

NCHRP Project 08-108

**Developing National Performance
Management Data Strategies to Address
Data Gaps, Standards, and Quality**

Final Research Report

Prepared for NCHRP
Transportation Research Board
of
The National Academies of Sciences, Engineering, and Medicine

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1.0 Introduction

1.1 Research Objectives

Transportation Performance Management (TPM) is an established practice for driving improvements to meet safety, mobility, reliability and other important transportation agency objectives. It involves (1) measuring performance, (2) setting realistic targets for improvement, (3) developing plans, programs and management actions to meet the targets, (4) monitoring of actual results and other factors impacting these results and finally (5) adjusting plans, programs, actions, and targets. Each TPM activity is informed by data and analysis. Federal Moving Ahead for Progress in the 21st Century (MAP-21)/ Fixing America's Surface Transportation (FAST) Act requirements are providing motivation for state Departments of Transportation (DOTs) and Metropolitan Planning Organizations (MPOs) to examine their TPM capabilities and undertake strategies to take them to the next level. Improving collection, management and use of data is foundational to effective TPM.

NCHRP Project 08-108 was initiated in recognition of importance of effective data utilization for transportation agencies, and the need for agencies to carefully consider how they specify, define, obtain, store, manage, analyze, use, share, present, and communicate data. The research statement recognized that transportation agencies face numerous demands, opportunities and challenges with respect to improving how they use data. Therefore, the research was scoped to:

- Examine leading practices regarding data utilization to support TPM including specifying, defining, obtaining, storing, managing, analyzing, using, sharing, presenting, and communicating data.
- Identify contributing factors, both positive and negative, to the effective use of data to support transportation performance management.
- Present conclusions, cross-cutting themes, lessons, and strategies for overcoming shortcomings based on examples that will assist practitioners and decision makers to better utilize data to support transportation performance management.
- Prepare an approach (building on prior research) to assist transportation agencies implement a self-assessment on data utilization by identifying the critical building blocks for transportation practitioners to improve their efforts to specify, define, obtain, store, manage, analyze, use, share, present, and communicate data to support transportation performance management.

1.2 Research Tasks

NCHRP Project 08-108 was accomplished through a series of nine tasks, which are summarized briefly below.

- **Task 1. Literature Review** - Conduct a critical review of recent work related to transportation data utilization for TPM, including existing transportation data self-assessment tools.
- **Task 2. Draft Guidance Framework** - Develop a draft framework describing the structure and content of the guidance and identify a candidate set of case study vignettes that provide coverage of the identified TPM activities, performance areas, challenges, and data types.

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- **Task 3. Stakeholder Consultation** - Conduct and document results of 20 stakeholder interviews to understand current practice and key challenges.
- **Task 4. Interim Report** – Produce an interim report presenting the results of the initial tasks: literature review, framework, and stakeholder consultation.
- **Task 5. Panel Meeting** - Participate in a one-day panel meeting to present and discuss the results of tasks 1-4 and preliminary thoughts on the Task 6 interview protocols and pilot approach.
- **Task 6. Draft Guidance and Pilot Testing** - Prepare draft guidance material and review this material with a set of pilot agencies. Debrief on the value of the draft guidance and obtain suggestions for improvement. Document results in a technical memo.
- **Task 7. Final Guidance** - Prepare an updated version of the guidance incorporating feedback from the pilot test agencies and comments from the panel.
- **Task 8. Final Report and Technical Memo on Implementation of Research Findings** - Prepare draft final products from the project, to include: (1) a final report summarizing the methodology and results of the project; (2) a separate volume containing the final guidance produced in Task 7; (3) a set of presentation slides summarizing the objectives and key findings of the project, the products, and their intended application; and (4) a technical memo on implementation of the research findings that provides input to the National Cooperative Highway Research Program (NCHRP) project implementation team for moving the research products into practice.
- **Task 9. Webinar** - Conduct a webinar under the auspices of the Transportation Research Board (TRB), utilizing the summary slides prepared in Task 8. Work with TRB to obtain a recording of the webinar, and to make the recording, along with the presentation slides available to interested agencies for use as a training tool.

1.3 Report Overview

This report documents the key findings and recommendations of the project. The primary product of the research –*Management and Use of Data for Transportation Performance Management: Guide for Practitioners* is provided under separate cover.

Chapter 2 describes the guidance development process.

Chapter 3 presents the results of the literature review and synthesis of current practices, challenges and opportunities, data management techniques and success factors.

Chapter 4 documents the results of the stakeholder survey.

Appendix A is a detailed annotated bibliography produced by the literature review.

Appendix B is a copy of the stakeholder interview guide.

2.0 Guide Development Process

2.1 Overview

The Guide was developed through the following process:

- A literature review to identify what guidance already exists and what gaps need to be addressed through new guidance;
- Development of an initial framework, outline, list of case study vignettes and sample content;
- Stakeholder interviews to validate and supplement information on gaps identified in the literature review and get feedback on the sample content;
- Meeting with the project panel to get agreement on the content and format of the guidance;
- Completion of a draft Guide – including case study vignettes;
- Review of the draft Guide with 16 reviewers from three DOTs, three MPOs, and one local agency; and
- Revision of the draft Guide based on feedback.

Detailed results of the literature review and stakeholder interviews are provided in chapters 3 and 4. The remainder of this chapter:

- Highlights key findings about the state of the practice and key challenges in using data within TPM – based on these initial research activities,
- Discusses how these findings influenced the scoping of the Guide, and
- Provides an overview of the Guide contents.

2.2 State of the Practice Summary

Transportation Performance Management is a maturing practice at DOTs.

Transportation performance management (TPM) is a strategic approach that involves measuring transportation system performance and using this information to achieve established goals. Typical performance goals for transportation agencies include safety, mobility, accessibility, operational efficiency, infrastructure state of good repair, economic vitality and environmental sustainability.

When TPM practice is mature:

- There is a commitment to a performance-driven approach to planning, programming improvements and managing the system – based on explicitly stated goals and priorities;
- A hierarchy of performance measures have been established that link high level measures (e.g. statewide fatality rates) to tactical measures that can be used to help individual business units and employees understand how their activities contribute to achieving agency goals;
- There are well-established practices in place for measuring performance – and there is trust in the underlying performance data;
- A performance trend line has been established to provide context for review of current performance results and a basis for setting targets;
- There are established processes for using performance information to target areas for improvement, identify the most effective strategies, allocate resources within and across program areas, and prioritize investments; and

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- There are feedback loops in place to evaluate effectiveness of actions taken and adjust future actions based on what has been learned.

Performance management practices vary across transportation agencies. Within a given agency, practices for different program areas are at different levels of maturity due in part to availability of data and analysis methodologies and tools. For example, many agencies have well-established, performance-based practices for pavement, bridge and safety management but are in earlier stages of maturity for other program areas.

Quality data is foundational for effective TPM.

As illustrated in Figure 1, the performance management process begins with an understanding of current performance based on available data. When the right data is not available, or when data are old, incomplete, inconsistent or unreliable, there is no objective basis for establishing a performance baseline – or setting targets for the future. Putting a sound data gathering and quality assurance process in place is an important step for building a performance trend line that can be used to establish a baseline. However, this is just the beginning of an effective TPM program.



Figure 1. Use of Data in TPM

Once adequate data are assembled to establish baseline performance, additional and/or better data are needed to determine how the agency can best *improve* performance in the most cost-effective manner. Identifying strategies for improving performance may require data in a more disaggregated and detailed form. It also typically involves use of modeling and analysis tools to predict future conditions and assess how candidate strategies would improve performance. Visualization capabilities may be required to help the analyst understand the mix of needs and the relative effectiveness of different strategies.

After strategies for improving performance have been identified, additional analysis is needed to prioritize across candidate strategies and select the best mix of actions to address multiple objectives. New types of data to support prioritization and tradeoff analysis must be assembled and made available in a useful form.

Finally, after strategies are implemented, *monitoring* of strategy impacts and effectiveness is conducted to inform future planning, programming and operations activities – and to communicate progress to stakeholders. This monitoring must go beyond answering the question of whether the targeted level of performance was achieved. It needs to provide insight that can be used to “tell the story” of what happened - what the agency did, and what other factors came into play to produce the observed result. The process of developing this performance story – and then presenting it in a digestible form for different audiences requires integrated access to a variety of data sets – and the ability to explore and manipulate this data in multiple ways.

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A variety of challenges exist – and many are institutional – not technical.

Transportation agencies face a host of challenges related to efficient and effective data utilization within the TPM processes discussed above. Some challenges cut across different performance areas – for example, finding skilled staff to analyze and present data. Others are specific to individual performance areas or data sources – for example, obtaining data that provides insight into pavement structural health. Data utilization challenges generally fall into two categories: technical challenges and institutional challenges:

- **Technical challenges** are related to the process of *producing* data and related information suitable for use within TPM. They include data availability and accuracy; data consistency and interoperability; analysis methods and tools; and information technology infrastructure. Many of these challenges can be addressed by individual agencies through investments in data collection or purchase, tools and technology; adoption of data standards and quality assurance (QA) processes; and devoting resources to development of analysis approaches or methodologies. Some of these challenges can be addressed through national or collective efforts – the Federal Highway Administration (FHWA)’s provision of a national data travel time data set for the National Highway System (NHS) is one example.
- **Institutional challenges** are related to actual *use* of data and related information for agency decision making. These include management commitment to performance management; willingness (and ability) to invest in staff capabilities, data collection, and system improvements; and general receptivity to changes in practices among agency staff. These challenges are in many ways more difficult to overcome than the technical challenges. Transportation agency leaders at all levels can look to their peers that have demonstrated successful application of TPM for inspiration and strategies.

Table 1 provides examples of these challenges.

Table 1. Summary of Data Utilization Challenges for TPM

Technical Challenges	Cultural and Institutional Challenges
<ul style="list-style-type: none">• Gaps in data needed to support performance monitoring, diagnostics, analysis, decision making and communication• Difficulty integrating data from disparate sources due to lack of linkages and inconsistencies in specification and coding of key analysis variables• Difficulty aggregating data across districts or between DOT and MPO sources due to use of different measures and/or levels of granularity (e.g. zones, boundaries, road sections, time frames)• Aging technology infrastructures for storing, managing and reporting data• Lack of infrastructure and technical capacity to store and process “big data”, and lack of	<ul style="list-style-type: none">• Limited resources necessarily focused on meeting external reporting mandates, resulting in less emphasis on improving internal decision support• Tendency to rely only on available data rather than seek new types of data that could be more helpful to guide decision making• Lack of integration between agency TPM and broader agency management and governance activities• Leadership doesn’t view data improvement as a priority• Decentralized decision making about data system development, resulting in fragmentation

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Technical Challenges	Cultural and Institutional Challenges
<ul style="list-style-type: none">internal expertise in "big data" management or analysis• Lack of tools and processes for sharing data across divisions and groups within the agency; and with external stakeholders• Lack of tools and processes to identify and address data quality issues (e.g. missing data in travel time data set)• Data storage and purging practices that prioritize storage space over maximizing flexibility for future business use• Lack of skills and experience for effective data presentation	<ul style="list-style-type: none">• Lack of collaboration across business units to share existing data or jointly pursue improvements that address common needs• Lack of trust in externally collected data• Discomfort outsourcing data functions historically managed internally• Perfection paralysis – lack of willingness to share data when it may not be 100% accurate• Overly restrictive data use agreements with public and private partners• Difficulty attracting and retaining staff with technology implementation, data architecture, analysis and communication skills• Lack of ability to keep up with changes in data improvements in the marketplace

Technical and institutional challenges are often intertwined and must be addressed in tandem. For example, lack of institutional willingness to shift to a performance-driven approach to project prioritization may be based, in part on lack of trust in the underlying data or concern that a proposed scoring methodology does not account for important non-quantifiable factors. While these technical concerns may be valid, the critical question is how the agency chooses to proceed in the face of these challenges. With a strong commitment to performance management, a path for data improvement combined with a methodology that factors in judgement might be pursued. Without this commitment, the technical challenges might be viewed as a reason to not pursue any change to project prioritization approaches.

A holistic approach to data improvement is an emerging practice.

At the intersection of technical and institutional challenges is the absence of a deliberate and holistic strategy for investing in data, staff resources, and technologies to support agency business needs – including TPM. A few agencies have undertaken overarching or targeted data business planning efforts to assess data needs and develop strategies and roadmaps for improvement, and these efforts are providing models for others to follow.

Interest in data management is growing given changes on the horizon.

There is increasing recognition that the data landscape is changing, providing opportunities for substantial gains in data accessibility and value for decision making. More detailed data are available from multiple sources, including an expanding array of private sector sources. We can anticipate emergence of private sector data products in the coming years that will offer new insights into travel patterns and system performance. In addition, new tools and techniques are available for data integration, sharing, analysis and visualization. However, agencies with limited budgets, strapped workforces and relevant skills/expertise are having difficulty capitalizing on new opportunities. Now is an opportune time to provide additional guidance for agencies seeking to strengthen data utilization for TPM.

The state of the practice varies widely by performance area

TPM practices for pavement, bridge and safety are relatively mature, with longstanding data programs, established practices for making use of data for targeting of improvements, and in some instances, processes for monitoring of results to learn about effectiveness of different strategies. Practices for mobility and operations are somewhat established and are rapidly advancing. Methods for addressing economic vitality and environmental sustainability goals exist within planning processes but are less mature. Making performance tradeoffs across goal areas and prioritizing across a set of heterogeneous project types is still an emerging area of practice.

2.3 Scoping a New Guide: Filling the Gaps

The state of the practice review identified a number of challenges faced by transportation agencies seeking to improve their practices in using data for TPM. However, given the broad array of literature and guidance already available, the research team sought to scope a new Guide that built on – but didn’t duplicate existing resources.

TPM literature is extensive and covers key data concerns and techniques

The TPM literature is rich with assessment tools, case studies, and guidebooks on TPM and supporting data management practices. FHWA’s Guidebook for Performance-Based Planning and Programming (1), and the FHWA TPM Technical Assistance Program Guidebook (2) are two general references that cover the basic concepts of TPM and include pointers to other sources. A series of NCHRP reports have covered data management practices (3), (4), (5), (6) and recent NCHRP and FHWA reports have addressed data utilization for safety management (7), (8), operations (9), (10), (11), (12) and asset management (13), (14).

Because there are so many existing resources, it can be overwhelming for a busy practitioner to keep up with what is available. Boiling down the existing material into essential tips would be useful to people.

There are many TPM and data assessment tools available.

A review of the literature identified several existing assessment tools for TPM – Including data management and usability components (15), Data Management (4),(6), Safety Data (8) and others. Existing assessment tools enable agencies to explore their current level of maturity in depth within specific areas of data management. While new detailed assessment tools aren’t needed, higher level checklist-style tools could be useful.

Scoping Guidance to Fill the Gap

Based on the literature review, the guidance was designed with the following principles in mind:

- Clearly state that the purpose of the guidance is to help agencies improve their TPM data utilization practices, not to provide “official” guidance on meeting federal TPM requirements.
- Address the key challenges that agencies are facing in making data improvements.
- Complement (don’t duplicate) existing guidance.
- Recognize variations in practice across agencies and across performance areas.
- Focus on a relatively limited set of high value techniques that have strong potential for wide adoption. Don’t try to be “all things to all people” related to data and TPM.

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- Keep the content generic but include examples representing different performance areas (mobility, safety, pavement condition, etc.)
- Emphasize essential concepts in the guidance – don’t attempt to provide a detailed tutorial.
- Include “Lite” assessments in the form of practical checklists rather than formal assessments that require time consuming and resource intensive processes to complete.
- Design the guidance to consist of modular, “bite sized” components that are linked to one or more unifying graphical framework images – rather than a traditional report. These components should include case study vignettes (examples of practice) and checklists.
- Include curated links to reference material (rather than a comprehensive bibliography).

2.4 Final Guide Framework and Contents

Framework

The final Guide is structured around the framework illustrated in Figure 2.

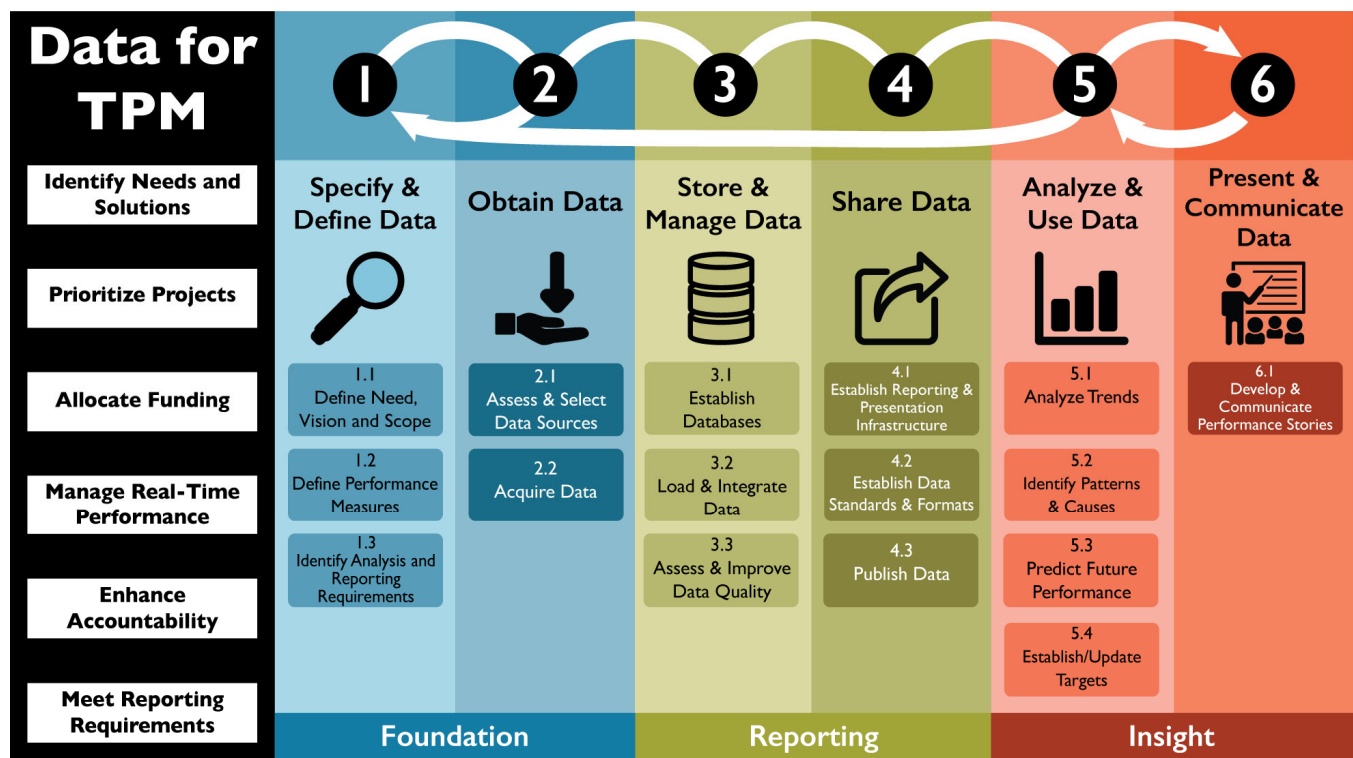


Figure 2. Framework for Improving Data Utilization for TPM

The left side of the figure describes the needs for data within TPM. These needs motivate initiation of data improvements for TPM.

The framework is organized into three fundamental data processes:

- **Establish a Data Foundation** – defining performance measures, identifying data requirements, selecting data sources, and obtaining the data.

