. **Data compilation expediency.** To ensure adherence to the overall project schedule, a major consideration was the extent to which data is readily available. For bridges, the potential good/fair/poor approaches rely on NBI

data, which is readily available from all DOTs. Therefore, the data expediency considerations focused on pavement data. The potential good/fair/poor approaches for pavements rely on HPMS 2010+ data. Therefore, the pilot States should have already submitted HPMS 2010+ files to FHWA. In addition, to minimize data compilation requirements, the pilot selection focused on corridors solely owned and operated by DOTs, as opposed to a combination of DOTs and toll authorities.

4. **Overlap with the TWG.** Include a representative from each pilot State on the technical working group.

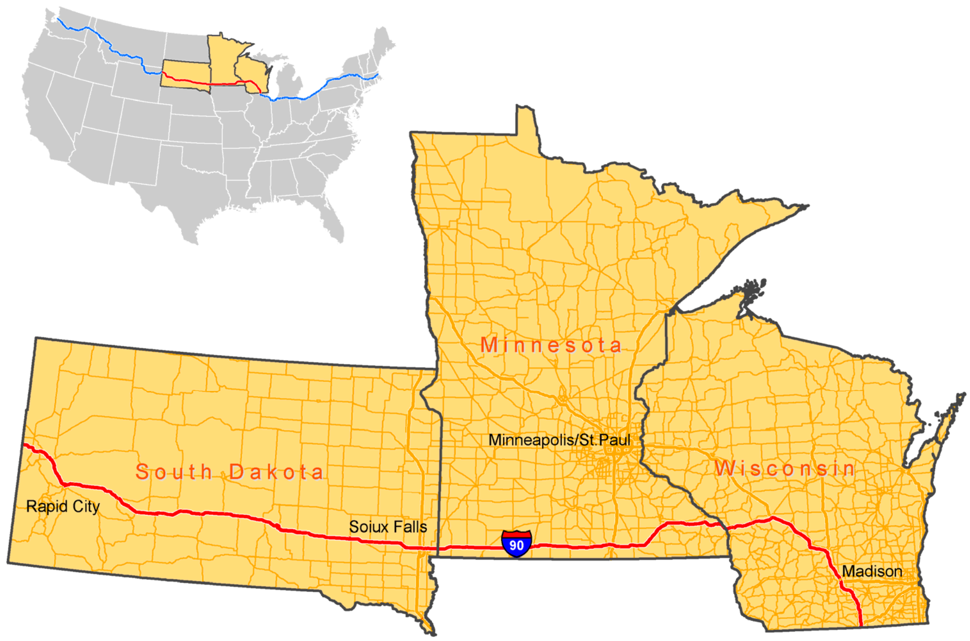
Figure 2.4 provides a geographic view of four potential pilot corridors that were considered.

Figure 2.4 Pilot Corridor Candidates



The I-90 corridor through Wisconsin, Minnesota, and South Dakota was selected because HPMS 2010+ data is available in all three States, and because no portion of it is operated by a tolling agency. Figure 2.5 illustrates the pilot corridor in more detail. For more details on the proposed approach to the pilot data collection and data gathering effort, refer to the Phase II work plan in Section 3.0.

Figure 2.5 I-90 Pilot Corridor



3.0 Phase II Work Plan

Based on the results of Phase 1, this section presents a detailed work plan for Phase 2. This work plan clarifies and expands upon the Phase 2 work plan presented in the Task Order Proposal Request and the project team's original proposal to reflect the decisions made during Phase 1.

Phase 2 consists of the following tasks (Phase 1 consisted of Tasks 1-4):

- Task 5 - Data Collection
- Task 6 - Identification of Critical Data and Tools
- Task 7 - Pilot Study Reports
- Task 8 - TWG Meeting

The following sections detail the specific work steps and deliverables to be provided for each of the tasks included in Phase 2.

3.1 TASK 5 – DATA COLLECTION

Objective: Collect and gather pavement and obtain bridge condition data on a three-state pilot study corridor, compare it to and analyze it along with State provided data, HPMS, and NBI data.

The selected pilot study corridor is I-90 in South Dakota, Minnesota, and Wisconsin as shown previously. This is approximately an 864-mile corridor.

A data gathering, collection and analysis plan will be developed based upon the metrics recommended during Phase 1 and will be submitted to the FHWA for review and approval prior to undertaking any further activity under the task. Upon approval, we will begin the data collection and gathering process.