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- **Set Up Reporting Processes** – standing up databases and reporting systems, publishing data and reports.
- **Gain Insights for Decision Making** –analyzing performance data to understand trends and explanatory factors/root causes, developing predictive capabilities, setting performance targets, and communicating the agency’s “performance story” to different audiences.

Each step is described briefly below.

Establish a Data Foundation

Step 1: Specify and Define Data. Determine what types of data are needed, how data will be used within TPM business processes, and based on this – specify attributes, scope, level of spatial and temporal granularity, and frequency of updates.

Step 2: Obtain Data. Acquire the data needed for calculating performance measures and for understanding trends and root causes of performance results.

Set Up Reporting Processes

Step 3: Store and Manage Data. Set up data repositories either within the agency or “in the cloud”; load, validate, clean and integrate the data; document the data for both technical and business users; and manage access to the data – to both protect it from unauthorized use and to ensure that it is accessible to those who need it.

Step 4: Share Data. Put the infrastructure in place to produce data products (e.g. reports, maps, interactive portals), and share data across business units within the agency, with partner agencies or with the general public.

Gain Insights for Decision Making

Step 5: Analyze and Use Data. Configure and use various data analysis tools to understand trends, predict future performance, and formulate performance targets.

Step 6: Present and Communicate Data. Translate data and analysis results into information that can be understood and used by different customers.

Content

The content of the Guide consists of:

- An *Introduction* that introduces the purpose and intended audiences for the Guide, and describes the framework.
- A section for each of the six framework steps, including:
 - A discussion of what’s involved in implementing each step and some of the critical choices to be made. Most steps are broken down into sub-steps.
 - A synthesis of key points in the form of “Do’s and Don’ts”
 - Checklists that can be used to assess agency capabilities and identify opportunities for improvement. The checklists include separate lists of “basic” and “advancing” capabilities. The intent is that agencies focus first on getting the “basic” capabilities in place, and then seek to further advance their practices.
 - Call out boxes with references to case examples (included at the end of the Guide)

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- A set of curated references for readers seeking additional information relevant to the step.
- A set of case study vignettes that illustrate examples of agency practice utilizing data for TPM. Cases are summarized in Table 2. Each case includes:
 - An overview section highlighting what the case illustrates;
 - Sections for the relevant data processes (Foundation, Reporting, Insight) describing what was done;
 - A section on success factors;
 - A section on challenges faced and lessons learned; and
 - A call out box with additional references.
- An appendix that compiles all of the checklists into a pull-out section.

Table 2. Case Study Vignettes included in the Guide

Case	Agency Type	Steps Illustrated					
		1-Define	2-Obtain	3-Store	4-Share	5-Analyze	6-Present
Arizona DOT Long Range Plan Investment Tradeoffs	State DOT	X				X	X
Caltrans State Highway System Management Plan	State DOT	X	X	X		X	X
Florida DOT Transportation Data Portal	State DOT				X		X
I-95 Corridor Coalition Probe Vehicle Data Procurement	Multi-Agency	X	X				
Maryland State Highway Administration's Incident After Action Reviews	State DOT	X		X		X	X
MATOC Regional Operations Evaluation	Multi-Agency			X	X	X	
Creating a Team of Data Experts to Support TPM at the Mid-America Regional Council	MPO	X		X		X	
New Jersey DOT Project Assessment Reporting	State DOT	X		X		X	X
Ohio DOT Winter Performance Management	State DOT	X	X			X	
Pennsylvania DOTs Statewide Transportation Operations Data Warehousing Business Plan	State DOT	X					
Virginia DOTs Pavement Monitoring Program	State DOT	X	X	X		X	X

3.0 Literature Review

3.1 Relevant Resources

The topic of data utilization for transportation performance management is one that has received considerable attention over the past 10+ years. Much has been learned through prior research efforts about data management challenges, opportunities and techniques. A considerable body of guidance exists for transportation agencies seeking to improve their data resources for TPM. Appendix A provides individual summaries of recent reports and guidance documents. The following section highlights some of the most relevant resources.

NCHRP Data Self-Assessment Guide

Over the past decade, several efforts have been undertaken with the goal of improving transportation agency data management and utilization capabilities and practices. In 2008, members of the Transportation Research Board (TRB) Data Section identified the need for an assessment tool that DOTs could use to identify gaps in their agency's data and elevate the priority of filling these gaps. In response, a scoping study (5) and a follow up project were funded within the NCHRP program, culminating in *NCHRP report 814: Implementing a Transportation Agency Data Program Self-Assessment* (6). This research involved interviews and focus groups with DOTs and MPOs to understand data challenges, and reviews of the literature to identify and document successful agency practices that can be pursued to advance agency data management capabilities. A comprehensive data management self-assessment tool was produced, covering five key elements: Data Strategy and Governance, Life Cycle Data Management (including collection, storage, documentation and delivery), Data Architecture and Integration, Data Collaboration, and Data Quality Management. A companion guidance document was prepared including a data improvement catalog with relevant practice examples for data improvement strategies within each assessment element.

NCHRP Research on Target Setting and Data Management

Within this same time frame, several reports were produced out of NCHRP Project 08-70, *Target-Setting Methods and Data Management to Support Performance-Based Resource Allocation by Transportation Agencies* (4). This work included several case studies on data management practices, and a high-level assessment tool for data management, organized around three elements (People/Process, Technology/Tools and Institutional/Governance.) This work stressed the value of agency data business planning to coordinate implementation of governance standards, policies and procedures, set goals for use of data sharing and integration technology to support data programs, and link data programs to performance measures, targets and planning functions.

FHWA TPM Toolbox

Over the past two years, the Federal Highway Administration's (FHWA) Office of Transportation Performance Management (OPM) has been working with a 40+ member stakeholder group of TPM practitioners within state DOTs, MPOs and transit agencies to produce a comprehensive TPM Toolbox that is based on a Capability Maturity Model (CMM.) The toolbox includes a web-based assessment tool and detailed implementation guidance (2). The TPM framework (shown in figure 3) includes two components that are specifically related to data management and usability for TPM. The data management component covers quality, accessibility, standardization and integration, data collection

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efficiency and governance. The data usability component covers data visualization and exploration, performance diagnostics, and predictive capabilities. For each of these components (and subcomponents), five levels of maturity are defined, and guidance on steps needed to advance to the next maturity level are provided, backed up by practice examples.

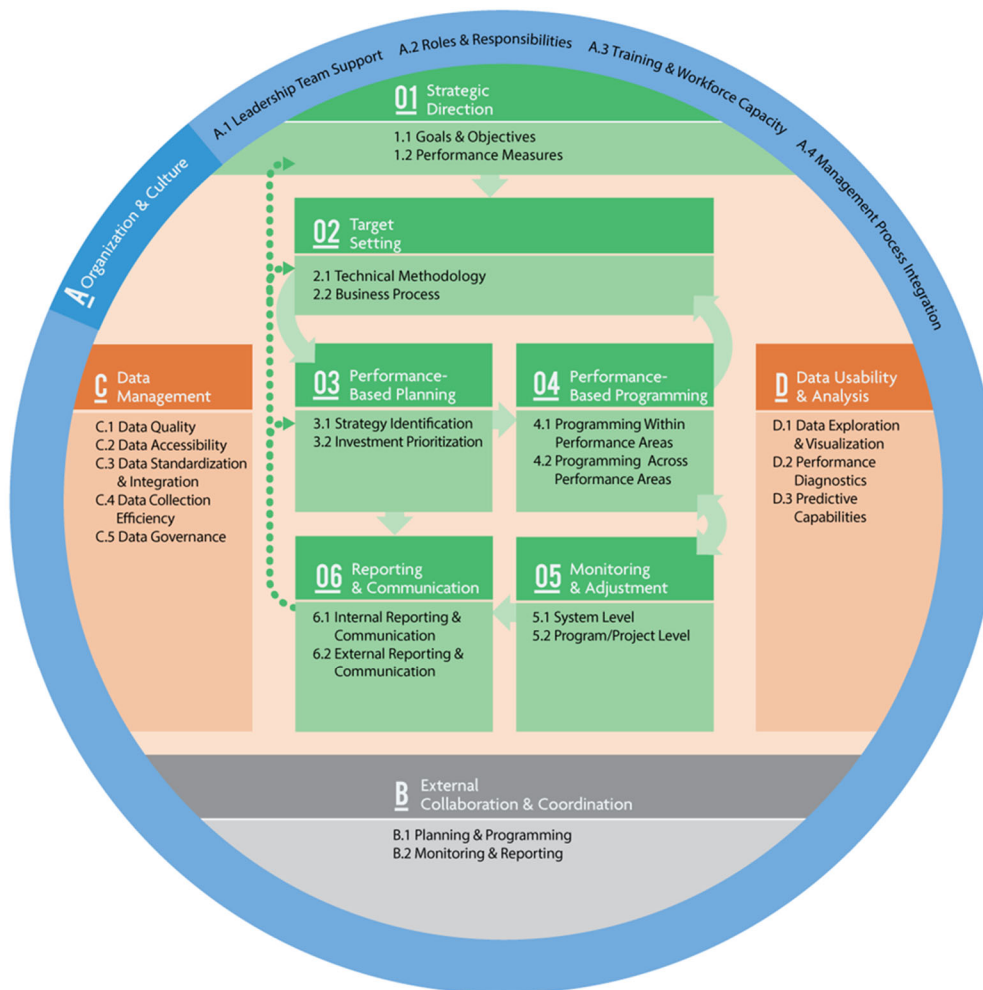


Figure 3. FHWA TPM Framework

FHWA's has sponsored development of several National Highway Institute (NHI) courses covering various aspects of TPM, including one specifically focused on the role of data in TPM.

Safety-Related Data Guidance

In addition to these general efforts to develop guidance for transportation agencies that can strengthen use of data within TPM, there are also several ongoing efforts that are focusing on data improvements within particular performance areas. For example, FHWA's Office of Safety sponsors the Roadway Safety Data Program (RSDP), which, in its initial round assessed roadway data for safety planning in all 50 states (8). The assessment considered: roadway data quality (completeness, timeliness, accuracy, uniformity/consistency), data analysis tools and uses for network screening, countermeasure selection and evaluation, data accessibility to stakeholders, data management and

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governance, and data interoperability and expandability. A second round of assessments is currently underway, which includes a new element for safety performance management practices. FHWA and NHTSA have similar efforts for crash and traffic safety data. FHWA has also developed a guide to safety data business planning (16).

Asset Management-Related Data Guidance

The Transportation Asset Management (TAM) gap assessment tool developed under NCHRP Project 08-90 in 2014 (14) includes assessment areas for Data Management and Information Systems. The Data Management area considers asset inventory and condition data availability as well as data governance processes. The Information Systems area considers available tools for decision support, system features, and integration capabilities. Beyond the Data Management and Information Systems areas, the tool includes several areas related to TPM such as “performance-based management”, “resource allocation”, “data-driven targets”, and “benchmarking” – and the assessment of each area includes consideration of data and technology.

FHWA has also sponsored several efforts to assess and improve data quality for the Highway Performance Monitoring System – which is currently envisioned to be the mechanism for States to report the required national pavement performance data.

Operations-Related Data Guidance

Within the operations area, FHWA has sponsored development of a publication titled *Applying Archived Operations Data in Transportation Planning: A Primer* (9). This document aims to help planners understand what types of operations data exist, and then show how that data can be effectively leveraged to improve TPM and other planning functions. Portions of the document explain how to obtain this data, and discuss challenges and how to get past them.

3.2 Synthesis: Data Utilization for TPM

Available literature provides a wealth of information on contributing factors to effective data utilization, barriers to improved practice and leading practices. Key findings within each of these topic areas are highlighted below. These findings provided a resource base for the Guide.

Contributing Factors to Effective Use of Data for TPM

The following factors were noted across multiple reports, case studies and guidance documents as key to making effective use of data for TPM:

- **Agency Performance Management Commitment.** A clear agency commitment to performance-based, data driven decision making, and an appreciation on the part of agency leadership for the need for investment in data.
- **Integration of Performance Measures into Decision Making.** Adoption of meaningful performance measures that the agency can impact through actions within its control provide the necessary context and motivation for gathering the right data, assuring its quality and making sure it is presented effectively.
- **Sustainable Data Collection and Maintenance Strategy.** Ability of an agency to develop a strategy for collecting and maintaining performance data at an acceptable cost level – considering budgetary constraints and the value to be added by the data.

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- **Suitability of Available Data.** The extent to which available data is suited to its intended purpose(s), considering:
 - Granularity (spatial and temporal)
 - Accuracy and Precision
 - Timeliness and Currency
 - Completeness
 - Consistency – over time and across sources
 - Integration – ability to link different data sets
- **Data Accessibility/Ease of Use.** The ease with which agency staff can access data in processed, integrated “analysis-ready” form. This depends on agency investments in data cleaning and integration activities.
- **Analysis, Visualization and Communication Capabilities.** Availability of expertise and tools for data analysis, visualization and presentation. This includes staff capabilities (and time commitment) to transform data into information, and tools that provide the ability to map, chart, filter, segregate, and aggregate data (by section, zone, subnetwork, district, jurisdiction, time period.)
- **Modeling Capabilities.** The availability of methods, tools and expertise for predicting future values of performance measures under varying scenarios.
- **Data Awareness and Understanding.** The ability of agency staff to understand what data are available, and to obtain accurate information about data definitions, derivations and limitations.

Leading Practices and Barriers to Improvement

Leading practices as well as barriers to improved data utilization for TPM noted in the literature are synthesized below – organized by data life cycle phase.

Specify and Define

This life cycle phase involves determining what types of data are needed, how data will be used within performance management business processes, and based on this – specifying attributes, scope, level of spatial and temporal granularity, and frequency of update.

Insufficient attention to specification and definition of data to meet agency needs is the source of many downstream difficulties with effective utilization of data. Key barriers include:

- Lack of widespread understanding within the agency of the importance of data, performance measures, etc.
- Emphasis on providing data needed to meet external reporting requirements rather than on how the data can be used for internal agency planning, programming, operations and management decision making.
- Over-reliance on “how things are currently done” – including a tendency to focus only on performance metrics that are supported by existing data. Rather than asking the question: “what data do we need to provide meaningful insight into performance”, people ask: “what can we do with the data we currently have?”

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- Lack of emphasis on identifying data sources that are needed for understanding the context for observed performance results to supplement and provide context for the data used for computing the performance measures.
- Concern about the loss of continuity with historical trendline information that would result from shifting to new, improved performance measures based on new data, collection methods and/or calculation methods.
- Difficulty reaching consensus on the appropriate level of detail for data collection given varying needs for accuracy, precision and granularity across different business units
- Lack of defined efforts to plan for collecting data necessary to track the impacts of transportation improvements – through before/after measurements. This involves work to track what work was done where and when, identify appropriate timing for measurements and account for exogenous factors that may influence performance results.
- Lack of coordination across business units to define common needs and align activities

Leading practices for specifying and defining data for TPM (as well as other purposes) include:

- Planning to ensure alignment between data and business needs and coordination across different business units
- Using data communities of interest to define business needs and assess adequacy of existing data
- Mapping linkages between data, analysis results, and decision making
- Designating authoritative data sources for particular uses
- Conducting before/after evaluations for particular project types as part of normal agency practice

Obtain

This life cycle phase involves acquiring the data needed for calculating performance measures, identifying root causes, and determining strategies for improving performance. Data may be acquired by the agency itself using in-house staff or contract forces; it may be available from federal, state, regional or local agencies; or it may be purchased or licensed from private sources. Some data related to TPM such as work history and project costs may be derived from agency information systems. Key barriers faced by agencies in obtaining data include:

- Gaps in availability for certain types of data or prohibitive costs of obtaining data at a useful level of detail. Examples include:
 - asset inventory and condition (for non-major assets);
 - asset condition data for non-state-maintained roads (including those on the NHS)
 - travel time and speed data for non-freeway routes
 - bicycle and pedestrian travel data
 - commodity data at the level of specific roadways
 - multi-modal supply chain data
 - freight data for other than long haul travel (e.g. “last mile” and urban deliveries)
- Difficulty providing a reliable and consistent source of funds for ongoing data collection and quality assurance activities
- Lack of expertise for evaluating adoption of new data sources: Sensors/Probes/LiDAR, etc.

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- Not invented here syndrome - lack of staff receptiveness to or comfort level with external data sources and services
- Desire to have complete control over data – inherent mistrust of 3rd party data and concern about risks of future loss of continuity, lack of control over future price increases, etc.
- Lack of experience with negotiating data purchase/usage/sharing agreements with private vendors
- Lack of planning for and investment in data quality management as part of data gathering efforts

Leading practices for obtaining data for TPM (as well as other purposes) include:

- Employing newer and emerging technologies for data collection that provide a higher level of data coverage and level of detail than conventional data collection methods. These include 3D Laser Scanning, Light Detection and Ranging (LiDAR), Unmanned Aerial Vehicles (UAVs), Traffic Sensors, and Video
- Purchasing or licensing probe data derived from Global Positioning System (GPS) devices and packaged by private vendors
- Using “crowdsourcing” methods to obtain data on asset condition (e.g. potholes, pavement roughness), incidents or road hazards. This data may be acquired directly by the agency or through a partnership with a private vendor.
- Partnering with other agencies to pool resources for collecting data of common interest
- Developing and executing data quality management plans including activities to be performed prior to, during and after data collection.
- Improving coordination and handoffs through mapping data collection and processing workflows with clearly assigned responsibilities and deadlines
- Using video analytics, computer vision and machine learning applications – for example, to estimate vehicle classification or body types from video imagery
- Fusing multiple data sources (e.g. from induction loops and Weigh-in-Motion)

Store and Manage

This life cycle phase involves processing raw data – which may include validating, cleaning, normalizing, aggregating and integrating the data with other sources; storing the data in one or more repositories – either within the agency or “in the cloud”; producing documentation needed for both technical and business users of the data; and managing access to the data – to both protect it from unauthorized use and to ensure that it is accessible to those who need it. This phase also includes activities to design, develop and manage databases and technical infrastructure for data storage and data integration. Key barriers related to data storage and management include:

- Limited resources for new hardware and software – and existing legacy systems that are difficult to modify or adapt.
- Lack of infrastructure and technical capacity to store and process large data sets that can’t be accommodated within desktop database applications or in conventional relational databases.
- Lack of ability to integrate or consolidate disparate data sets due to inconsistent or incompatible data definitions, formats, levels of granularity, levels of precision, or variations in timing of collection.

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- Lack of sound decision making processes for determining what data to keep and for how long.
- Premature purging of potentially valuable data sets to make room for other or newer data sets.
- Aggregating data sets to the lowest common denominator to save on storage space or to accommodate least capable components or stakeholders – and limiting usefulness of the data

Leading practices for data storage and management include:

- Establishing roles and accountability for determining how best to store data to meet agency needs; to establish and adhere to data quality standards, and determine retention schedules for different data sets.
- Utilizing cloud storage to reduce or minimize an agency's IT footprint and make it easier to scale storage up or down based on need.
- Adopting standards (through data governance bodies or focused coordination efforts) to enable combining data from different sources such as:
 - data element definitions and formats
 - lists of values
 - location referencing
 - units of measure
 - aggregation/disaggregation dimensions
- Requiring data dictionary and data set-level metadata to be provided and making this information accessible to ensure proper data management.
- Establishing central data repositories integrating data from multiple sources that can be used as a source for reporting and analysis (data warehouses, data lakes.)
- Providing a data catalog that allows technical and business users to identify available data and understand its derivation and limitations.
- Creating annual data snapshots for reporting – coordinated across data programs.
- Intelligent data blending – combining data from multiple sources in order to assemble a more complete and accurate data set than would be possible from any single source.

Analyze and Use

This life cycle phase gets to the root of “data utilization” – it involves consumption of data by analysts, planners, managers, engineers, and operations personnel to inform decision making – from the strategic level (what should we allocate to the pavement program?) to the tactical and operational level (what message should be displayed on this freeway sign?) Barriers in this area include:

- Lack of established expectations and protocols for how data should be used within the context of decision making (see barriers listed under “Specify and Define”)
- Lack of analytical tools (and underlying methodologies) to predict likely impacts of investment levels and candidate strategies on performance.
- Limited availability or capacity of staff with skill sets for data analysis and application of specialized analysis tools.
- Capability paralysis - limited vision and capability to know how to use available data
- Precision paralysis – unwillingness to use data due to lack of understanding of what is good enough for a particular purpose.

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- Lack of coordination and collaboration across agency business units resulting in missed opportunities for synergies.

Leading practices supporting data analysis and use include:

- Establishing cooperative arrangements across agencies to transform data into information (e.g. the state DOT performs analysis of travel time reliability, computes measures for each facility and provides the data for use by MPOs and local agencies).
- Leveraging existing commercial off-the-shelf, open source and publicly available tools for analysis, visualization, forecasting and scenario analysis
- Utilizing private sector or university contractors to provide data analysis services as alternatives to standing up analysis capabilities in-house
- Edge computing - data processing at the source (e.g. at the site of the field sensor) rather than within a centralized repository
- Predictive analytics and machine learning – for predicting asset failure probabilities and other performance measures
- Data mining in support of “backcasting” (which involves starting with a future vision and analyzing current and historical data to estimate changes required to move from the current situation to the future vision.)

Share

Data sharing involves policies, practices and technologies for sharing data across business units within an agency, across agencies, or with the general public. When data sharing practices are not established, inefficiencies and duplication of data can occur – which means that available resources are not being well-utilized. Data sharing across agencies and with the public is also important to support accountability and transparency, which are integral to successful TPM efforts. Typical barriers to data sharing include:

- Lack of central repositories – or lack of Information Technology (IT) staff capacity to create new centrally available data sources
- Technical constraints on sharing data outside of the agency firewall
- Lack of awareness on the part of data owners that others may find value in their data; and lack of awareness on the part of potential users about what data exists in the agency (or within partner agencies)
- Lack of willingness to share data due to concerns about airing of dirty laundry or feeling that there is nothing to gain but everything to lose by making data accessible.
- Perfection paralysis – unwillingness to share data that is not perfect (and lack of time and resources to make it perfect)
- Tendency to be risk averse with respect to security and privacy issues – taking the position that everything should be protected unless there is a justification for sharing.
- Inability to overcome technical, policy and legal challenges to data sharing

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Leading practices supporting data sharing include:

- Establishing data governance and stewardship structures that facilitate communication about data sharing and identify opportunities for synergies across business units for collaborating or combining data sources;
- Establishing clear agency policies that data should be shared unless the need to protect it is demonstrated;
- Leveraging hosted or cloud services for data sharing;
- Using open data portals established at the federal and state levels;
- Providing standard data feeds (e.g. the General Transit Feed Specification or GTFS) or Application Programming Interfaces (APIs);
- Establishing cross agency collaboration on establishing data clearinghouses or shared repositories; and
- Executing data sharing agreements (internal to an agency and between and agency and its partners) that specify what data will be shared, when and how – and establish a clear understanding of data limitations and expectations for use.

Present & Communicate

Presenting and communicating data is closely related to the “Analyze and Use” phase – it is the process of translating data into information and developing effective ways of communicating the “so what” behind the data. Key barriers include:

- Lack of suitable tools supporting effective communication of data.
- Lack of staff with the right skill sets for effective communication of data to different audiences (or limited capacity of available staff that do).
- Lack of interaction with data audiences to understand their questions and obtain feedback on data products. and
- Inability to compete with the private sector for hiring of data scientists

Leading practices for data presentation and communication include:

- Strengthening relationships between data producers and consumers to obtain feedback on effective presentation methods;
- Training internal staff to specialize in data analysis, presentation and communication;
- Taking advantage of University internship programs to tap into students with data science skills;
- Creating effective data visualizations including heat maps, thematic maps, timelines, and other infographics;
- Creating effective, interactive data presentation and dissemination vehicles such as dashboards and story maps;
- Automating data summarization and reporting to minimize ongoing staff resources needed for producing reports;
- Performance journalism – a style of reporting created at the Washington State DOT that: “combines effective narrative writing with visual graphs, tables and measurements in order to provide a clear and accurate assessment to the widest possible audience”;

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- Using social media to communicate key results or draw people to more detailed communication products; and
- Developing specialized visualization and analysis environments – e.g. virtual reality simulators.

Gaps, Shortcomings and Strategies

Table 3 presents five key building blocks for effective data utilization, along with common gaps or shortcomings related to these essential building blocks and strategies for overcoming these gaps. This material was compiled from the literature review and stakeholder survey, and served as a resource for guidance development.

Table 3. Gaps, Shortcomings and Strategies to Overcome Them

Building Block for Effective Data Utilization	Common Gaps or Shortcomings	Strategies for Overcoming Shortcomings
Commitment and Resourcing	<p>Lack of leadership commitment and resourcing for data</p> <p>People view TPM as threatening rather than as a path for improvement</p> <p>Increasingly limited agency staff capacity – focus on “must do” rather than “should do”</p>	<p>Point to success stories – improvements to accountability, ability to secure funding</p> <p>Show examples of what a performance culture looks like</p> <p>Pooled fund efforts</p> <p>Development of templates for common activities</p>
Coordinated Vision and Requirements	<p>Lack of vision for how data will be used for decision support; emphasis on required reporting</p> <p>Lack of coordination across business units on data; challenges specifying data to address multiple needs</p>	<p>Provide examples of successful coordination efforts</p> <p>Provide examples of data uses for decision making – highlighting the key attributes, level of granularity, etc. made a difference</p>
Suitable Data Sources	<p>Gaps in available data (varies by performance area and agency)</p> <p>Lack of staff awareness of available data sources – both internal to an agency and externally</p> <p>Hesitancy to pursue private data sources due to cost, use restrictions, lack of disclosed methodologies, inflexibility and perceived risk</p> <p>Lack of standardization limits ability to combine sources</p>	<p>Continued federal/national efforts to purchase and provide data such as the National Performance Management Research Data Set (NPMRDS) as well as integrated views of multiple national data sources-the Highway Performance Monitoring System (HPMS), National Bridge Inventory (NBI), and Financial Management Information System (FMIS)</p> <p>Support increased local/regional partnering to pool resources on data collection</p>

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Building Block for Effective Data Utilization	Common Gaps or Shortcomings	Strategies for Overcoming Shortcomings
		<p>Demonstrate approaches and tools for publishing catalog information about available data sources</p> <p>Share examples of successful use of private data sources</p> <p>Identify specific opportunities for standardization</p>
Established Data Management and Sharing Practices	<p>Uneven or unknown data quality limits trust in data; challenging to devote resources to data quality management tasks</p> <p>Lack of single authoritative versions of data – within and across agencies</p> <p>Lack of metadata and documentation</p> <p>Lack of IT resources for system purchases, enhancements or data cleansing and integration services</p> <p>Disincentives for sharing data (e.g. risk of misinterpretation or misuse)</p> <p>Challenges keeping consistent location referencing across different systems</p>	<p>Demonstrate use of formal data quality management plans and approaches to automating data quality tasks</p> <p>Identify and share model data sharing policies and agreements</p> <p>Identify and share model processes for designating single sources of truth and minimizing “rogue copies”</p> <p>Identify and share models of IT support that are working well</p>
Tools and Skills to Create Actionable Information	<p>Lack of in-house skill sets for data analysis and presentation – or limited availability of these resources</p> <p>Limited tools available for analysis and forecasting</p> <p>Some available tools are costly to implement due to data requirements and need for specialized expertise to use</p> <p>Tools are siloed with different data sources – creating inefficiencies and inconsistencies</p> <p>Agencies rely on consultants to provide specialized expertise – but</p>	<p>Training on “data wrangling” and analysis techniques for transportation agency staff</p> <p>Continued efforts to improve available analytical tools supporting analysis and prediction – including strategies for integration across available tools</p> <p>Share successful agency strategies for hiring data scientists or building these in-house skills</p>

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Building Block for Effective Data Utilization	Common Gaps or Shortcomings	Strategies for Overcoming Shortcomings
	are challenged to sustain internal staff with knowledge to oversee this work and provide continuity	

4.0 Stakeholder Outreach

4.1 Key Findings

Stakeholders are Focused on Meeting Federal TPM Requirements

Stakeholders interviewed for this project were very focused on producing the required federal performance measures for pavement, bridge, safety, system operations, and freight; and complying with the target setting requirements. This focus on “checking the boxes” and producing the required reports appeared to take precedence over thinking about how to obtain and use data that would be most valuable for guiding agency decisions. Meeting the federal requirements appears to be the current primary “pain area” when it comes to data utilization for TPM.

Agencies with already established TPM practices appreciated the need for consistent national measures but viewed the federal requirements as extra work and a diversion from their existing, more productive TPM activities. For example, some agencies stated that the need to produce a new set of pavement performance measures meant that staff had to spend time to maintain “two sets of books” and explain to stakeholders how these new measures differed from the agency’s existing, longstanding measures. Changes to required levels of precision and data definitions were creating the need to devote already limited staff capacity to revising data systems and processes – with limited perceived value to the agency. Lack of consistent and detailed federal guidance on meeting the requirements was also brought up by several agencies.

For less mature agencies, the federal requirements were motivating progress in getting the fundamental data sets and tools in place – though even some of these agencies observed that the national measures had limited value for their internal decision-making processes.

Another indication of the focus on federal compliance with implications for the products of this research was the reaction of two respondents to the questions about what guidance is most needed. These respondents interpreted the term “guidance” as something that would be telling them what they *should* be doing – a “though shalt” rather than seeing it as a document with helpful tips.

Conclusion: Make it clear that the products of NCHRP 08-108 are intended to help agencies advance their TPM data utilization practices rather than to provide “official” guidance on how to meet federal requirements.

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Stakeholders Seek Help on Inherently Challenging Activities

The stakeholder interviews asked about areas where guidance would be helpful. While some respondents were uniformly interested in all aspects of TPM, the greatest concentration of interest was in areas that are inherently challenging – such as data gaps that would require substantial funds to fill, setting targets, root cause analysis, performance prediction, cross-program tradeoffs, and cross-agency coordination and partnering.

Conclusion: While the guidance wasn't intended to break new ground in these areas, it can add value by highlighting existing successful examples.

The Audience for Data Guidance is Diverse and Has Varying Needs

Responses to the interviews were diverse – varying based on the level of experience with TPM practice, the performance area represented (e.g. pavement versus operations), the nature of individual responsibilities (e.g. division manager versus hands-on data manager) and the type of agency (State DOT, MPO, City.) Each potential user brings a different set of needs – and material produced for one will not necessarily be valuable for another. For example, there were different reactions to the sample case study vignette that was provided for review. Some thought it was very helpful; some thought it wasn't relevant to their agency; and some found it overly long and not focused enough on answering a specific question that an agency might have.

Conclusion: The guidance should acknowledge varying audiences and clearly identify the intended users for each of the elements of what is produced. Target users should be able to quickly identify what is of interest to them and navigate to relevant information.

DOTs and MPOs Have Limited Staff Resources – Many Rely on Consultants for Data Support

The ability of transportation agencies to make progress in their TPM practices is highly constrained by available staffing. Eighty percent of respondents cited limited access to needed skill sets as an issue impacting their ability to effectively use data for TPM. A few agencies reported that they had been able to bring on staff with data analysis and presentation skills, but many of the respondents said that they rely on external consultants for these tasks.

Conclusion: The guidance should address ways to build or supplement staff skills.

Stakeholders Don't Read Reports – They Prefer Face to Face Conversations

When asked: "What sources of guidance have you found to be most helpful to get ideas for collecting, managing, analyzing and using data for TPM", the near-universal response was that people preferred face to face interaction with their peers at workshops, peer exchanges or conferences. They found peer to peer discussions valuable for both keeping up with what others were doing, and to have the opportunity to talk about specific questions – e.g. "how are you able to hire people with data analysis skills?" Some people referred to the FHWA and American Association of State Highway and Transportation Officials (AASHTO) websites; very few identified a specific report. It was clear from the conversations that few people have the time to read reports – especially long ones.

Conclusion: Keep the guidance concise and create a layout that makes it easy to read.

Successful TPM Means Impacting Decisions – and Having Good Data is Not Enough

For the respondents at the high end of the TPM maturity spectrum, the bottom line definition of “successful TPM practice” was whether performance information was being used to actually impact the decisions (as opposed to just producing interesting reports or attractive dashboards). However, these respondents pointed out that even with the most accurate and persuasively presented information, it takes funding for implementing improvements, organizational commitment, political will, and champions.

Conclusion: Highlight cases where decisions have been impacted using data. While these examples should acknowledge that it takes more than data to impact decisions, the content produced should stay focused on data aspects - finding the right data, translating it into information, injecting it into the right processes, etc.

4.2 Methodology

Stakeholder Selection and Engagement

The purpose of the stakeholder outreach was to obtain input from the target audience that will help to shape the guidance to be developed in this project and make it as useful as possible. Several factors were considered in building a list of agencies and individuals to include:

- Plan for approximately 20 total interviews – some of which may be with different individuals/groups at a single agency
- Include a mix of DOTs, MPOs and local agencies, with relative emphasis on DOTs
- Achieve geographic and agency size diversity
- Include agencies with a mix of staff capabilities and levels of sophistication
- Include individuals that were recommended by panel members and/or those that research team members know would have valuable perspectives to offer on this topic
- Include performance management generalists, infrastructure specialists, safety specialists and congestion/mobility specialists
- Include some relatively senior individuals as well as more hands-on analysts and data managers

The interviews targeted at least one individual who was broadly knowledgeable about data challenges related to performance measurement and management, and 1-2 additional individuals who specialized in data collection, analysis, visualization, and/or communication within a specific performance area (safety, pavement, bridge, congestion/system reliability, or freight).

Figure 4 shows the agencies included in the final set of interviews. Table 4 lists the individuals included in each interview.

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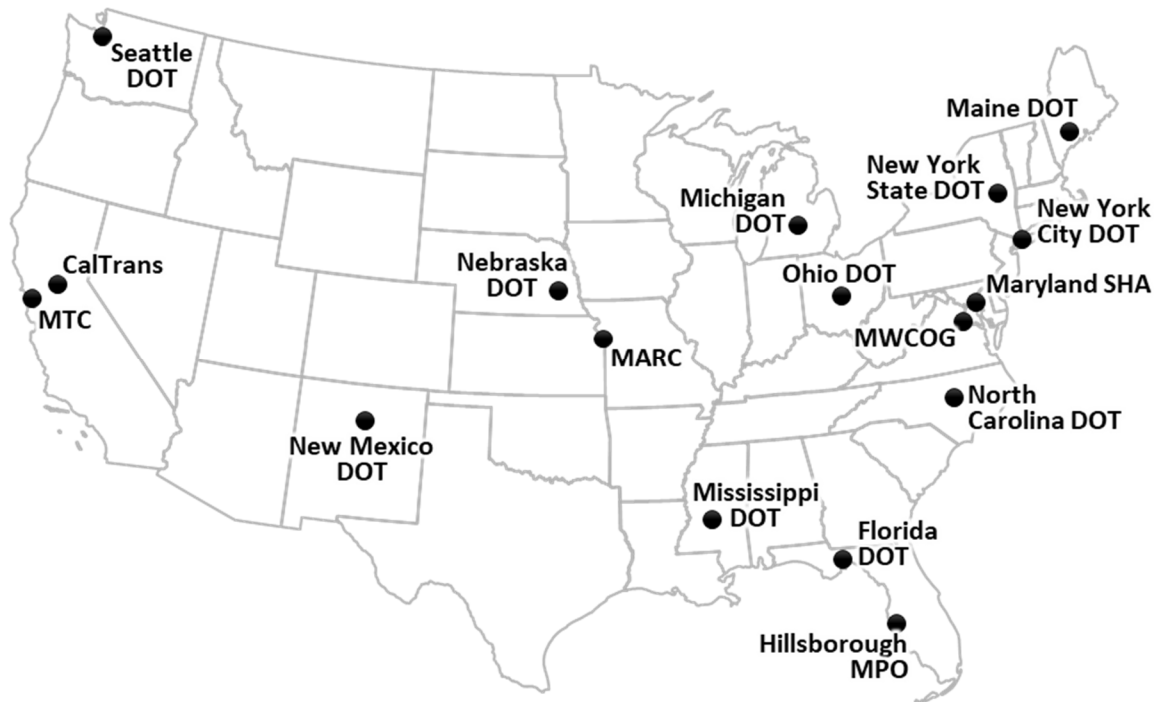


Figure 4. Participating Agencies

Table 4. Interview Participants

#	Region	Type	Agency	Positions of Staff Interviewed
1	1 - NE	Local Agency	New York City DOT	<ul style="list-style-type: none"> Deputy Director of Asset Management Director of Performance Analysis and Reporting
2	1 - NE	MPO	MWCOG	<ul style="list-style-type: none"> Director of Systems Performance Planning, Department of Transportation Planning – Systems Performance Planning Manager Performance Analysis, Department of Transportation Planning – Systems Performance Planning Transportation Planner Department of Transportation Planning – Systems Performance Planning Principal Transportation Engineer, Department of Transportation Planning – Systems Performance Planning Transportation Engineer, Department of Transportation Planning – Systems Performance Planning

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#	Region	Type	Agency	Positions of Staff Interviewed
3	1-NE	State DOT	Maine DOT	<ul style="list-style-type: none"> Assistant Director, Results and Information Office Bridge Management Engineer, Results and Information Office Highway Management Engineer, Results and Information Office
4	1-NE	State DOT	Maryland SHA	<ul style="list-style-type: none"> Director of CHART & ITS CHART Systems Administrator Transportation Engineering Manager
5	1-NE	State DOT	New York State DOT	<ul style="list-style-type: none"> Director, Office of Policy, Planning & Performance Acting Director, Office of Policy, Planning & Performance - Statewide Policy & Performance Bureau Senior Planner, Office of Policy, Planning & Performance Asset Management Program Engineer, Office of Technical Services Director, Maintenance Program Planning Bureau Bridge Management Engineer, Office of Structures
6	2-SE	MPO	Hillsborough MPO ¹	<ul style="list-style-type: none"> Executive Director Senior Planner, Performance Management Program
7	2-SE	State DOT	Florida DOT	<ul style="list-style-type: none"> State Managed Lanes Engineer Performance Coordinator Planning Manager Performance Management Program Coordinator HPMS Coordinator
8	2-SE	State DOT	Mississippi DOT ¹	<ul style="list-style-type: none"> Asset and Performance Management Engineer, Planning Division
9	2-SE	State DOT	North Carolina DOT	<ul style="list-style-type: none"> Mobility Program Manager, Mobility and Safety Division Director of Highway Operations, Chief Engineers Office – Division of Highways
10	3-MW	MPO	MARC	<ul style="list-style-type: none"> Principal Planner, Transportation & Environment Transportation Planner

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#	Region	Type	Agency	Positions of Staff Interviewed
11	3-MW	MPO	Nebraska DOT	<ul style="list-style-type: none"> Division Manager, Intermodal Planning Division
12	3-MW	State DOT	Michigan DOT	<ul style="list-style-type: none"> Congestion and Mobility Unit Manager, Operations Field Services, Transportation Planning, Supervisor, Statewide and Urban Travel Analysis Section
13	3-MW	State DOT	Ohio DOT	<ul style="list-style-type: none"> Administrator, Office of Technical Services, Division of Planning Administrator, Office of Assets Inventory and System Integration, Division of Planning GIS Manager, Office of Technical Services, Division of Planning
14	4-W	Local Agency	Seattle DOT	<ul style="list-style-type: none"> Asset Management Strategic Advisor, Finance & Administration Division Manager, Asset and Performance Management, Finance & Administration Division
15	4-W	State DOT	Caltrans	<ul style="list-style-type: none"> State Transportation Asset Engineer, Transportation Asset Management Geographic Information Officer, Office of Data Services and Technology Chief, Office of Planning, Policy and Research Branch
16	4-W	State DOT	New Mexico DOT	<ul style="list-style-type: none"> Director, Strategic Planning and Asset Management Division
17	4-W	Transit Agency	MTC	<ul style="list-style-type: none"> Principal Planner/ Analyst, Planning Section
¹ Agency participated in the pre-testing of the questionnaire.				