In order to undertake this process, the team will obtain data from three sources, including:

1. National Data;
2. State Data; and
3. Field Data.

National Data

The study team will access data from the National Bridge Inventory (NBI) for the selected corridor. These data will be examined to identify bridges on the corridor and identify the type and condition of each bridge.

The study team also will access data from the Highway Performance Monitoring System (HPMS) to obtain inventory and pavement information from HPMS sample sections that reside on the study corridor. The data will be formatted and input into the project database for further evaluation in later stages of the project.

State Data

The State data gathering phase will involve gathering of data that resides in the States' management systems.

The team will establish contact points with each of the State DOTs (South Dakota, Minnesota, and Wisconsin). We intend to utilize these contact points as the conduit for the team to perform the State data gathering effort for pavement and bridge information.

One of the key success factors for this task will be to manage our interaction with the States during the data gathering process and make it efficient and painless for the participating States. This management strategy will include assigning one person to act as the project team's point of contact with each State (our State POC). This will negate the possibility of several team members contacting the State asking for the same information multiple times. In our experience, States are receptive to providing data. However, it is a burden in time and resources to perform this activity and not productive to have more than one point of contact. Our approach must be efficient by providing very clear instructions as to the data and associated documentation needed for the study and clear expectations for delivery must be established early in the process. When follow-up is needed, our State POC will perform the follow-up to ensure consistency in message and request.

The team will develop a data request that includes the type of data requested, the required data elements, desired format, supporting information (standards for data collection, frequency, sampling interval, etc.) and deadline for receipt. The data request will be submitted to the State liaison and a follow-up call will be made within two days to determine if the State has any questions or concerns with the data request. In order to reduce the effort by the State, it is likely that we will request the data in its native format (with appropriate metadata) so that the State does not need to reformat their data. The data elements to be requested from each State include:

- Inventory and linear referencing data including right-of-way images (if feasible/available);
- Financial information (if available);
- Traffic data (AADT, and percent trucks);
- National Bridge Inventory (NBI) data;
- Pavement type (flexible, composite, PCC);
- HPMS 2010+ pavement data (from the State's HPMS submission); and

- Pavement condition information from the State's Pavement Management System (both directions) including:
  - Pavement structure (best available);
  - PCI data (if available);
  - Pavement maintenance/rehabilitation history including costs (best available);
  - Falling Weight Deflectometer data (if available);
  - Cracking/Distress (in raw and processed format);
  - IRI (raw and processed);
  - Rutting (raw and processed); and
  - Faulting (raw and processed).

Upon receipt of the data, it will be checked for completeness and outlier data and anomalies will be discussed with the State POC. The data will be entered into the project database in a consistent format across the three States so that it can be compared during the analysis phase of the project.

Field Data

A critical task for this project will be to collect data in the field in order to compare apples-to-apples on a multi-state network. As decided with FHWA, bridge information will not be collected in the field as the project team will rely on NBI data provided by the DOTs and obtained from FHWA.

Previous projects have shown that while each State collects data, even "standard" data such as IRI can be collected using different methods, protocols, and equipment resulting in incomparable outputs. The results of this task will allow a comparison between network performance and health measured using consistent procedures and equipment, health measured using State-reported HPMS and NBI data, and additional condition data contained within agency pavement and bridge management systems. Field data collection will focus on pavement condition information.

To perform this task, the team will use the following multi-step process:

Step 1. Establish Data Collection and Analysis Procedures

Pavement condition information will be collected using a Rolling Wheel Deflectometer and an automated multi-sensor pavement data collection vehicle moving at highway speeds. For pavement data collection, the project team will focus on field data collection of the following information:

- Rolling Wheel Deflectometer (RWD) data[4];
- Right-of-Way (ROW) digital images (used for QA purposes); and
- Pavement condition data, including:
  - Cracking/Distress (in raw, HPMS 2010+, and ASTM Pavement Condition Index – PCI - format[5]);
  - IRI (raw and processed using ProVal);
  - Rutting (raw and processed using AASHTO Provisional Standards); and
  - Faulting (raw and processed using ProVal).

The specifics of data collection will be outlined in the detailed data collection plan described earlier. The data collection plan will include specifications for equipment (including calibration requirements), data types, data collection intervals, and interpretation and analysis parameters. In addition, data quality parameters will be established to be used to check the completeness and reasonableness of the data collected. Data formatting and storage requirements will also be addressed. The plan will contain the segments to be examined, State coordination requirements, and safety considerations. This data collection plan will be shared with FHWA and the TWG prior to field data collection.