Interview Protocol

An interview guide was created, reviewed with the project panel, and revised. In order to gauge the effectiveness of the questions being asked, and the types of responses that were provided, the researchers held interviews with two agencies (Mississippi DOT and Hillsborough County MPO) were held to pre-test the questionnaire. The feedback received was incorporated into the questionnaire for the remaining interviews. The final questionnaire is included as Appendix B.

The interviews were scheduled for 90 minutes and typically had two or more agency staff members in attendance. Prior to the interview, the research team provided a soft copy of the questionnaire, a sample case study vignette, as well as some information on the purpose and goals of the interview. This allowed participants an opportunity to preview the content prior to the interview. The questionnaire was a replicate version of the questions that were used during the actual interview. The

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sample case study vignette was a draft example of how the TPM guidance, which is an objective of this research, could be provided. The interview covered five question areas that included staff background, TPM data challenges, TPM data successes, gaps in existing guidance, and feedback on the sample case study vignette.

Interview meetings were held via a web conference. The web conference allowed for the participants to visualize the notes being taken by the researcher and offer corrections to any text in real-time thereby ensuring an accurate accounting of the discussion.

The participant's responses to the questionnaire varied by agency, by type of agency, and by individual within the agency. The responses are synthesized below.

4.3 Summary of Interview Responses

Interview responses are summarized within the following categories:

- Participating Staff
- Data Challenges
- Success Stories
- Gaps in Available Guidance
- Feedback on Sample Guidance and Case Study Vignette

Participating Staff

The interviews were held over a period of approximately six weeks. Most of the interviews included at least two individuals; the range was one to six. The job titles for the more than half of the participants related to 'transportation planning' and 'performance management'. Approximately one-third of the job titles included 'asset management' and 'engineering' for highways, pavement, and bridges. Most of the participants had supervisory, management, or executive duties based on formal titles.

Participants were provided the opportunity to identify in which transportation performance areas they had expertise in order to focus the questions. Many participants reported knowledge in more than one area:

- Pavement: 18%
- Bridge: 18%
- Safety: 13%
- Mobility / System Performance: 14%
- Freight: 11%
- Transit: 11%
- Air Quality: 6%
- Other: 8%

This representation of different performance areas provided a relatively balanced basis for the responses to the specific questions in the interview questionnaire.

Data Challenges

There are many data challenges that impact an agency's ability to obtain, manage and make effective use of transportation system performance data (for safety, infrastructure condition,

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mobility/congestion, etc.). Eleven possible data challenges were presented, and participants were asked to rate them on a scale of 1 to 3, where:

- 1-No impact means that it has not affected you.
- 2-Some impact means that it has slowed you down some but hasn't required management intervention.
- 3-Major Impact means that it has created major roadblocks to your ability to move forward and required management intervention.

Ratings are summarized in Figure 5.

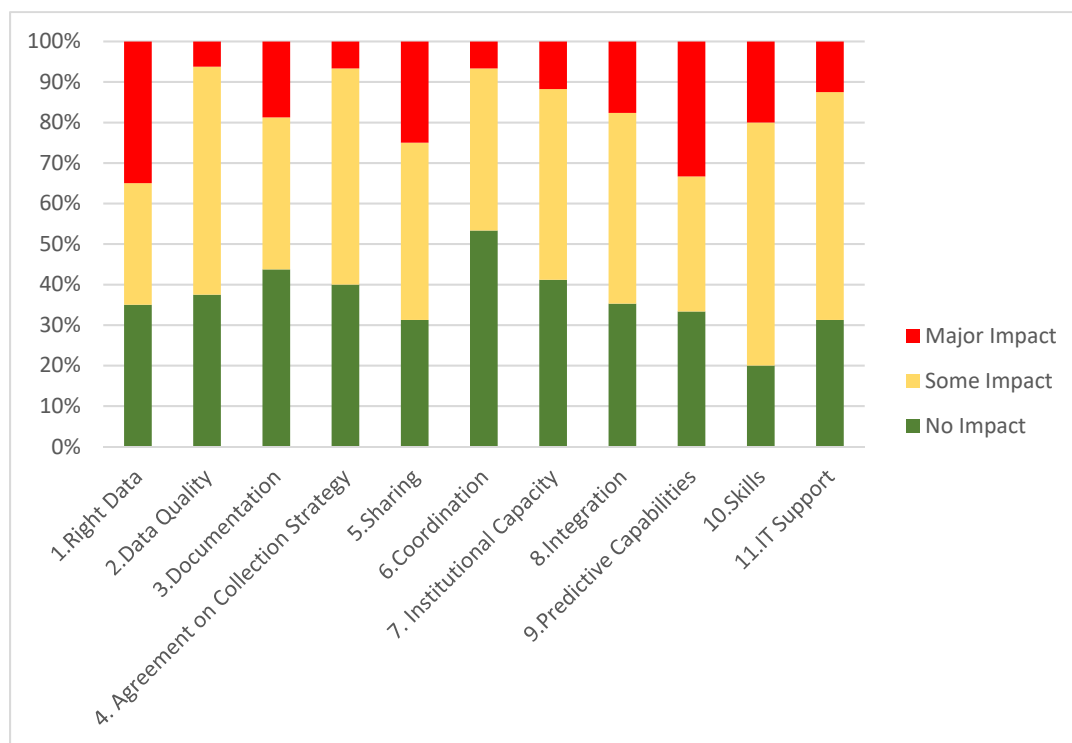


Figure 5. Impacts of Data Challenges on Effective Use of Data for TPM

Each of the eleven data challenges was reported to have some impact or a major impact for at least half of the respondents. The two challenges that were most frequently rated as having a major impact were 1-Not having the right data to provide meaningful insight into performance, and 9-Lack of capabilities to predict future performance. Two additional challenges that were most frequently rated as having either some impact or a major impact were 10-Limited access to needed skill sets and 5-Concerns about sharing data.

When participants rated a challenge as a 2 or 3, they were asked to provide an example. These examples are summarized below:

1. Not having the right data to provide meaningful insight into performance – challenges include:
 - Lack of NPMRDS coverage of non-freeways
 - Lack of data to meet MIRE requirements

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- Lack of ability to satisfy MAP-21 requirements for pavement data (current data collection meets internal agency standards which differ from MAP-21)
 - Lack of pedestrian and bicycle datasets and livability measures which are not readily available and are difficult to obtain
 - Lack of real-time traffic volume data and lane specific probe data is a concern
 - Lack of reliable travel time data for local road systems
 - Lack of ability to obtain a breakdown of commercial and passenger data
 - Lack of data for off-state portions of the NHS
 - Lack of comprehensive data for some assets
 - Lack of sufficient resolution in available federal Freight Analysis Framework (FAF) data for understanding freight transportation within a state
2. Poor or uneven data quality that limits our trust in the data that we have – challenges include:
- Differences in data quality standards, data timeliness (daily, annualized), data resolution (corridor, lane), data formats (file types)
 - Difficulty integrating original data collection and purchased data
 - Quality gaps in NPMRDS data (but quality is improving)
 - Differing interpretations of pavement condition data
 - Time consuming nature of researching data quality issues
3. Insufficient documentation about data sources, derivations or meaning (metadata) – challenges include:
- There are gaps in data set documentation about the definition of data items, update frequency of the data, and the owner of the data.
 - Vendor / consultant datasets lack metadata.
 - Data without corresponding data dictionaries and standards can impact the consistency of the data.
 - Lack of metadata can lead to questionable analysis results.
 - Lack of metadata creates challenges conflating from TMC segments to HPMS.
4. Difficulty getting agreement on what data to collect at what level of detail; or how (e.g. private sources, new collection technologies, etc.) – challenges include:
- There are differing perspectives on the value of data, and how to define performance measures.
 - Different divisions within the agency or between state and local agencies can have varying or unknown data standards.

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- Use of vendor-collected or purchased data results in little or no control or even knowledge of how the data was collected.
5. Concerns about sharing data (within the agency and/or externally) – due to fear that it may be misinterpreted or that limitations would be exposed – challenges include:
- High risk of data misinterpretation, misuse and associated liability concerns
 - Concern about data interpretation and use in a highly political environment
 - Concern about mixing data from snapshot (point in time) data sets with more dynamic data sets, creating inconsistencies or mismatches of information.
 - Data may not be in a usable state, and may require resources to make data more usable before it is shared
 - Burdens associated with the need to obtain multiple authorizations or negotiate data sharing agreements to share data from some systems (e.g., crash) with partners or vendors
6. Difficulty developing a coordinated data strategy within the agency and/or with partners (e.g. state DOT/MPO/localities) – challenges include:
- Standardizing processes when responsibilities for data management are highly decentralized
 - Coordinating targets and associated calculations between central offices and divisions internally when responsibilities are highly decentralized
 - Coordinating across a large number of counties, cities, and MPO's
 - Obtaining both top town (leadership) support as well as buy in-from data owners
7. Lack of institutional capacity to ensure data is transformed into information that decision-makers can routinely use to support their actions – challenges include:
- Getting people see the value of performance measures as a path to improvement rather than as a grade
 - Meeting growing requirements as funding and staffing levels are trending downward
 - Increasing reliance on consultants due to lack of institutional knowledge within the department/agency
 - Training of capable and technical resources, which is very important for data analysis
 - Improving analysis capabilities – analysis tools are limited
 - Demonstrating cause and effect with performance data - resources only allow this to occur on major projects
 - Making effective use of performance measures to make decisions for a “typical” day (link from strategic to tactical)
 - Making time for data validation and review when staff have other job responsibilities

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8. Lack of ability to integrate or aggregate data from different sources due to incompatible location referencing, linkage elements or inconsistent definitions – challenges include:
 - Linking (conflating) NPMRDS data to HPMS; changes to Traffic Message Channel (TMC) definitions every 6-12 months compound this issue
 - Combining data from traffic and pavement datasets for HPMS
 - Integrating data sourced from different systems (including those of external vendors) that have different formats
 - Integrating unlike datasets (bus, car, truck pavement, financial asset values) with limited or varying common identifiers limits usability of data analysis
 - Lack of unique identifiers or references to common identifiers can make datasets unusable outside of a very specific purpose
 - Automating data aggregation, import, conflation and/or integration can be time consuming and is reliant on specialized skills that may only be available within the Information Technology unit.
 - Data consistency issues make it difficult to integrate data. For example, the MPO boundaries maintained by the state DOT may not match what federal agencies have.
 - A lot of effort goes into matching the linear referencing methods / systems, especially during and after a system is upgraded or changed.
9. Lack of analysis tools or staff capabilities to predict future performance under varying assumptions (e.g. scenario analysis) – challenges include:
 - Reliance on consultant staff to perform analyses
 - Disconnect with respect to operations data going into microsimulations / models
 - Lack of a readily available tool that forecasts travel time reliability, user delay cost, and other performance measures
 - Tools to measure actual delay are data intensive and there is a lack of traffic count data for validation.
 - Lack of forecasting tools for the new national measures; even existing pavement and bridge management systems are not set up to predict these measures.
 - Federal measures for safety and system performance are subject to short-term spikes and dips which makes it difficult to set targets.
 - The ability to forecast in the short term is harder than long-term.
 - Travel demand modeling is not calibrated to speeds and cannot be calibrated to predict future reliability.
 - Need stripped down or simpler measures to gauge future performance on bridges, structures, and safety.

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10. Limited access to needed skill sets – e.g. database design, data integration, report development, data visualization, interpretation and communication (the “so what” behind the data) – challenges include:

- While skillsets and knowledge are accessible via a mix of in-situ consultants and project consultants, staff who oversee effort and understand the process are limited.
- The reasons “why” or “so what” behind the data are not easy to determine with current staffing levels.
- Staff are struggling through data visualization, database design, data integration for annual reports.
- As big data becomes more of a source for data and information, knowledgeable technical staff could become more of an issue.
- There aren’t enough technically skilled staff that can create a report, automate processes, or integrate datasets.
- There is a large reliance for technical work on a small number of staff, which creates a backlog of work for those individuals.
- Fear of doing something wrong may be preventing staff from taking the next step.

11. Information technology issues – e.g. lack of sufficient hardware/software for data storage and management; restrictive policies related to cloud storage or using software as a service – challenges include:

- Technology is always advancing but agencies can’t afford to keep up.
- There are restrictions on who can update software – limited administrative privileges can be an impediment.
- It is difficult to communicate with IT – they speak a different language.
- Agencies with centralized IT have difficulty getting improvements into the pipeline; IT wants complete control over systems which creates roadblocks. In some cases, consultant support is used for development but there is still a need for in-house expertise.
- Consultants tend to store data offsite.
- It is difficult to retain staff that have a combination of IT and business understanding.
- Not having software or not being able to develop software/tools to utilize TPM data is a barrier.

Other data issues that were identified include:

- Management/leadership changes and reorganization of business units can cause delays and loss of continuity.
- National measures are too high-level to base decisions on at a state or local level.
- Agencies are keeping two sets of books to accommodate the national measures given that existing measures are well established and better suited for agency needs.

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- There is a need for more consistent and detailed guidance on the national measures – this has been a moving target.
- Changes in measure specifications and definitions have introduced problems. For example:
 - The pavement measure specification changed the definition of a wheel path used for calculating cracking percentage.
 - Change in HPMS precision requirements for the All Roads Network of Linear Referenced Data (ARNOLD)
 - Changes in representing bridges from point to linear assets
 - Changes in the NHS definition

Success Stories

Each agency provided an example of a project or effort that was a successful and effective use of TPM data in the execution of the agency's performance management strategy. A summary of each agency's responses is provided below.

- **Caltrans** – The agency has had successful data sharing relationships with local agency partners. Crash data at the county level is made available in the form of spreadsheets that are posted online. The agency also provides summarized HPMS and NBI data for roadways and bridges to their local partners.
- **Florida DOT** - The implementation of the I-95 express lanes provide an example of a data-driven approach to determine the performance of the project based upon measured vehicle speeds in both the express lanes and general lanes.
- **Hillsborough MPO** – The MPO published their *State of the System* report which incorporated the adoption MAP-21 requirements. The report was well-received and was utilized as a call to action for investment and decision making. A second successful example involved integration of performance measures within scenario analysis for the long-range transportation plan. Presenting scenario results in terms of predicted performance outcomes was a useful means with which to engage stakeholders and the public.
- **Maine DOT** – The agency produces two reports that present information highways and bridges in Maine. The Roads Report provides data-driven recommendations on investment priorities. The Keeping Our Bridges Safe publishes similar information regarding the status of the bridge assets. The agency uses an asset management system (dTIMS) to produce performance summaries and projections. The reports were championed internally, and involved key staff from across the agency's bureaus and local partners. Recommendations from the report have helped the agency move away from 'worst first' investment strategies.
- **MARC** – The annual performance report has been established as a recognized product by stakeholders and has a repeatable process for data compilation and analysis. The report is made available before decisions need to be made on any new projects and helps to inform decision making. Success factors include release of the report at the right time, ensuring that the report is championed and holding regular meetings with internal and external stakeholders.
- **Michigan DOT** – The agency has a long history of performance-based planning and programming for preservation and safety – it developed one of the first true performance-

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based plans in the nation. Michigan has created a Road Quality Forecasting System (RQFS) tool that provides “what if” investment versus performance predictions – which they feel are very helpful and generally accepted as accurate. More recently, the agency has been using real time mobility data for multiple purposes, including building support for US-23 Flexroute project (identified as the most congested route outside of the Detroit Metro area), conducting before/after studies to evaluate and adjust lane closures and merge strategies (e.g. the zipper merge), conducting work zone reviews and calibration of demand models.

- **Mississippi DOT** – The agency reported success with bridge pavement, maintenance, and safety data. A decision tree is utilized to help identify deficiencies in the pavement condition and utilizes a methodology which is moving away from a ‘worst first’ approach. The pavement data that is fed into the decision tree is collected every two years. A similar process helps to guide the bridge management and preservation program.
- **MTC** – A performance monitoring website tracks trends over five areas, including transportation and utilizes federal measures as a guide. Keys to the success of this process is that it was transparent to stakeholders and was data-driven. This has helped stakeholders understand the performance-based approach is a neutral method with which to measure and monitor progress.
- **MWCOG** - A Quarterly Congestion Dashboard Report provides a review of performance measures over time, and highlights certain activities and the effect of those activities on performance. For example, an analysis and ranking of traffic bottlenecks has helped guide decision factors to consider in determining the components of a solution (e.g., ramp lengthening).
- **Nebraska DOT** – The collection and analysis of TPM datasets has resulted in the recognition that particular interventions and maintenance actions on certain bridge types can typically extend the service life of those bridges. These proven and data-driven factors are not part of the decision-making process moving forward. The support of executive leadership in this process was key to its success, in addition to a Lean approach to manage projects, and the necessary changes in staff business processes.
- **New Mexico** – The agency has focused on reducing the number of structurally deficient bridges in the state. A collaborative approach with FHWA in the funding of new bridges or repair of existing bridges, in addition to measuring the progress of bridge rehabilitation, has enabled the number of deficient bridges on the NHS to drop from approximately 13% to less than 5%. This data and analysis driven approach has helped to prioritize not only what structures are repaired, but also what is repaired on the structure.
- **New York City DOT** – The Mayor’s Management Report, which is published twice a year and is online, quantifies over sixty performance-related indicators for all city agencies. A number of those indicators are based on transportation performance management data. The collaboration required by employees to regularly compile and analyze the data has helped staff to engage on this effort and take ownership of the work.

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- **New York State DOT** – The agency has had a long history of using performance measures to inform the capital programming process. This has enabled a modeling process to evolve and performance measures to be established for both pavement and bridges. The Capital Management Team, which is cited in their Transportation Asset Management Plan (TAMP), is the culmination of this effort. The Team is developing holistic measures in four core areas among the agency's 11 divisions and 14 MPO's. Concurrent with this effort, is the re-centralization of the definition of standards for datasets, which will be required for success. The agency has had success in meeting with and working with local agencies and universities on a regular basis, which has helped avoid redundant efforts.
- **North Carolina DOT** – The agency has a data and performance-driven process to prioritize projects. A series of web-enabled dashboards provide information on the performance of agency measures, including the evaluation of an employee's performance. This process is a relatively new initiative and has iterated through a few versions as feedback and lessons learned are incorporated into the process. How an employee might influence a given performance measure, and vice-versa, is one of the drivers behind linking the two together. It is suggested that a balance be struck between data driven performance and values of employees and the agency.
- **Ohio DOT** – The agency is expecting to save approximately \$400 million over six years based upon the TAMP and also by having the necessary data in the appropriate management systems. The agency has executive champions and policy statements that bind the plan, the systems, and the staff to a common set of goals. This process enables the communication across the agency, education of the meaning for a given set of performance measures, and implementation of steps to meet those measures (e.g., treatment plan for pavement).
- **Seattle DOT** – The City compiles their Asset Status and Condition Report periodically, which is very close to an asset management plan. This report provides the foundation for managing the assets, forecasting financial needs, and determining an acceptable level of service. In addition, a recently published a report that compiled multiple performance efforts from across the City. This has been made possible, in part, by better data comprehensiveness and data quality. For example, maps have been published depicting the presence or absence of curb ramps, which would not have been possible several years ago due to the lack of data. These efforts help to drive next-steps, such as a discussion of risk management and mitigation.

Success Factors

In conducting the interviews, there were several common factors that were part of most or all of the agency's success stories with the effective use of TPM data. These common factors are synthesized below:

- An effective champion
- Data-driven decision making
- Internal communication of measures, and their meaning
- Ownership of the process and effort by staff
- Controls on data systems and standards to provide consistency

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- Managing data collection, analysis, reporting with Lean-related techniques
- Publishing and presenting data in a transparent and neutral manner

Gaps in Available Guidance

Participants were asked a series of questions regarding what type of TPM guidance is needed. The questions focused on the background of what guidance has been useful, what guidance is not currently available, other suggestions for the content of the guidance, and who should the guidance be tailored to.

Existing Guidance

Feedback on sources of guidance that have been found to be helpful for collecting, managing, analyzing and using TPM data include the following items:

- Peer exchanges on pavement, safety, bridge, performance metrics
- Professional conferences (North American Travel Monitoring Exposition and Conference [NaTMEC], GIS-T, etc.)
- Relationships with peers in other agencies
- National Highway Institute (NHI) workshops
- Association of Metropolitan Planning Organizations (AMPO) Performance Based Planning and Programming Work Group and Workshops
- AASHTO workshops
- FHWA webinars
- FHWA HPMS and Model Inventory of Roadway Elements (MIRE) manuals
- FHWA division office
- TPM website
- TRB website
- Regional Integrated Transportation Information System (RITIS) website / webinar
- Handbooks and other documentation on visualizing data
- Searching for and navigating ‘performance dashboards’

Needed Guidance

Participants were asked what type of guidance is needed that is not currently available. Several options were provided, and respondents could offer comments about each option. Comments on the four options are summarized below. The options are listed in the relative order of priority based on participant feedback.

Guidance related to particular aspects of TPM

- Staff has a good understanding for target setting and monitoring. Better guidance may be needed on prediction to help answer the question of 'can we move the needle?' Target setting for bridges and pavements is still a challenge. Current NCHRP reports are not practical enough in answering the questions of how to select a target, and what metrics

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should be evaluated in establishing that target. The guidance could be made available and advertised with local agencies as well.

- We are adapting the Congestion Management Process (CMP) to use in target setting and project prioritization. Further guidance is needed on the implications of (fiscally constrained) target setting.
- Guidance resources for the National Transit Database (NTD). Information is spread out over Federal Transit Administration (FTA) website and blogs, etc., which causes confusion. The Transit Asset Management rule, for example, has different revenue vehicle categories from NTD categories. MPO's need access to transit agencies data in NTD. There is a disconnect between the Transit Asset Management (FTA) and FHWA (TPM Rules). Agencies are struggling to understand what is required, how to implement, etc.
- Guidance is needed on how best to frame the performance story and new ideas for data visualization.
- Prediction capacity is a gap. More guidance is needed about what the expectations are, and what the narrative in the Transportation Improvement Program/State Transportation Improvement Program (TIP/STIP) and long-range plan should look like to make that tie between the program and achieving performance target.
- Guidance is needed on methodology for performance prediction, project/strategy prioritization and selection, and formats for performance reporting (in coordination with the HPMS submittal)
- There is plenty of research out there, but there is a need to take existing information and make it more useful / accessible. A matrix of simple guidance would be helpful: If I am at point A and want to go to point B, these are the steps I need to go through. For example: if I have the data and want to measure on time performance, tell me how to proceed. What are the steps and outcomes? Many people are not familiar with statistical methods. Provide insight into visualization and business intelligence. Keep it simple.
- More guidance is needed on target setting, project selection and performance prediction.
- Include an appraisal of different forecasting methodologies, lessons learned, and best practices. Distinguish aspirational goals from data driven goals. Project/strategy prioritization and selection is challenging with multiple jurisdictions.
- Prediction and target setting are the biggest challenges for all performance areas.
- Include best practices and templates.
- Target setting guidance may be useful to make sure that staff are doing things in a way that makes sense, and are not missing anything that other states and agencies may be doing in their process. Diagnosing the root cause of mobility issues is not something agencies do well. They may identify the issue and data to describe the challenge, but there is a lack of understanding of the root causes. In project prioritization process, agencies start with projects, rather than needs. The assumption is that the projects are reasonably identified by localities, but really there needs to be a move to identifying needs and that should drive what projects are necessary to address those needs.

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- Staff say what they want, but not how they want it. Need for more specifics on use and limitations of specific measures – for example, pavement rutting and percent cracking don't provide a good basis for managing the network. For cross-asset decisions, people understand the concept, but not how to execute the methods.
- Consider the audience – how to tailor products to engineers, public administrators, general public. TPM is more of an organizational culture issue rather than a technical problem. Target setting is a strategic process, not a scientific one.

Guidance related to particular performance areas or data sources

- How to address gaps in hourly traffic volumes, and posted speed limit data.
- Provide target setting guidance including specifics on how best to check and validate the information.
- Target setting unrelated to MAP-21. For example, project level target setting given the system and strategy. How can the monitoring data be used to set realistic goals?
- Linking NPRMDS data to HPMS segmentation. How is this handled on the federal level?
- Safety, pavement, and bridge performance areas are well covered. Other areas (freight and system performance) are less so. How-to guidance would be helpful for reducing burden on state DOTs.
- Guidance on new data sources but also explanation on methodology for use of 3rd party provided data. We need to go beyond the black box (without explaining the proprietary technology). This impacts probe data, as well as turning movement data, and vehicle occupancy data.
- Big data- how to process it, understanding how it is stored and collected.
- Address sources of freight data. Freight through trip data are available but there are gaps in data on imports / exports by truck vs. rail.
- Bridge performance prediction is a work in progress.
- Guidelines on how to integrate and optimize the different data together. Have pavement, bridges, ancillary assets. Bringing in socio-economic factors will be critical to supporting connected and automated vehicles (CAV), and developing multimodal strategies.
- Need for pedestrian and bike counting guidance.

Guidance geared to particular job functions or roles in your organization

- Consider the role of library science professionals for improving data findability.
- Possibly additional guidance on change management from the psychological perspective.
- Information on how DOTs and MPOs organize internally to support TPM. How are they using their technical staff or program to make more data-driven decisions?
- How is this affecting agency employees' jobs? The challenge is with numbers of available employees rather than specific competencies. It would be good to see how other states use consultants. For planning, there are knowledge gaps. Experts have departed to other

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opportunities or retirement, so there is a need for education for staff. How can that knowledge be maintained?

- Everyone has the data, focus on how to use it – sanitize, filter, access what is needed.
- Perhaps incorporate a train-the-trainer concept. Guidance would be used by pavement, bridge, IT. Some agencies do not have a centralized function / division for asset and performance management. IT staff need a general picture of what data are used for.
- Our DOT's organizational structure is in flux. We now have 'management analyst' positions, meant to analyze the data, but the role needs to be defined better. The role can involve a mix of collecting, quality assurance, and presenting data. Some people filling these roles come from other agencies outside of transportation and need to be brought up to speed.
- Talk about roles and qualifications. We have a point person for each performance area and an overall coordinator. Maybe having civil engineers perform certain data analyst type of functions are not the best type of employee to put in that role. There might be an opportunity to identify other skill sets that could assist or lead some of these efforts within engineering groups. Organizational knowledge can be used to explain anomalies or specific patterns in data that someone without that historical context would not make sense – example of a new person analyzing customer service call volumes and seeing a spike in October (during a hurricane).
- Data scientist – bridge between IT staff and DOT business users. Ability to develop visualizations, reports, analysis.

Guidance geared to addressing particular issues or challenges

- Within asset management, the ability to spatially combine multiple assets is difficult. Would like to see consolidation of and development of common standards. With ARNOLD, we need to have another conversation about data compatibility.
- Need to recognize the importance of engineering judgement. Asset management systems generate candidate projects; the information is valid for network level. Need to keep an engineer in the decision process.
- Need guidance on MAP-21 System Performance Reports. Long range plans and TIPs are supposed to include performance targets. How do we need to convey that information to FHWA?
- Need guidance on High Occupancy Toll (HOT) lanes or other type of managed lanes data. The FAST Act has new planning factors that MPOs have to focus on regarding resiliency. What kind of data and tools exist related to resiliency?
- Need guidance on what data to collect and why; what is the benefit of collecting a particular element - the “who, what, when, where, and why are you collecting”. Then ask: how are you going to use it (reporting requirement, target setting, resource allocation decisions).

Guidance Suggestions

Participants made the following additional suggestions:

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- Use of the term 'guidance' may connote 'though shalt', as opposed to 'here are some things that might be helpful to you'. Perhaps a different term should be considered.
- Integration of pavement and bridge data at the federal level would help. An indication of why bridges are taken out of service would be useful. Defining specific examples of “other allowable sources” of data beyond NPMRDS is needed. Reference specific FHWA tables. The “Monday Morning Dashboard” concept would be useful to relate 'what you need to know for the week'. What is the elevator pitch for TPM data?
- Previously, there was more opportunity to travel and interact with peers from other states. Would like a way to go online and find out what other states are doing, what have they accomplished, what are they using. For example, how many states are using AASHTOWare software? Would like to see good example of metadata management at the department level. Frameworks and checklists are useful. Need to point out the lead time required for implementation.
- Guidebooks with lots of case studies are most useful. Case studies can explore how an agency implements a topic and describe the challenges they faced. It is useful to see how different people approached it.
- Webinars are useful. Not that excited for another set of printed documents since they are not searchable, take up space and can become outdated. A peer exchange (including subject matter experts) is a good way to share information and understand what’s going on. FTA published an FAQ website with sections covering MPOs specifically. The question-answer format is helpful for finding topics that then link to other guidance and documentation that can be reviewed.
- The GIS for Strategic Asset Management (GSAM) webinars are a great example – they addressed many topics – “here’s how we did it”, included private sector, government.
- Need a cheat-sheet on what are the known variables that impact performance and conditions.
- Need guidance on resiliency measures, e.g. hardening assets to the effects of climate change.
- Need additional background on performance management as a whole – e.g., how performance affects funding / budgeting, making the connection with why you are doing the work you are doing every day.
- Guidance should be quick and easy to read and digest. Keep it short. Good example: trade magazines that say who is doing what, ability to reach out for further information.
- Make it accessible, clear, plain English, larger fonts, directive. Younger generation doesn’t respond to long, involved narratives.

Guidance Audience

Participants were then solicited for their thoughts on what roles within their agency might benefit the most from receiving and reading the guidance material. The suggestions that were offered included the following:

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- People who manage data – people working at the data level. For example, senior transportation planner/analysts who crunched the numbers for the Fatality Analysis Reporting System (FARS.)
- Both staff and consultants at districts. There are different levels and the guidance information packaging would have to be appropriate. Project summaries that can be shared are valuable.
- On performance areas (i.e. system performance) this would be for someone who is a data analyst. For a higher level, like performance prediction or project selection, that is management level or someone in a cross-cutting role (across performance areas). Transportation staff have a pretty good understanding of the rule requirements, but management has so many other responsibilities, and do not always have the details. Executives need a way to digest all this. This is where visualization comes in, and visualization needs to be done right. This is an important topic. Lots of interesting best practices that could be pulled into a guidance document.
- Planning staff and subject matter experts (SMEs). Planning staff need to bridge the gap between SMEs and MPOs, and a lot of times the MPOs are looking to DOT's for guidance.
- Business owners for different data sets (e.g. pavement, bridge); different levels of management – like district/region engineers. They need to use the data to make maintenance decisions. Design and construction groups – understand how design impacts overall system performance. Their role in impacting targets (e.g. on time delivery, construction quality.)
- Everyone would benefit, new employees may benefit the most, new employees have fresh knowledge and insight.
- SME's on different measures would find this guidance useful. New employees can read the guidance to understand what analysis is used for and how it fits together – context for better understanding for the new people.

Glossary

Application Programming Interface (API). A set of commands, functions, protocols, and objects that programmers can use to create software or interact with an external system. It provides developers with standard commands for performing common operations, so they do not have to write the code from scratch.

Backcasting. A planning method that starts with defining a desirable future and then works backwards to identify policies and programs that will connect that specified future to the present.

Computer Vision. The automatic extraction, analysis and understanding of useful information from a single image or a sequence of images.

Data Accuracy. The degree to which data represents actual conditions as they existed at the time of measurement.

Data Community of Interest. The data owner, data steward, data users and other stakeholders with an active interest and role in the data program.

Data Completeness. The degree to which the data provides sufficient coverage and includes values for all required data elements.

Data Currency. The extent to which the data represents current conditions.

Data Feed. A real time or near real-time stream of data.

Data Fusion. The process of integrating multiple data sources to produce more consistent, accurate, and useful information than that provided by any individual data source

Data Governance. The accountability for the management of an organization's data assets to achieve its business purposes and compliance with any relevant legislation, regulation and business practice.

Data Granularity. The level of depth represented by an observation. (For example, pavement condition data summarized in 500-foot linear roadway sections would represent a high level of granularity; data summarized into 1-mile sections would represent a low level of granularity.)

Data Lake. A hub or storage repository that holds a large amount of an organization's raw data in its native format, including structured, semi-structured, and unstructured data. The data structure and requirements for how the data will be used are not defined until the data is needed.

Data Life Cycle. The stages through which data or information passes, typically characterized as creation or collection, processing, dissemination, use, storage and disposition.

Data Management. The processes and activities in place to develop, implement and enforce policies and practices for protecting and enhancing the efficiency, value and effectiveness of data and information.

Data Normalization. Reducing or eliminating data redundancy; transforming data values so that they align with a standard measurement scale.

Data Owners. People or groups with decision-making authority for initiating or discontinuing the data program and who determine the content of what data is collected.

Data Precision. The degree to which multiple data observations are close to each other – it is a measure of statistical variability.

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Data Mining. A process of discovering meaningful correlations, patterns and trends by sifting through large amounts of data stored in repositories.

Data Quality. The degree to which data is accurate, complete, timely and consistent with requirements and business rules and relevant for a given use.

Data Quality Assurance. Processes to ensure that data meets specified requirements.

Data Quality Control (QC). Processes to detect defects in collected data and take appropriate action.

Data Steward(s). People who are accountable for the quality, value and appropriate use of the data.

Data Visualization. Techniques for graphical representation of trends, patterns, and other information.

Data Warehouse. An integrated, centralized decision support data base and related software programs that can be used to collect, cleanse, transform, and store data from various sources to support business needs.

Infographic. A graphical representation used to present information so that it can be easily understood.

Linear Referencing System (LRS). A system for maintaining location information for events that occur along a linear network such as a road or rail line. It includes one or more methods for specifying the location of any point along the network based on distance from a known reference location (e.g. intersection-offset or county-relative milepoint.)

Meta Data (or metadata). Data describing the context, content, and structure of documents and records and the management of such documents and records through time. Literally, data about data.

Predictive Analytics. A data mining technique that extracts information from existing data sets in order to determine patterns and predict future outcomes and trends.

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Appendix A: Detailed Literature Review

Over the past decade, many efforts have been undertaken with the goal of improving transportation agency data management and utilization capabilities and practices. There is an extensive body of research and guidance covering the topic of improving data for transportation performance management. References include those providing generalized guidance as well as those that focus on specific performance areas. Several maturity models and assessment tools were identified that provide structured ways for agencies to develop a baseline of their current capabilities and identify gaps.

The literature review focused on recent publications that cover the landscape of TPM performance areas, data types and data management techniques. Resources included in the review are shown in Table A-1.

Table A-1. Sources Reviewed

Title	Year
<i>General references related to transportation data management for performance management</i>	
NCHRP Synthesis 20-05/Topic 48-14: Analyzing Data for Measuring Transportation Performance by State DOTs and MPOs (under development) (17)	2017
NCHRP Synthesis Report 508: Data Management and Governance Practices (18)	2017
FHWA Transportation Performance Management Technical Assistance Program Guidebook and Toolkit (2)	2017
AASHTO Communicating Performance website (19)	2016
FHWA TPM Capability Maturity Pilot Workshop Report – Chicago (20)	2015
Transportation Systems Performance Measurement and Data: Summary of the 5 th International Conference (21)	2015
FHWA Performance Reporting - Prototype Technical Report, Final Report (22)	2014
Performance-Based Planning and Programming Guidebook – FHWA (1)	2013
NCHRP 20-24(37), Measuring Performance among State DOTs: Sharing Good Practices. (23)	2007-2013
Establishment of Comparative Performance Measures Program Infrastructure to Support System Performance Data Collection and Analysis – Final Report (24)	2011
Colorado DOT Performance Data Business Plan (25)	2011

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Title	Year
NCHRP Report 706: Uses of Risk Management and Data Management to Support Target-Setting for Performance-Based Resource Allocation by Transportation Agencies (3)	2011
NCHRP Report 666: Target-Setting Methods and Data Management to Support Performance-Based Resource Allocation by Transportation Agencies (4)	2010
NCHRP Document 154: Target-Setting Methods and Data Management to Support Performance-Based Resource Allocation by Transportation Agencies - Volume III: Case Studies (26)	2009
NCHRP Project 08-36/Task 100 Final Report (5)	2011
TRB Circular: Challenges of Data for Performance Measures: A Workshop (27)	2006
<i>References related to specific data types</i>	
FHWA Guide for State DOT Safety Data Business Plans (16)	2017
Innovations in Freight Data, Transportation Research Circular E-C223 (28)	2017
FHWA Applying Archived Operations Data in Transportation Planning: A Primer (9)	2016
Improving Safety Programs Through Data Governance and Data Business Planning: A Peer Exchange (29)	2015
NCHRP Project 20-05, Topic 44-13, Synthesis 460: Sharing Operations Data Among Agencies (10)	2014
U.S. DOT Roadway Transportation Data Business Plan (Phase 1) (30)	2013
Benefit-Cost Analysis of Investing in Data Systems and Processes for Data-Driven Safety Programs (7)	2012
FHWA Traffic Monitoring Guide (31)	2013
NCHRP Project 20-24(37)D: Recommendations for Improving the use of Traffic Incident Management Performance Measures when Comparing Operations Performance Between State DOTs (11)	2011
Asset Management Data Collection for Supporting Decision Processes (13)	2006
<i>Maturity Models and Assessment Tools</i>	
FHWA Office of Performance Management - Transportation Performance Management Capability Maturity Model (15)	2016

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Title	Year
NCHRP Report 814: Data to Support Transportation Agency Business Needs: A Self-Assessment Guide (6)	2015
AASHTO Asset Management Gap Analysis Tool (14)	2015
United States Roadway Safety Data Capabilities Assessment (8) (update of this is in progress, including new section on performance management.)	2012
Creating an Effective Program to Advance Transportation System Management and Operations: Primer (12)	2012

General References

FHWA TPM Guidance. FHWA has sponsored multiple efforts to develop guidance for transportation performance management and related data issues. The Performance-Based Planning and Programming (PBPP) Guidebook was published in 2013, which provides a useful reference for understanding data needs and uses in the context of key PBPP activities. A companion checklist tool was produced that allows agencies to assess their progress towards implementing PBPP.