Step 2. Secure Data Collection Vendor(s)

Once the data collection parameters have been established, the team will secure data collection vendors. The same data collection vendor and equipment will be used in all three pilot States. The FHWA has stated that they expect RWD testing to be performed on a sample of the network. Applied Research Associates, Inc. (ARA) is the only vendor who can perform this type of data collection; thus the team will subcontract with ARA to perform the RWD data collection. Based on preliminary cost estimates provided by ARA (~$60/mile = ~$52,000) it should be possible to conduct RWD testing of the entire corridor (in the east direction so as to be consistent with HPMS 2010+) using project funds. We will coordinate the sample size (whether full or partial coverage) with FHWA prior to execution of the RWD testing.

The team will also contract with a data collection vendor to perform the other pavement data collection activities. We expect that the vendor will perform a 100 percent survey in the right-most travel lane of the corridor in one direction (in

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[4] According to the vendor, texturing and tining in PCC pavements renders RWD data unreliable, thus only results for asphalt concrete data will be analyzed.

[5] It should be noted that automated data collection procedures may not be able to recognize some distresses (e.g. raveling and others) used in the PCI calculation without extensive manual intervention.

the east direction so as to be consistent with HPMS 2010+) and that we will establish a sampling procedure to develop cracking indices from this data so as to minimize data collection/processing costs (it is estimated – rough estimate - that data collection and data processing will cost approximately $160 per mile = ~$163,000). The sampling interval will be developed as part of the data collection plan. It is expected that ROW imagery, IRI, faulting, and rutting will be collected for the entire corridor.

Step 3. Conduct Data Collection

Once the data collection types, procedures and vendors have been identified, data collection can commence. One of the key parameters to be addressed during this step is to <u>engage, inform and coordinate with the State DOTs</u> involved with the corridor study. Our State POC will inform the contact at each DOT of the timing, location, and type of data collection being performed. Since all of the proposed data collection is performed at highway speeds, traffic control is not required.

Data collection will commence according to the plan developed under step 1. It should be noted that several weeks will be required after data collection for the vendor to process the RWD and pavement condition data. It is expected that 200 miles of either RWD or pavement condition data can be collected in a day so the entire corridor can be collected in a one-week period assuming weather is not a factor.

For pavement condition data, the selected data collection vendor will provide the project team with raw and processed data in accordance with the data collection plan. The project team will perform quality assurance review of the collected data to determine completeness, reasonableness, and calculation accuracy.

Progress in field data collection will be reported to FHWA on a weekly basis by email and a bi-weekly teleconference will be held to discuss progress.

Step 4. Analyze Data

The team will review and identify issues related to data collection, uniformity, and availability. In particular we will investigate to what extent independent (but uniform) data gathering and collection identifies differences between national data, State data and the collection sample. We will also investigate data consistency between national level data and State supplied data for the same information (for example NBI data from the FHWA versus State supplied NBI data, and national HPMS data versus State supplied HPMS data).

This comparison will be accomplished by calculating and comparing key statistics (e.g., minimum, maximum, average and standard deviation) for each data set. Identifying the existing limitations of each method of data collection and data sources will be a key finding from this study.

Another key analysis parameter will be the comparison of various types of pavement distress indicators. For example the HPMS pavement condition information yields a list of values for all of the data items. However, there is no method in existence to convert these values into a condition index (such as the ASTM PCI). By necessity the team will need to create such a transfer function and ground-truth the results using information collected as part of the study. One method we will explore is to emulate the PCI calculation procedure in structure. Simply put, the PCI procedure uses a series of deducts based on the extent and severity of each distress. These deduct curves are used to assign a deduct which is combined for all distresses and subtracted from 100. We intend to explore this method to convert raw data to a condition score. The PCI data collected during the pilot can be used to validate or correlate the HPMS "PCI" and the ASTM based PCI. We will also consider the use of the RWD structural data[6] in the HPMS PCI calculation or as an adjunct to the distress/IRI based HPMS data. Pavement performance will be assessed for both directions using PMS data and will be compared to pavement performance based on HPMS data and data collected by the study team (which will be collected in one direction). The purpose is to understand the degree to which performance based on data from one direction represents the performance of the entire system.

In addition to the above, an algorithm for a new NBI-based measure of structural adequacy may also be developed.

The results of this review will be reported under Task 7.

Deliverables:

- Data Gathering, Collection and Analysis Plan

3.2 TASK 6 – IDENTIFICATION OF CRITICAL DATA AND TOOLS

Objective: Identify data and analysis tools needed to develop the infrastructure performance and health reports in Task 7.

The project team will review the outcomes from the TWG meeting held in Task 3 as well as the results of the data gathering effort in Task 5 to identify missing data and analysis tools required to produce the pilot study reports in Task 7. Depending on the specific metrics selected for the pilot study and the data provided by the pilot States, the team may uncover issues with the availability and/or quality of the data and the availability of analytical models (or tools that encapsulate these models). For example, the team may determine that additional data will be required from all States in order to fully implement a national standard for pavement or bridge health. However, States may lack equipment,

[6] Usually this is done using a simple "strong versus weak" classification.

expertise and/or funding to collect and report these data. Also, given variations in materials and construction techniques for roads and bridges, there may be issues with capturing consistent data in all cases. It will be especially important to review data quality and data consistency among the pilot States.

For each deficiency, the team will propose one or more resolutions along with estimated costs. These costs will be developed in consultation with the pilot States regarding the level of effort to obtain these data.

In situations where analytical capabilities are not available, the team will draw on its own experience in developing pavement and bridge management tools as well as condition and performance models to estimate the cost of designing and implementing tools at different levels of sophistication. The team also may consult with FHWA personnel to gain a better understanding of the environment in which these tools might be deployed.

At the conclusion of this task, the team project manager will submit a memorandum to the task monitor. This memorandum will document any gaps in data or analytical capabilities as well as potential resolutions and estimated costs for each.

Deliverables:

- Memorandum detailing gaps in available data and tools and recommended strategies, and estimated costs, to address these gaps.

3.3 TASK 7 – PILOT STUDY REPORTS

Objective: Develop sample Infrastructure Performance and Health reports[7]. Compare the output of these reports with other pavement and bridge reporting mechanisms. Document results to date, including recommendations on how to address deficiencies in the data gathering process.

Following analysis of pavement and bridge data from the pilot States, the project team will prepare sample reports using the data obtained in Task 5. The specific metrics, visualization techniques and presentation medium used to show both performance and health will be based on feedback received from FHWA and the TWG supplemented by the team's experience in preparing and presenting this type of information.

At the present time, we envision that these reports will share a common structure. Users will be able to specify a geographic area (e.g., State, corridor, region, national). This will constrain the assets included in the report and

[7] The project team will coordinate with FHWA so as not to duplicate other ongoing FHWA efforts (e.g. HIPAT, QlikView).

determine the level at which information will be summarized. Each report will be divided into separate sections. Potential sections include:

- An overview of condition and health metrics in tabular, graphical, and static map formats, summarized by one or more categories (e.g., good/fair/poor, asset size, functional class); and
- A critical asset list that identifies infrastructure (either individual items or specific regions) in need of immediate attention.

Each report will be designed to operate off different data sets (e.g., State data, national data, pilot study data) to the greatest extent possible. It is possible that the appropriate data may not be available in each data set. Task 6 will address these specific deficiencies.

The team also will consider how to display condition and health information in a dynamic mapped-based format using a Geographic Information System (GIS)[8]. Our team has extensive practical experience using GIS to show asset data, including development of a system for FHWA to display pavement and bridge metrics for the Mid-Atlantic States using the Interstate 95 Corridor Coalition's Integrated Corridor Analysis Tool (ICAT). ICAT provides a consistent road network and an Internet-based mapping system for the I-95 corridor. We anticipate development of a prototype system equivalent to ICAT using road networks provided by the pilot States. We will also review dashboards from the three pilot States to learn how they report their performance measures.

Throughout the report design and creation process, the team will schedule two or three web conferences at which results to date will be presented to FHWA and TWG personnel. Comments received on these interim results will be used by the team to adjust the content and layout of the reports to ensure that the final product accurately reflects the vision of all stakeholders. These web conferences will include a discussion of data requirements, techniques used to create the reports, and any other issues that may affect the adoption of these reports at a national level.

Once the sample reports are complete, the team will hold a final web conference to allow FHWA and TWG members to provide any additional comments. At this time, the team will discuss not only the process for creating the reports but what the reports indicate with regard to infrastructure condition and health in

[8] The GIS work and any tool developed as part of this effort will be considered a prototype that illustrates a "proof of concept" of the approach. Additional work will be necessary to determine how best to deploy a production version of this system that, for example, enables FHWA to distribute the information widely over the internet without licensing issues.

the pilot States. Following this conference, the team will prepare a draft report that documents:

- Information on data obtained, including issues of data quality and consistency;
- Details on the sample Infrastructure Performance and Health reports, including what these reports indicate for the pilot States and any caveats regarding these results;
- Recommendations on how to improve the data gathering and analysis processes to the point where they can support the infrastructure reports;
- Recommendations for State DOTs for explaining any differences between FHWA's infrastructure health index and their own approach;
- Manual versus automated crack detection and reporting;
- Recommendations for future HPMS development including a "wish list" of improvements to be considered during the next update; and
- Estimated level of effort to roll-out these reports on a national level.