Over the past two years, the Federal Highway Administration's (FHWA) Office of Transportation Performance Management (OPM) has been working with a 40+ member stakeholder group of TPM practitioners within state DOTs, MPOs and transit agencies to produce a comprehensive TPM Toolbox that is based on a Capability Maturity Model (CMM.) The toolbox includes a web-based assessment tool and detailed implementation guidance. The TPM framework includes two components that are specifically related to data management and usability for TPM. The data management component covers quality, accessibility, standardization and integration, data collection efficiency and governance. The data usability component covers data visualization and exploration, performance diagnostics, and predictive capabilities. For each of these components (and subcomponents), five levels of maturity are defined, and guidance on steps needed to advance to the next maturity level are provided, backed up by practice examples.

National Highway Institute Training Courses. FHWA's OPM is also sponsoring development of several National Highway Institute (NHI) courses covering various aspects of TPM, including one specifically focused on the role of data in TPM. The course is structured around four key TPM business practices and five data management elements:

TPM Business Practices

- Establish Measures
- Establish Targets
- Develop Plans and Programs
- Monitoring and Reporting

Data Management Elements

- Data Governance
- Data Sourcing & Collection
- Data Storage & Processing
- Data Analysis & Visualization
- Data Distribution

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NCHRP Target Setting Guidance. NCHRP Project 08-70 resulted in Report 666: *“Target-Setting Methods and Data Management to Support Performance-Based Resource Allocation by Transportation Agencies.”* This work included several case studies on data management practices, and a high level assessment tool for data management, organized around three elements (People/Process, Technology/Tools and Institutional/Governance.) It stressed the value of agency data business planning to coordinate implementation of governance standards, policies and procedures, set goals for use of data sharing and integration technology to support data programs, and link data programs to performance measures, targets and planning functions. A second phase of the project produced NCHRP Report 706: *Uses of Risk Management and Data Management to Support Target-Setting for Performance-Based Resource Allocation.* This second report investigates the use of information technology (IT) tools and data management practices to support data sharing and integration in support of target setting.

AASHTO Comparative Performance Measurement Series. From 2007-2013, the AASHTO Standing Committee on Performance Management sponsored a series of studies that investigated use of performance data from multiple states for the purposes of identifying and sharing effective practices for improving performance. Studies involved assembling data from multiple agencies that could provide an “apples to apples” comparison. Several performance areas were covered – pavement and bridge condition, safety, incident management, and project delivery. Each study identified challenges and recommendations related to compilation of comparable measures and identification of peer groupings. A related study developed a concept for establishing a central performance measurement repository and analysis toolkit.

Guidance on Communicating Performance. AASHTO’s Communicating Performance website provides guidance on communicating performance. It highlights common scenarios such as “telling the story”, “reporting progress”, and “educating the public” and provides links to noteworthy examples of agency performance management communications. An FHWA Performance Reporting – Prototype Technical Report also focuses on communication of performance information and provides a useful synthesis of attributes for effective performance websites (based on stakeholder outreach.) It also includes a review of national and state DOT performance websites.

References for Specific Performance Areas

In addition to the general efforts to develop guidance for transportation agencies that can strengthen use of data within TPM, there are also several ongoing efforts that are focusing on data improvements within particular goal areas.

FHWA Safety Data Guidance. The FHWA Office of Safety has produced an extensive set of resources related to use of data for safety performance improvement:

- *Safety Data Business Plans.* The Guide is organized around a seven step process. FHWA plans to roll out a web site including the Guide as well as case studies, pilot studies, and training resources.
- *Applying Safety Data and Analysis to Performance-Based Transportation Planning* provides guidance for state DOTs and MPOs on safety data collection and analysis to support development of safety goals, objectives, performance measures, and targets;

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- *Crash Data Improvement Program* provides guidance on identifying, defining and measuring the characteristics of the data quality within the state crash database. The guide covers six data quality attributes: timeliness, accuracy, completeness, consistency, integration and accessibility; and provides a mechanism by which States can establish baseline measures, and subsequent assessments, related to the crash data quality characteristics.
- *State and Local Data Integration Project* provides guidance on safety data integration State, Tribal, and local agencies. Its purpose is to help agencies identify cost-effective ways to develop safety data systems that integrate safety data on all public roads. A website (https://safety.fhwa.dot.gov/rsdp/data_activities_state.aspx) provides access to case studies, pilots and documentation of noteworthy practices.
- *FHWA's Roadway Safety Data Program (RSDP) Toolbox* website (<https://safety.fhwa.dot.gov/rsdp/toolbox-home.aspx>) provide access to a wide range of other resources related to safety data.

System Operations Guidance. The FHWA *Traffic Monitoring Guide* provides guidance and recommendations for traffic data collection and management – and includes best practices for data sharing, data quality management and integration. An NCHRP Synthesis (Topic 44-13, Synthesis 460 – *Sharing Operations Data Among Agencies*) documented challenges and strategies for sharing, integrating and analyzing operations data across agencies, the private sector and the public. A recently published FHWA Primer on *Applying Archived Operations Data in Transportation Planning* provides guidance for creating and using archived operational data for identification of congested locations, understanding the nature of congestion (recurring or non-recurring); analyzing causal factors; computing a variety of operations performance measures for reporting; and evaluating impacts of implemented projects and programs.

Asset Management Guidance. The AASHTO Transportation Asset Management Guide, Volume 2 includes chapters on data collection & management and information systems supporting asset management.

Assessment Tools

FHWA TPM TAP Capability Maturity Model. As noted above, the FHWA TPM TAP Toolbox includes an assessment tool that agencies can apply to identify their current level of maturity and develop strategies for moving to a higher level. Data-related components and subcomponents cover the full life cycle of data acquisition, storage, integration, analysis, sharing, reporting, and communicating to different audiences.

NCHRP Data Self-Assessment Tool. In 2008, members of the Transportation Research Board (TRB) Data Section identified the need for an assessment tool that DOTs could use to identify gaps in their agency's data and elevate the priority of filling these gaps. In response, a scoping study and a follow up project were funded within the NCHRP program, culminating in *NCHRP report 814: Implementing a Transportation Agency Data Program Self-Assessment* (published in 2015.) This research involved interviews and focus groups with DOTs and MPOs to understand data challenges, and reviews of the literature to identify and document successful agency practices that can be pursued to advance agency data management capabilities. A comprehensive data management self-assessment tool was produced, covering five key elements: Data Strategy and Governance, Life Cycle Data Management

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(including collection, storage, documentation and delivery), Data Architecture and Integration, Data Collaboration, and Data Quality Management. A companion guidance document was prepared including a data improvement catalog with relevant practice examples for data improvement strategies within each assessment element.

Asset Management Gap Analysis. The AASHTO Asset Management Guide included a maturity model and assessment tool. NCHRP Project 08-90 built on this work and developed an asset management gap assessment tool. This tool includes assessment areas for Data Management and Information Systems. The Data Management area considers asset inventory and condition data availability as well as data governance processes. The Information Systems area considers available tools for decision support, system features, and integration capabilities. Beyond the Data Management and Information Systems areas, the tool includes several areas related to TPM such as “performance-based management”, “resource allocation”, “data-driven targets”, and “benchmarking” – and the assessment of each area includes consideration of data and technology.

FHWA Roadway Safety Data Capabilities Assessment. This effort developed a detailed tool for assessing adequacy of roadway data for use in safety planning. The tool was applied in all 50 states. The assessment considered: roadway data quality (completeness, timeliness, accuracy, uniformity/consistency), data analysis tools and uses for network screening, countermeasure selection and evaluation, data accessibility to stakeholders, data management and governance, and data interoperability and expandability. FHWA is currently preparing for a second round of assessments, which will include a new element for safety performance management practices.

Detailed Document Reviews

The following section presents further details for selected resources that were reviewed. Where applicable, specific data challenges and opportunities, and data management techniques and success factors covered are highlighted. These will be used as a resource for development of the guidance.

General References

NCHRP Synthesis 20-05/Topic 48-14: Analyzing Data for Measuring Transportation Performance by State DOTs and MPOs

From the NCHRP Website:

“The objective of this synthesis project is to better understand what data State DOTs and MPOs are using and how they are measuring transportation performance as part of anticipated changes to the Federal program or current performance-based programs an agency may have implemented.

Specifically, the synthesis will identify:

- Current state of practice in the availability and use of data and analysis tools;
- Research and development underway of promising new tools;
- Gaps that need to be addressed to better support State DOT and MPO needs;
- Future research needs, including multimodal approaches.

Information will be gathered through a literature review and survey of State DOTs and a sample of MPOs and university transportation centers. The report should include no less than four case studies of

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state DOTs and MPOs. The state DOT survey should be sent to the voting members of the AASHTO Standing Committee on Performance Management.”

FHWA Transportation Performance Management Technical Assistance Program Guidebook and Toolkit (2017)

Link: <https://www.tpmttools.org/>

Overview: The purpose of the guidebook is to provide “how-to” information for transportation agencies interested in implementing or improving the application of TPM. It is built around a framework including six process elements (strategic direction, target setting, performance-based planning, performance-based programming, reporting and communication, monitoring and adjustment), and four additional cross-cutting elements (organization and culture, external collaboration and coordination, data management, and data utilization and analysis.) Each chapter includes definitions of key terms, presentation of implementation steps (with related practice examples), and resources to consult for further information. An accompanying toolkit includes a maturity model for TPM and an online assessment tool.

TPM/Data Areas Covered:

- The guidance is generic and applicable for multiple TPM areas

Data Challenges and Opportunities:

- Lack of awareness among agency staff as to what data exists and how to access it
- Data may not have sufficient coverage; or may not be at the right level of granularity to meet TPM analysis needs.
- Data are not available in an analysis-ready form with sufficient metadata to enable the analyst to assess their suitability for a given purpose. Analysts may lack the time and expertise needed to locate, evaluate, clean and transform data.
- Agencies may lack staff with skills in data visualization, statistical analysis, and predictive modeling that are needed to support trend analysis, target setting, and performance diagnosis.
- Tools may not be available for data manipulation (e.g., filtering, sorting, and aggregating), viewing (e.g., mapping and charting) or analysis.
- Agencies striving to “collect data once and use for multiple purposes” may find that this means the data must meet quality requirements of the most demanding business use.
- It can be challenging to identify and meet the needs of different data audiences – requiring delivery of data in different formats and provision of different access methods and levels of documentation.
- Simple data validation processes (checking to make sure that data values are within acceptable ranges) are not sufficient to ensure accuracy. Independent verification processes are needed to gain a true assessment of accuracy, but add significant costs to data collection.
- Lack of consistency in attributes, attribute definitions, and collection methods can pose barriers to use of data for baseline development, trend analysis and benchmarking. Incompatible location references make it difficult to integrate different spatial data sets.

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Data Management Techniques and Success Factors:

- Data quality management involving training, equipment calibration, inspector and equipment certification, independent validation, acceptance criteria, automated validation, use of supplemental data sources, and specialized applications
- Data warehouses to supply pre-packaged data sets to meet a range of uses – updated through automated extract-transform-load (ETL) processes from designated authoritative sources
- Data delivery via a variety of methods: APIs, dashboards, ad-hoc reporting environments, interactive maps, etc.
- Staff skills assessment and training
- Data access policies and associated controls
- Metadata management and delivery
- Data catalogs
- Data standardization, including use of common location referencing systems
- Master data management and reference data management
- Reducing data collection costs through automating manual processes, use of sensing technologies, consolidation of multiple efforts within the agency, establishing regional partnerships, leveraging private sector data
- Establishing data governance policies, structures, roles and accountabilities

AASHTO Communicating Performance Website (2016)

Link: <http://communicatingperformance.com/>

Overview: AASHTO website providing guidance on communicating performance and links to noteworthy examples of agency performance management communications. Six “scenarios” requiring performance management communication are highlighted:

- Telling the Story – communicating outputs, outcomes, and impacts
- Reporting Progress – performance management-related plans
- Putting Performance in Perspective – agency’s performance is lagging behind peers
- Educating the Public – measures and targets
- Funding Choices – investing in performance
- Opening for Business – building project support
- Facing Extreme Weather – winter response

TPM/Data Areas Covered:

- The website is generic and applicable for multiple TPM areas

Data Challenges and Opportunities:

- Performance data are presented in an overly technical way that is difficult for the layperson to understand.
- Technical performance measures (e.g. structurally deficient bridges) are not familiar to people or intuitively obvious and are subject to misinterpretation.
- Performance data are not provided with sufficient context that enables people to understand their meaning and implications.

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- Standard formats for presenting performance data are dense and difficult to interpret even for knowledgeable agency staff.
- Communication materials are overly text-based and do not make effective use of graphics.

Data Management Techniques and Success Factors:

- Communications plans that consider measures, context, audience, message and media
- Communications products that help educate the public on the fundamentals of performance management: what is measured, why it is measured, and why it matters.
- Communications products that tell a compelling performance story based on proven examples.
- Communications products that orient messaging to focus on the user's experience (as opposed to the system's condition)
- Performance dashboards and interactive reports
- Use of infographics
- Communication of performance through social media outlets

FHWA TPM Capability Maturity Pilot Workshop Report – Chicago (2015)

Link: <http://www.fhwa.dot.gov/tpm/resources/docs/chicago2015.pdf>

Overview: Summary of a workshop to pilot the FHWA TPM Capability Maturity Model (CMM), held in conjunction with the 2015 AASHTO Annual Meeting. Featured presenters from FHWA, RIDOT, MNDOT and NCDOT. Representatives of 15 state DOTs were in attendance. The workshop included a series of exercises covering a broad set of topics, including discussion of data challenges related to TPM.

TPM/Data Areas Covered:

- The workshop was generic and applicable for multiple TPM areas

Data Challenges and Opportunities:

- Assessing accuracy and precision
- Understanding data reliability – especially when it is estimated or modelled
- Data time lags
- Timing of data gathering/processing to meet reporting requirements
- Costs of data; need to weigh benefits and costs of data collection
- Ability to effectively leverage technology
- Need to elevate the role of the data professional in DOTs – from “back office” to a more visible position.
- Skill sets
- Improving understanding of data customer needs

Data Management Strategies and Success Factors

- Not discussed

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Transportation Systems Performance Measurement and Data: Summary of the 5th International Conference. (2015)

Link: <http://www.trb.org/main/blurbs/174018.aspx>

Overview: Proceedings of a conference held in Denver, Colorado covering transportation performance measurement and data topics. The conference had four tracks:

1. Driving decisions—aligning performance measures to support decisions;
2. Tracking the moves—intermodal performance measurement;
3. Untangling the data web—using advances in data and technology to support performance measurement; and
4. The state of the practice and opportunities.

Numerous case examples were presented that could serve as potential case study vignettes for the guidance.

TPM/Data Areas Covered:

- A wide-ranging set of performance measures were covered, covering infrastructure condition, safety, mobility and operational performance across multiple modes

Data Challenges and Opportunities:

- Creating data systems to meet decision making needs – as opposed to making decisions based on what data are available
- Understanding the context for observed performance results to distinguish correlation from causality
- Having sufficient data to assess (and predict) impacts of safety countermeasures
- Ability to make the case for investment in data and systems
- Ability to project future performance based on anticipated economic and demographic shifts
- Integrating and utilizing operational data sources (internal, external, customer) for performance management and system optimization
- Ability to effectively present and communicate technical information
- Ability to understand data strengths and limitations – “the confidence in decisions cannot exceed the confidence in the data”
- Many performance measures rely on data from external sources (e.g. employment levels, gasoline prices, and population)
- Value of supply chain/commodity flow data for understanding how to reduce transportation costs and support economic growth
- Importance of having data on products, customers, modes, origins and destinations, and costs to inform transportation investments.
- Need for high quality “machine-ready data” and a structure to support them
- Limitations of using fatalities as a performance measure given that they are a rare occurrence; but absence of a national database on serious injuries or standard definitions across states
- Working with LiDAR data – post-processing; updates
- Vehicle probe data – differences in data feeds, reporting formats, intervals

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- Using available data to communicate the link between transportation and broader societal goals (e.g. quality of life, health, etc.)

Data Management Strategies and Success Factors

- Data partnerships/collaboration across agencies
- Agreed-upon processes for data collection and analysis
- Policies on data ownership and use
- Interactive dashboards, Infographics and heat maps
- Use of the General Transit Feed Specification (GTFS) to deliver real time information for transit schedule adherence measures
- Use of real time data to make operational decisions impacting performance (e.g. holding trains and skipping stops)
- Combining probe data sources using intelligent data blending,
- Crowdsourcing

FHWA Performance Reporting - Prototype Technical Report, Final Report (2014)

Link: <http://www.fhwa.dot.gov/tpm/engage/reporting/prototype.pdf>

Overview: This report presents the results of an effort to develop a prototype national performance management website. It includes a summary of feedback from a series of audience outreach meetings about attributes of an effective performance website, and presents a mockup of the prototype FHWA site. It also includes a review (with multiple examples) of national and state DOT performance websites.

TPM/Data Areas Covered:

- The document was generic, but the eventual goal of this effort was to support the national performance measures

Data Challenges and Opportunities:

- Not discussed

Data Management Strategies and Success Factors

Key aspects of a successful performance website (based on audience feedback) included:

- Simplicity for the general public; additional complexity for transportation professionals
- Start with simple displays but build complexity as the user drills down
- Focus on what the audience wants to see rather than organizing information based on the agency's management structure
- Personalization to include local information and stories that communicate how transportation impacts the everyday citizen
- Show trends, a way to mark progress, and a link to actions taken to improve performance (not just snapshots)

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- State by state comparisons matter to legislators, but must be presented with care to avoid misinterpretation
- Use single-issue, single-page, graphic-heavy infographics
- Tell a story with data so that it comes alive

Performance-Based Planning and Programming Guidebook – FHWA (2013)

Link: https://www.fhwa.dot.gov/planning/performance_based_planning/pbpp_guidebook/

Overview: This guidebook describes a Performance-Based Planning and Programming (PBPP) process, and provides examples of effective practices. The guidebook provides a useful reference for understanding data needs and uses in the context of key PBPP activities including establishing goals and performance measures, identifying performance trends, setting targets, analyzing alternatives, developing investment priorities, allocating resources, programming projects, monitoring and reporting on results, and evaluating strategy effectiveness. Case studies from the Minnesota DOT, the Southeast Michigan Council of Governments, the Champaign Urbana Urbanized Area Transportation Study and the Washington Metropolitan Area Transportation Authority are included.

A related resource: “Performance Based Planning and Programming Self-Assessment” produced by the Michigan FHWA Division Office in 2014: <http://www.grpc.com/wp-content/uploads/2015/11/Performance-based-planning-assessment.pdf> provides a checklist-style tool that agencies can use to assess their progress towards implementing PBPP.

TPM/Data Areas Covered:

- The Guidebook provides general guidance on PBPP with examples from multiple performance areas.

Data Challenges and Opportunities:

- Data must be available to both track actual performance and also to forecast performance under varying scenarios.
- While data availability and cost to collect are important factors in selecting performance measures, it is important to “measure what matters” as opposed to selecting measures solely based on what data are currently available.
- There is a need for dedicated staff time for data collection and analysis
- Analytical skills necessary to handle the growing complexity and amount of performance data may be lacking.
- It can be challenging to maintain data consistency needed performance tracking and analysis as data formulations, models, and tools change.

Data Management Strategies and Success Factors

- Use of GIS platforms to store and manage a range of external and internal agency data and share data with partners
- Use GIS-based decision-support software tools for performance visualization and scenario analysis.
- Use of trend data to inform development of realistic targets

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- Use of trend data to pinpoint performance problems and develop improvement strategies (e.g. crash data for safety; probe data for congestion)
- Inclusion of data fields within project databases that link individual projects to specific performance factors
- Gathering, storing and using information on strategy effectiveness - measured through “before-after” studies
- Use of dashboards and scorecards
- Performance journalism – communicate performance in terms that are readily understood by the public and decision-makers; don’t just provide data but “tell a story”
- Including trend information in reports to provide a context for current performance; including “counterfactual” information on what would have happened without implementation of performance improvements.
- Producing reports that show investment versus performance tradeoffs
- Success factor: accounting for appropriate time horizons in developing a data collection strategy for performance monitoring - considering the likely speed of changes and responses to implemented strategies.