The team project manager will submit the draft report in electronic format to the task monitor, who will distribute it to FHWA, TWG, and pilot State personnel for comment. The task monitor will gather any comments and submit them, in writing, to the team project manager. Once all comments have been received, the team will prepare and submit a final report, in electronic and hardcopy formats, that incorporates all the comments received.

Deliverables:

- Sample Infrastructure Performance Report;
- Sample Infrastructure Health Report;
- Draft report (electronic); and
- Final report (electronic and hardcopy) that incorporates comments from FHWA, the TWG and the pilot States.

3.4 TASK 8 – TWG MEETING

Objective: Present infrastructure reports to the TWG and discuss the viability of using these reports on a national scale.

Following review of the Task 7 deliverables by FHWA and TWG personnel, the project team will organize a one-day meeting to discuss the Infrastructure Performance and Health Reports and any issues related to using these reports at a State, corridor, regional or national level. The team will lead meeting participants in a discussion of issues such as:

- What the reports are intended to show;

- What the reports do not show;
- Impediments, if any, to implementing the reports using current data and analytical methods; and
- How the reports can be used to understand infrastructure performance and health.

The TWG meeting will be held at a location to be determined in consultation with FHWA. The team will assist TWG and pilot State participants with travel arrangements, if necessary, and reimburse all travel costs. Discussion materials will be distributed in electronic form at least one week prior to the meeting date.

Deliverables:

- One-day TWG meeting (including meeting materials and travel support for up to six TWG members and, if appropriate, up to six participants from the pilot States).

Summary of Deliverables

As a result of the activities of Phase 2, the following deliverables will be developed by the project team:

Table 3–1: Summary of Deliverables

Phase 2: Conduct a Pilot Study to Document Infrastructure Performance and Health	
Task 5 – Data Collection	Data Gathering, Collection and Analysis Plan
Task 6 – Identification of Critical Data and Tools	Memorandum Summarizing Gaps in Available Data and Tools
Task 7 – Pilot Study Reports	Sample Infrastructure Performance Report
	Sample Infrastructure Health Report
	Draft Project Report
	Final Project Report
Task 8 – TWG Meeting	One-day TWG Meeting

3.5 SCHEDULE

Figure 3.1 contains the proposed schedule for execution of Phase 2, shown in context with the entire project schedule. We propose to follow the schedule developed during the original proposal process.

Figure 3.1 Phase 2 Schedule

ID	Task Name	Start	Finish
1			
2	**Task 0 - Notice to Proceed**	Mon 10/4/10	Mon 10/4/10
3			
4	**Phase 1 - Development**	**Mon 10/4/10**	**Thu 3/17/11**
29			
30	**Phase 2 - Conducting a Pilot Study to Document Infrastructure Health**	**Fri 3/4/11**	**Fri 9/23/11**
31	**Task 5 - Pilot Study - Data Collection**	**Fri 3/4/11**	**Thu 7/21/11**
32	Develop Pilot Study Work Plan (States/Methods)	Fri 3/4/11	Thu 3/17/11
33	***Deliverable: Pilot Study Work Plan***	Thu 3/17/11	Thu 3/17/11
34	**Conduct Pilot Study**	**Fri 3/18/11**	**Thu 7/21/11**
35	Gather and Analyze Data from National Sources	Fri 3/18/11	Thu 7/21/11
36	Gather and Analyze Data from States	Fri 3/18/11	Thu 7/21/11
37	Collect and Analyze Field Data	Fri 3/18/11	Thu 7/21/11
38	**Task 6 - Identification of Critical Data and Tools**	**Fri 3/18/11**	**Thu 7/21/11**
41	**Task 7 - Pilot Study Reports**	**Wed 6/1/11**	**Fri 9/23/11**
58			
59	**Phase 3 - Hold National Meeting**	**Mon 5/2/11**	**Fri 2/17/12**
69			
70	**Phase 4 - Progress Reports**	**Mon 10/4/10**	**Fri 3/9/12**