NCHRP 20-24(37), Measuring Performance among State DOTs: Sharing Good Practices (2007-2013)

Link: <http://144.171.11.40/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=543>

Overview: A series of comparative performance measurement studies were conducted under the auspices of the AASHTO Standing Committee on Performance Management. Each study compiled data and computed performance measures from state DOTs, and explored approaches to grouping of similar states and comparison of similar measures across states.

TPM/Data Areas Covered:

- Pavement smoothness, bridge condition, safety, on-time/on budget project delivery.

Data Challenges and Opportunities:

- Differences in source data collection methods, definitions, performance measure calculation methods

Data Management Strategies and Success Factors:

- Adoption of standard definitions and measurement protocols
- Data collection QA/QC

Establishment of Comparative Performance Measures Program Infrastructure to Support System Performance Data Collection and Analysis – Final Report (2011)

Link: [http://onlinepubs.trb.org/onlinepubs/nchrp/docs/NCHRP20-24\(37\)F_FR.pdf](http://onlinepubs.trb.org/onlinepubs/nchrp/docs/NCHRP20-24(37)F_FR.pdf)

Overview: This report offers a design concept for a centralized database and web site supporting storage, access and analysis to performance measures from multiple state DOTs. The design was based on the series of comparative performance measurement studies (described above).

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TPM/Data Areas Covered:

- The infrastructure design covered measures that were included in the comparative performance measurement studies. However, it was designed to be extensible to new measures.

Data Challenges and Opportunities:

- Differences in source data collection methods and definitions
- Variations in availability and consistency of key dimensional variables across states
- Variations in data availability for particular years
- Sensitivity to making performance data available/concern about mis-interpretation
- Need to support different types of data subsets for comparison for each measure (e.g. rural/urban for safety; rigid/flexible for pavement condition)

Data Management Strategies and Success Factors

- Building data feeds from national and state data sources
- Automating computation of performance measures from raw data sets
- Building data marts to facilitate filtering and sorting based on common dimensions (e.g. climate zone, AASHTO region, year, urban/rural, functional class)

NCHRP Report 706: Uses of Risk Management and Data Management to Support Target-Setting for Performance-Based Resource Allocation by Transportation Agencies (2011)

Link: <http://www.trb.org/Publications/Blurbs/166250.aspx>

Overview: The document is organized into two sections; the first uses case studies and the framework developed in NCRP Report 666 to discuss how risk management can support performance based management, and the second investigates the use of information technology (IT) tools and data management practices to support data sharing and integration.

TPM/Data Areas Covered:

- The intent of the guidance is to support target setting for multiple TPM areas

Data Challenges and Opportunities:

Collection

- Determining how to collect the right data and get it to the right person at the right time
- Determining how/when/where to use real time data to supplement traditional traffic data sources
- Determining level of data granularity and accuracy (cost implications)
- Determining whether to outsource data collection – can speed up process but may require internal staff time for processing
- Collection and integration of local road data with on-state system road network- different standards

Archiving/storage

- Determining what data to keep, where and for how long – accommodating large data files; paying for internal or external storage; ensuring accessibility

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- Collection of data across jurisdictional boundaries - may be difficult to consolidate data and level of detail at boundary lines, county to county, state to state.

Processing

- Redundant data kept in duplicate systems (siloes) – difficult to integrate
- Determining data update/refresh cycles – and obtaining updates from external data sources
- Conversion of legacy data systems is time consuming and costly
- Staff reluctance to change existing practices to adopt more efficient, automated processes

Analysis

- Developing new analysis systems/tools –time consuming and costly
- Data quality – not understood; responsibilities not well-defined
- Metadata is essential, but time-consuming to develop and maintain

Reporting/Dissemination

- Limited staff resources to produce reports in a timely manner
- Need to change business processes to meet changing reporting needs
- Need to produce reports in multiple formats for different audiences – may result in additional costs and staff training needs

Sharing

- Variations in data standards
- Lack of commonality in georeferenced data, including accuracy of linear referencing system
- Staff reluctance to share data without knowing how it will be used
- Staff reluctance to purchase external data due to cost or quality concerns
- Staff limitations (time, skills) may limit ability to share data across agencies

Access

- Data security – managing access
- Data privacy – balancing public's right to know with privacy laws

Institutional issues

- Changes in leadership may impact continuity of support for data programs
- Challenges obtaining agreement across business units on terminology
- Differences of opinion between IT and business units on data-related roles and responsibilities
- Statewide and agency policies may dictate contracting methods that prohibit the use of certain hardware, software and communication protocols.

New technology

- Need for ongoing process to evaluate integration of new technology
- Collection of GPS data – equipment selection, signal availability in remote areas, need for post-processing (differential correction)

Data Management Strategies and Success Factors

- Establish common linear referencing system
- Implement a geodatabase containing a comprehensive network of state and local roads

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- Implement enterprise databases (including data warehouses)
- Implement dashboards to present performance information to executives and build their understanding of the value of data
- Use automated tools (including GIS) to enhance analysis and processing of data
- Use a variety of data dissemination methods tailored to the needs of different audiences: dashboards/scorecards, FTP sites, cloud computing services, etc.
- Utilize data sharing agreements
- Develop, maintain and distribute good metadata
- Document clear definitions and standards for data quality
- Use encryption at the source of data collection to ensure individual privacy
- Identify data stewardship roles

CDOT Performance Data Business Plan – Final Draft (2011)

Overview: The Colorado Department of Transportation (CDOT) completed this Data Business Plan to ensure that their use of data – for decision-making, operations, and reporting both internally and externally – is efficient, effective, and coordinated across agency offices. The report recommends nine core performance measures for use by the agency.

The report considers and recommends best practices with respect to data management and data governance. It highlights elements of data governance efforts at a handful of state DOTs (Virginia, Minnesota, Alaska, the District of Columbia, Washington State, and Michigan).

As part of this effort, CDOT conducted a needs and gap assessment within the agency. The purpose was to assess the state of data governance for the support of performance reporting. The assessment included interviews and meetings with relevant data stakeholders at CDOT. As part of this effort, the Division of Transportation Development participated in a data management evaluation using the Data Management Maturity Index from NCRP 666. To support this assessment, the Performance and Policy Unit conducted an information survey with representatives from the Planning, Finance and Engineering Divisions. The questions were divided into the areas of policy guidance, planning and programming, program delivery, policy guidance, and information and analysis. The report also provides a set of recommendations and proposed timeline for CDOT to address their data governance needs and gaps.

Link: http://www.camsys.com/pubs/CDOT_Performance_Data_Business_Plan.pdf

Data Challenges and Opportunities:

- NA

Data Management Strategies and Success Factors

- Strong executive leadership;
- Partnership between the IT and the business units of the organizations;
- Effective communication between the various communities of interest regarding the data and associated application systems that are used to collect, maintain, and report information;
- Published definitions and standards for source data, metadata, and data used in the data marts for creating reports from the various data systems; and

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- Use of a knowledge management system to document work process, data dictionaries, data models, etc.
- Improved structure to reduce redundancy in data collection;
- Clarification of terms and definitions;
- Clarification of roles and responsibilities; and
- Identification and prioritization of stakeholder needs for data.

NCHRP Report 666: Target-Setting Methods and Data Management to Support Performance-Based Resource Allocation by Transportation Agencies (2011)

Link: <http://www.trb.org/Publications/Blurbs/164178.aspx>

Overview: This report, produced as a 3 volume set, provides guidance for transportation agencies on performance-based resource allocation, and highlights the role of data systems in supporting this process. It outlines the processes by which transportation agencies can use data management and governance to strengthen performance management.

Volume 1 of the report presents findings of the research, and includes a chapter on DOT data systems, reviewing the effective elements of data stewardship and management, and discussing both technical and organizational/institutional challenges related to producing high quality data for performance management. Information in this chapter includes a useful discussion of practical data management strategies.

Volume 2 of the report provides guidance for target setting and data management. The data management guidance chapter includes a data management maturity model, and a section on “assessing the current state of data programs.”

The data management maturity model has six maturity levels defined for three elements:

- **Technology/Tools** – the extent to which the agency has tools in place to support data management
- **People/Awareness** – the level of management and staff awareness of and support for data management policies, standards, and procedures
- **Institutional/Governance** – the extent to which the agency has implemented data governance as evidenced by artifacts such as defined roles and responsibilities, data business plans, and data catalogs

The data assessment section presents guidance on approaches that can be taken to gather information on existing data programs (through surveys, focus groups, and workshops), and analyze the information and use it to prioritize data programs for improvement. The guide suggests that the assessment results be used to assess gaps and develop an agency-wide data action plan.

A third volume (published as NCHRP Document 154) includes a series of case studies.

TPM/Data Areas Covered:

- The intent of the guidance is to support target setting for multiple TPM areas

Data Challenges and Opportunities:

- Need for more efficient ways to locate and take advantage of available data and information
- Need for better methods to look at and integrate data from multiple sources
- Need for processes and systems that reduce redundancy and promote consistency in data results
- Need for more timely and real-time data and information
- Need for department-wide spatial data and BI tools

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- Limited appreciation by decision-makers of the role of data systems in supporting business operations; difficulty gaining executive-level support for data governance
- Lack of formal policies and standards governing the collection, processing and use of data
- Establishing and sustaining data stewardship
- Developing agency-wide performance dashboards/scorecards incorporating information from multiple business units
- The time and effort required to assess data gaps
- Coordinating with outside agencies to assemble safety data
- Protection of sensitive data from unauthorized access
- Providing data query capabilities for multiple business units in an agency
- Building flexibility into system design to allow for future integration of new technology for data collection, processing, access and reporting
- Management of archived data

Data Management Strategies and Success Factors

The following data-related success factors are suggested:

- Establish, update, and enforce policies and procedures to govern data management.
- Manage data as an asset in the organization, through policies governing the collection, maintenance, and use of data.
- Use data standards to reduce the cost of multiple data collection efforts and maintenance of duplicate databases.
- Strive to collect data once, use it many times to facilitate consistent reporting of information.
- Communicate with stakeholders to sustain support for various programs.
- Develop a business terminology dictionary to align the use of business terms commonly used throughout an organization.
- Identify business units responsible for maintaining current metadata about each performance measure to facilitate the analysis required for user requested data and information system changes and enhancements.
- Use external data sources, such as environmental, historic, and other planning agencies for GIS data layers to improve the data used for the performance measurement process when funds are limited to collecting this data using internal resources.
- Use external data sharing agreements to obtain data for performance measures that the agency does not have and reduce costs associated with data collection and maintenance of data systems.
- Establish well-defined procedures, methods, and tools for sharing data both internally and externally.
- Use software that is procured or developed internally to automate as much of the performance measurement process as possible.
- Create an annual data file for each data program so that consistent information is provided throughout the year.

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- Use BI tools to allow easy access to data systems and sharing of information among employees and decision-makers.
- Design data systems so that they can be modified in the future without requiring a complete redevelopment of the software.
- Use Service-Oriented Architecture (SOA) and Open Database Connectivity (ODBC) in the design of new application systems to enable sharing of data and information across systems.
- Invest in the staff by providing training in new technology and tools to gain their buy-in for support of data programs and data governance initiatives.
- Provide professional development opportunities for staff.

NCHRP Project 08-36 Task 100 Final Report (2011)

Link: [http://onlinepubs.trb.org/onlinepubs/nchrp/docs/NCHRP08-36\(100\)_FR.pdf](http://onlinepubs.trb.org/onlinepubs/nchrp/docs/NCHRP08-36(100)_FR.pdf)

Overview: This report summarizes the results of a scoping study that established the starting point for NCHRP Project 08-92. The objectives of the study were to:

- Identify and define current practices that are applicable to development of a framework for a transportation agency data program self-assessment tool
- Understand the agency needs and challenges associated with data program management; and
- Provide a conceptual design and road map for future development of a self-assessment tool.

TPM/Data Areas Covered:

- The report scope goes beyond data for TPM, but is applicable for multiple TPM areas

Data Types/Sources Covered:

- Applicable to all types of transportation agency data

Data Life Cycle Phases:

- Applicable to the full data life cycle

Data Challenges and Opportunities:

- **Strategic Alignment** – Agencies are aware that aligning their data with strategic decision making needs is important, but lack a deliberate process for achieving this alignment.
- **Knowledge Loss** – Experienced staff with knowledge of data programs and systems are retiring which means that remaining staff may lack the in-depth understanding needed to assess data gaps and prioritize improvements.
- **Shortfalls in Financial Resources** – The deteriorating condition of transportation sector funding will likely put increasing strains on agency budgets; finding the resources to implement data improvements and reforms in such an environment could be difficult.
- **Institutional Momentum** – Many elements of an agency's data program typically have a significant and complex history within the organization, thus there may be internal turf considerations, institutionalization of processes, and entrenched data audiences, all of which may create resistance to change.
- **Absence of Leadership Continuity** – Many transportation agencies (particularly DOTs) have fast turn-over in their senior leadership which can make it tough to “stay the course” with multiyear data program improvement initiatives.

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Data Management Techniques and Success Factors:

- **Alignment with Strategic Goals** – practices to understand (qualitatively and quantitatively) the value of data assets and programs to the core strategic goals of the organization, and implement processes through which decisions and recommendations can be based on data.
- **Focus on Data Quality** – practices to measure, monitor and improve the quality of data, considering multiple dimensions: accuracy, consistency, completeness, reliability, timeliness, integrity, currency, confidentiality. This involves allocation of time and resources for data audits and validation procedures.
- **Clear Definitions** – practices to establish and maintain clear and consistent data definitions to ensure that the data is managed used appropriately.
- **Ability to Segregate, Aggregate, and Analyze Data Longitudinally** – practices to establish flexible data sets that can be parsed, parceled, and constituted in whatever way is the most relevant to the desired application. Coordination in this area is necessary between and within organizations if data sets are to be shared across internal and external jurisdictions.
- **Clear and Appropriate Organizational Roles** – practices that establish and designate data management roles for leadership, managers, data stewards, IT staff, data steering committees, etc.
- **Staff Capabilities** – practices for ensuring availability, capability, and training of staff for managing, analyzing and using data.
- **Time and Resources for Conducting Analysis** – practices for ensuring that necessary resources and guidance are provided to transform data into information as required for its desired uses.
- **Mechanisms for Security, Privacy, and Ethical Considerations** – practices for protecting data assets due to security, privacy, and proprietary concerns. Ethical considerations must also be applied when publishing analysis and visualizations to ensure that the results and conclusions are not manipulated to unfairly endorse a specific agenda.

TRB Circular: Challenges of Data for Performance Measures: A Workshop. (2006)

Link: <http://onlinepubs.trb.org/onlinepubs/circulars/ec115.pdf>

Overview: Report of a 2006 workshop sponsored by the TRB Performance Measures Committee and the Data and Information Systems Section. The workshop purpose was to identify ongoing issues and research directions in data management processes for performance measures. Fifteen state and local transportation agencies were invited to participate.

TPM/Data Areas Covered:

- The workshop covered multiple TPM areas

Data Challenges and Opportunities:

- Building a DOT culture that supports data
- Need for quality data to support performance measures
 - missing data for several areas including sustainability, people movement, on-time performance for transit
 - difficulty getting data for off the state system

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- Understanding and improving data quality – responsibilities, resourcing, tradeoffs (how much is enough)
- Challenges collecting before/after data for evaluation
- Challenges having data to understand causality
- Need to provide ready access to performance information for decision makers – need to adapt performance reports for various users
- Need for more sophisticated analysis and modeling tools – improvements to predictive capabilities
- Need for enterprise approach – disparate and duplicative databases lead to inconsistencies; need to standardize sources and definitions
- Need for data sharing across federal, state and local agencies; importance of developing trust
- Need for more nimble and dynamic systems to analyze and present information – processing requires time consuming manual efforts
- Data integration issues – including spatial linkage capabilities for GIS
- High data collection costs – opportunity to reduce in the future through new technology

Data Management Strategies and Success Factors

- Success factors for using existing performance data:
 - Processing and checking raw data
 - Transforming raw data into meaningful performance measures
 - Integrating for analysis and mapping
 - Developing trend information
 - Projecting measures into the future for target setting
 - Providing tools to decision makers
- Performance measures database system
- Enterprise information portal
- GIS/BI/Data marts
- Performance dashboards/websites
- Integrated Corridor Analysis Tool (ICAT)
- Data business plans
- Partnering across agencies – e.g. MPO/DOT collection of urban travel time
- Microsimulation modeling
- Tools to incorporate real time data

References Related to Specific Performance Areas or Data Types

FHWA Guide for State DOT Safety Data Business Plans (publication pending)

This guide presents a seven-step process for developing a safety data business plan.

FHWA Applying Archived Operations Data in Transportation Planning: A Primer (2016)

Link: <https://ops.fhwa.dot.gov/publications/fhwahop16082/>

Overview: This primer provides guidance for creating and using archived operational data for identification of congested locations, understanding the nature of congestion (recurring or non-recurring); analyzing causal factors; computing a variety of operations performance measures for

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reporting; and evaluating impacts of implemented projects and programs. It includes a set of detailed case studies illustrating use of the data for each of these purposes.

TPM/Data Areas Covered:

- Emphasis on congestion, reliability and freight performance
- Data discussed includes:
 - Real-time flow data tied from sensors, toll tag readers, license plate readers
 - Probe data from third-party vendors (e.g., HERE, INRIX, or TomTom)
 - Real-time event data and lane closure information from construction events, disabled vehicles, accidents, and special events from Advanced transportation management system (ATMS) platforms

Data Challenges and Opportunities:

Opportunities for making use of archived operations data include:

- Identifying and confirming congestion problems
- Developing and reporting mobility performance measures
- Providing inputs for (and calibrating) reliability prediction tools.
- Performing before and after studies to assess projects and program impacts.
- Identifying causes of congestion

Institutional challenges (for making use of archived operations data)

- Restrictive technology policies (constrain use of cloud storage; open source software, etc.)
- Resource constraints (availability of staff with specialized skill sets)
- Capability to manage large data sets (“few DOTs have dedicated and responsive IT teams that can plan out, install, and configure expensive hardware or cloud services to accommodate these massive archives for long periods of time.”)
- Capability to develop and manage data access and analysis tools
- Networking bandwidth
- Security concerns
- Internal resistance to sharing data – incentives to protect data; disincentives to provide it
- Lack of trust in the quality of operational data
- Lack of incentives or impetus to switch to use of operational sources when an existing, alternative source (and supporting process) already exists
- Translating/integrating data between probe data sets (Traffic Message Channel networks) and agency linear referencing systems

Challenges related to changing planning methods to incorporate use of archived operations data

- Obtaining full coverage of the systems of interest (e.g. arterials and collectors in addition to freeways)
- Maintaining continuity of trend data when cutting over to the new data source (from modeled data to archived data)
- Addressing differences in the underlying basis for performance measure computation (requiring conflation of archived data with forecast data)
- Developing forecasting models for new performance measures (e.g. reliability)

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Data Management Strategies and Success Factors

- Creation of a central data repository integrating archived data from multiple sources
- Use of off-the-shelf software providing sophisticated visualization, data exploration, reporting and analysis features
- Utilize compelling graphics that communicate problem impacts in a meaningful way
- Pooled-fund approach to building and maintaining analysis tools
- Utilize an ongoing process to edit and align disparate geometric (geographic information system) networks associated with different data sources

Improving Safety Programs Through Data Governance and Data Business Planning: A Peer Exchange (2015)

Link: <http://onlinepubs.trb.org/onlinepubs/circulars/ec196.pdf>

Overview: This report summarizes a 2015 peer exchange that was held to explore effective data governance and data business planning solutions for safety applications. Ten state transportation agencies participated. Discussions centered around four key themes: (1) the business case for data governance, (2) Essential elements of data governance, (3) Operationalizing data governance at a DOT, and (4) Using data governance to advance data sharing and integration.

TPM/Data Areas Covered:

- Safety – though many of the concepts discussed are applicable to other performance areas.

Data Challenges and Opportunities:

- Advancing state safety data systems to guide HSIP and SHSP processes, analyses and evaluations – which requires integration of roadway, traffic and crash data across multiple agencies/jurisdictions
- Consolidating across data dictionaries of different transportation business areas
- Difficulties establishing enterprise systems given siloed, redundant and conflicting data sources within a DOT
- Duplication of effort for data management
- Increasing public expectation of accessibility to transportation information across modes
- Communicating value of data governance; overcoming its negative connotations (related to control rather than value added)
- Collaborating across information silos
- Integrating data from multiple off-the-shelf products from different vendors
- Agreeing on the level of locational accuracy required for different business purposes
- State government implementation of centralized IT operations, impacting DOT operations
- Transportation agency decentralized IT operations, e.g., district IT operations impacting central office IT operations
- Staffing/skills limitations; differences in generational familiarity with IT and analytics
- Difficulties in incorporating enhanced data collection techniques
- Need to expanding data collection categories, data elements, and data types

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Data Management Strategies and Success Factors

- Creating a central LRS – via state/local collaboration
- Data sharing via Enterprise GIS Portal
- GPS standards
- Integrating data across asset management and safety for risk analysis (example: relationship between highway lighting and crashes)
- Establishing information management principles
- Defining critical data elements; evaluating and scoring data sets
- Establishing data stewardship roles
- Mapping out data governance workflows

NCHRP Project 20-05, Topic 44-13, Synthesis 460: Sharing Operations Data Among Agencies

Link: <http://www.trb.org/main/blurbs/170868.aspx>

Overview: This NCHRP Synthesis report documents the current state of practice in the sharing of operations data. It discusses both the qualitative and quantitative business cases as to why agencies share data, and documents institutional, legal, and technical challenges that can inhibit the success of sharing operations data between agencies, the private sector, and the public. It draws upon a literature review, agency survey, and follow up interviews. Forty-one state DOTs provided survey responses.

TPM/Data Areas Covered:

- The guidance is generic and applicable for multiple TPM areas

Data Challenges and Opportunities:

- Reluctance to share data that may not be fully accurate
- Reluctance to share data due to a concern that it may leave the agency open to criticism
- Vendor use of proprietary data formats and APIs that are not publicly accessible
- Some local agencies still use paper processes and are therefore unable to participate in electronic data sharing arrangements
- Real and perceived concerns about data quality; tendency to delay sharing incident data until after the incident is confirmed
- Bandwidth limitations – particularly from agencies to the broader internet
- Lack of effective data presentation methods that consider human factors
- Concerns about data security – which may be unwarranted given the nature of the majority of data being transmitted
- Costs associated with creating data feeds or ingesting data feeds
- Reintegration of shared operations data into an agency's native systems (disparate data types, incompatible time scales, information overload)

Data Management Strategies and Success Factors

Factors affecting the value of operations data:

- Methods for presenting data to the user – matching level of detail to different user needs
- The speed at which information is provided to other agencies and third parties

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- The degree to which bureaucratic and overly burdensome legal reviews are required for execution of data sharing agreements
- Restrictive state laws or internal agency policies that constrain the execution of data use agreements
- Negotiation of data use agreements that provide the agency with rights to use the data for internal purposes in perpetuity, share the data with operational partners, and summarize the data for multiple purposes.
- Existence of established personal relationships across agencies (which may be disrupted by leadership changes)

Data Management Strategies include:

- Requirements for third party data feeds
- Creation of interface control documents
- Use of standard data formats (e.g. TMDD)
- Creation of redundant test systems
- Use of Configuration Control Boards to manage changes

USDOT Roadway Data Business Plan – Phase 1 (2013)

Link: <https://ntl.bts.gov/lib/48000/48500/48531/6E33210B.pdf>

Overview: USDOT's Roadway Data Business Plan was developed to improve the coordination and communication mechanism across U.S. DOT offices to avoid investing resources on the same or similar types of data related programs. It was also intended to serve as prototype for other U.S. DOT offices; and provide leadership by suggesting or offering best data collection/management practices to primary data collectors. This review focuses on best practices for data management identified in the plan.

TPM/Data Areas Covered:

- Roadway mobility data: infrastructure/ inventory, roadway travel mobility (including vehicle, truck freight, bicycle/pedestrian, and transit, as well as roadway inventory data), climate data, modal data, and data capture activities associated with ITS JPO-sponsored research in wirelessly connected vehicle technologies.
- Also addresses cross-cutting data management issues that impact all data types: (e.g., data quality, standards, data privacy and security, etc.)

Data Challenges and Opportunities:

- General USDOT stakeholder needs potentially related to TPM included:
 - **Data acquisition and updating** – improved ability for users to obtain access to updated data as it becomes available within the original data source; lower data costs
 - **Data quality** - address missing/incomplete data; develop data quality performance measures; increase use of independent validation; address state use of default values for data submittals
 - **Data standards** – need for better integration of data across sources; processes to reduce duplication/overlaps; standard update frequencies; standard metadata elements; consistency with open data principles; consistent definition of “real time”

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- **Business analysis tools** – need for comprehensive analysis tools to support analysis at both the national and regional/corridor levels
- **Data privacy and security** – need to ensure data is usable at the state and local level; need to specify what data elements should not be released due to privacy concerns.
- **Data storage and access** – need for policy to address licensing and data ownership issues to determine whether data can be shared with others
- **Internal coordination** – need for improved communication (internally and externally) about what data is available and how to access it; improved coordination on acquisition of private sector data; mechanism for states to share information on alternative types of analysis that are being done with existing data
- **Performance measures**- need for improved consistency across U.S. DOT in definitions of performance measures (e.g., travel time reliability)
- **Data governance** – need for clarity on data ownership; improved coordination between U.S. DOT offices related to data collection and reporting functions
- **Data catalog** - Data catalog to clearly identify what data is being generated, owners of that data
- USDOT stakeholder needs related to specific data types included:
 - **Infrastructure data - standards**: need for improved consistency in state roadway inventory attribute definitions, domain values, positional accuracy and resolution, data collection methods, and frequency of updates
 - **Travel data - scope**: need for lane occupancy data; volume data to accompany probe speed data; supporting data on sources of congestion (e.g., bad weather, crashes, etc.)
 - **Travel data – quality**: need for uniform data quality from TMCs; improved GPS capability to adequately identify slowdowns and distinguish between frontage roads and interstate locations
 - **Climate data – scope**: need for weather condition data at or on the roadway
 - **Modal data – scope**: need for real-time transit data including monitoring passenger loads and transit vehicle health; truck volumes, shipments between city pairs
 - **Modal data – quality**: need for more accurate truck and bus VMT
 - **Modal data – standards**: need to improve ability to integrate bike/pedestrian data with other data; ability to integrate different freight data sources
 - **Modal data - data acquisition and updating** – need to improve willingness of transit agencies to share specific vehicle location and schedule adherence data with third party sources; bike/pedestrian travel measurement methods

Data Management Strategies and Success Factors

- Data Governance - A generic data governance framework is recommended involving: (1) mapping of data programs to business objectives, (2) defining stakeholder roles and responsibilities, (3) developing a data governance model, (4) developing a data governance charter, (5) developing a data catalog, and (6) assessing data governance maturity. Specific recommendations for USDOT included:

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- Create a data coordination group to identify gaps and redundancies and improve coordination
- Create data working groups (by data type) to develop policies, procedures, and business practices
- Create data community of interest to coordinate and share best practices on data management issues such as data quality, standards, data privacy and security, etc.
- Data Acquisition
 - Policy to define responsibilities for collecting and updating data
 - Specification of updating methods and responsibilities for updating
 - Annual review of data programs to identify where duplicate data collection and storage can/should be eliminated and replaced with a single source of data for specific data programs.
 - Development of a standard data template format that would foster joint usages and collaboration, minimize data duplications, and improve quality, standard and completeness of datasets.
 - Development of a standard data sharing agreement with third parties
- Data Quality
 - Policy to define responsibilities for data quality;
 - Adopt data quality standards for the collection, processing, use, and reporting of roadway travel mobility data – require use of metadata
 - Document QA/QC procedures for each data systems, with instructions on how to process data errors.
 - Develop validation rules and allowable values for coded fields and incorporate into data systems and repositories. (Leverage established validation rules (e.g., the NTCIP 1204 for Environmental Sensor Station observations)
- Data Standards
 - Policy to define responsibilities for supplying metadata standards for each type of data set (e.g., weather data, travel data, etc.)
 - Establish data dictionaries and descriptive information for data products
 - Develop metadata guidelines to indicate update frequency, age of data, and specify how data can be used or integrated with other data sources;
 - Coordinate with applicable data standards, the Federal Enterprise Architecture Data Reference Model, the Data Quality Act, and open data principles
- Business Analysis Tools
 - Explore the potential use of new and improved technology to support the roadway travel mobility data programs: e.g. use of XML formats for data exchange; GPS data collection technology; GIS tools for geographical display of data.
- Data Storage and Access
 - Define business requirements for data access, analysis and reporting
 - Develop a policy to define responsibilities for data storage, hosting, data retention (archive), and disposal
 - Develop a policy to define data ownership and dissemination rights

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- Explore methods to enhance access to information and data for the roadway travel mobility data programs – including web portals that are easily accessible by internal and external stakeholders.

Appendices to the document include a scan of data management best practices; selected points are highlighted below:

- Control the amount of information being transmitted – avoid information overload
- Start small and address critical needs first before expanding
- Build systems for scalability, leveraging technologies such as clustered databases, virtual warehousing, virtual servers
- Determine what data really needs to be stored and backed up; discard unnecessary data
- Consider allowing a third party to handle data storage needs to reduce costs
- Determine who owns the data from the start and who can use the data
- Make data available as soon as feasible
- Segregate critical data - processing elements behind a set of filtering mechanisms
- To improve data quality, gather and combine data from multiple (redundant) sensors
- Provide fast, general data quality analysis for real - time systems, and then thoroughly scrub and sanitize the overall data more diligently for historical and post real - time analysis and display.
- Carefully consider what level (granularity) of data are needed and how much and how often it should be transmitted.
- Determine what is critical to communicate.
- Minimize the lag between data collection and data quality control – perform QA locally and immediately by staff that are familiar with the network.
- Use third party independent verification of data to ensure continuous data quality improvement

Benefit-Cost Analysis of Investing in Data Systems and Processes for Data-Driven Safety Programs (2012)

Link: <http://safety.fhwa.dot.gov/rsdp/downloads/bcareport.pdf>

Overview: Study commissioned by the FHWA Office of Safety to develop guidance on methodologies that State and local Departments of Transportation (DOTs) could implement to make the case for investing in data collection, data systems, and processes. The study establishes a benefit-cost analysis (BCA) methodology to quantify the economic returns from investing in safety data improvements. Costs considered include investment costs, operations and maintenance costs, and data analysis costs. Benefits considered include reductions in staff time for data analysis; and crash reductions related to more optimal selection of countermeasures and faster deployment of safety improvements.

TPM/Data Areas Covered:

- Safety

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Data Challenges and Opportunities:

- The report addresses the challenge of making the case for investments in data and analysis capability improvements

Data Management Strategies and Success Factors

- The report recommends application of the BCA methodology for assessing whether implementation of a data collection project is economically justified, and for choosing between completing alternatives.

Traffic Monitoring Guide (2013)

Link: https://www.fhwa.dot.gov/policyinformation/tmguid/tmg_fhwa_pl_13_015.pdf

Overview: The Traffic Monitoring Guide (TMG); provides guidance and recommendations to transportation agencies for traffic monitoring, traffic data and traffic data management. The TMG covers the planning and implementation of traffic monitoring programs and data quality and data management strategies. It includes best practice examples for traffic monitoring design, data quality, and equipment calibration.

TPM/Data Areas Covered:

- Traffic monitoring – both motorized and non-motorized
- Transportation management and operations (e.g. traffic operations, incident management, special event management, safety)

Data Challenges and Opportunities:

- Understanding needs of different stakeholders with respect to: accuracy, completeness, validity, timeliness, accessibility (or usability), format, and nature of use
- Making best use of limited resources
- Challenges associated with sharing data within and across agencies (different needs, formats and standards)

Data Management Strategies and Success Factors

- Sharing data with partner agencies and eliminating duplication of data collection efforts (e.g. State/local partnerships for traffic counting off the state system)
- Consolidating data sources that are overlapping within an agency
- Resource sharing and coordination across different DOT business units: traffic monitoring, traffic operations, planning, commercial vehicles offices, safety offices, planning
- Implementing automated software technologies to eliminate manual or electronic processing of data as well as eliminating inefficient or unnecessary business process steps
- Purchasing and integrating private sector data to supplement existing data sources
- Upgrading site equipment to include cellular (preferred)/dial-up modems or establishing fiber network access eliminating the need for site visits to download data
- Integrating travel monitoring program data with Intelligent Transportation Systems (ITS) data eliminating duplication of efforts within an agency – this requires coordination and

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standardization of data collection efforts (time of collection 24 hours without gaps), resources, data export formats, etc.

- Data governance/coordination groups
- QA/QC data procedures
- Scalable enterprise-wide data warehousing solution for data access
- Robust traffic monitoring calibration program
- Quality metadata

NCHRP Project 20-24(37)D: Recommendations for Improving the use of Traffic Incident Management Performance Measures when Comparing Operations Performance Between State DOTs

Link: [http://onlinepubs.trb.org/onlinepubs/nchrp/docs/NCHRP20-24\(37\)D_FR.pdf](http://onlinepubs.trb.org/onlinepubs/nchrp/docs/NCHRP20-24(37)D_FR.pdf)

Overview: The original objective of this study was to collect traffic incident management (TIM) performance data from multiple states and demonstrate how a cross-state comparison and examination of changes in performance over time might identify best practices that could be instrumental in reducing incident duration with associated benefits to travelers. Data were collected from ten agencies, but the study found that data was not sufficiently standardized to enable meaningful cross-state comparisons. It was re-focused to make recommendations on enhancing existing agency TIM data collection and reporting efforts and the possible development of a standard approach to TIM performance data collection.

TPM/Data Areas Covered:

- Traffic Incident Management

Data Challenges and Opportunities:

- Lack of standardization in collection and use of nationally adopted TIM performance measures:
 - Differences in how agencies define a “traffic incident”
 - Differences in definitions of incident types
 - Variations in performance measures used
 - Variations in data sources and the basis for performance measure calculation (e.g. incident start and end time)
 - Variations in time stamp values collected
 - Variations in calculation methods
- Difficulty for DOTs to capture the time that incidents are first identified – requires coordination with law enforcement and emergency management agencies
- Lack of data on the time of incident clearance and roadway return to normal conditions – needed to calculate the primary performance measures selected for the study

Data Management Strategies and Success Factors

- Adopting standard performance measures, data element definitions and calculation methods
- Estimating “return to normal” conditions using probe data

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Asset Management Data Collection for Supporting Decision Processes (2006)

Link: http://www.fhwa.dot.gov/asset/dataintegration/if08018/assetmgmt_web.pdf

Overview: This project looked specifically at how state DOTs are linking their data collection and management processes to their asset management and project selection decisions. The report includes a literature review, case studies, and DOT survey results on current practices from throughout the country. The research culminated in a framework to help agencies structure their data collection effectively, and to support their project selection. The framework includes a set of questions that agencies should ask to assess their data collection strategies and need. It then lays out a high-level process and feedback loop for data collection to support project selection.

TPM/Data Areas Covered:

- Infrastructure condition/asset data

Data Challenges and Opportunities:

- Agencies collect very large amounts of data and create vast databases that have not always been useful or necessary for supporting decision making processes.
- Asset Management best practice involves cross-asset comparisons between the candidate projects for selection, which has increased the need for more consistent data collection among asset types and locations (as opposed to separate collection efforts)
- Ability to link data from disparate asset-specific systems that use different data management technologies and information technology environments
 - difficulty getting agreement on standard data formats, models, and protocols
 - difficulty achieving support from the agency staff and getting people to conform to a new standard
 - difficulty obtaining resources required to transition systems to new standards

Data Management Strategies and Success Factors

- Integrating roadway and asset databases; creation of common databases to store information about multiple assets
- Outsourcing asset data collection – with clear expectations for the vendor with respect to the data to be collected, required precision, and quality control and assurance procedures to evaluate the collected data.
- Applying a data collection framework for project selection involving:
 - Identification of candidate projects and corresponding treatments
 - Identification of project evaluation/assessment tools and their requirements
 - Identification of data needs for the evaluation to be performed
 - Identification of existing databases and data quality assessment
 - Determination of missing data elements; cost/benefit analysis of their collection
 - Selection of the appropriate data collection methodology and implementation

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Assessment Models and Tools

FHWA Office of Performance Management – Transportation Performance Management Capability Maturity Model (2016)

Link: <https://www.tpmtools.org/wp-content/uploads/2016/09/tpm-cmm.pdf>

As part of the FHWA Transportation Performance Management Technical Assistance Program (TAP) Toolkit, a maturity model and accompanying self-assessment tool were developed.

The data management assessment component includes:

- **Data Quality:** Processes and organizational functions to ensure data are accurate, complete, timely, consistent with requirements and business rules, and relevant for a given use.
- **Data Accessibility:** Processes and organizational functions to provide access to key data sets.
- **Data Standardization and Integration:** Processes and organizational functions to integrate and compare data sets as needed to support transportation performance management.
- **Data Collection Efficiency:** Efforts to maximize use of limited agency resources through coordination of data collection programs across business units and with partner agencies.
- **Data Governance:** Establishing accountability and decision making authority for collecting, processing, protecting, and delivering data.

The data utilization and analysis assessment component includes:

- **Data Exploration and Visualization:** Availability and value of data, tools, and reports for understanding performance results and trends.
- **Performance Diagnostics:** Availability and value of data, tools, and reports that allow an agency to understand how influencing factors affected performance results both at the system and project levels.
- **Predictive Capabilities:** availability and value of analytical capabilities to predict future performance and emerging trends.

To guide development of the model, several existing maturity models and assessment tools were reviewed. A summary of this review is shown below.

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Table A-2. Review of Relevant Maturity Models and Assessment Tools

Model	Applicability	Key Components	Levels
FHWA Roadway Safety Data Capabilities Assessment¹	State DOT roadway data systems – part of larger framework of safety data assessment	<ul style="list-style-type: none"> • Data collection/ technical standards (completeness, accuracy, timeliness, uniformity/consistency) • Data analysis tools and uses (network screening, diagnosis, countermeasure selection, evaluation, accessibility) • Data management (people, policies, technology) • Data interoperability and expandability (interoperability, expandability, linkage) 	<ul style="list-style-type: none"> • Initial/ Ad-hoc • Repeatable • Defined • Managed • Optimizing
FHWA Highway Safety Improvement Program (HSIP) Self-Assessment²	State DOT Highway Safety Improvement Programs	<ul style="list-style-type: none"> • Leadership: goals, accountability, champions • Administration: program staffing, established procedures • Planning: data-driven identification and prioritization of treatments • Implementation: resource allocation based on need, keeping actions aligned with plans • Evaluation: collection and analysis of data to identify effectiveness at strategy and program level 	<ul style="list-style-type: none"> • 1-Initialization • 2-Development • 3-Execution • 4-Evaluation • 5-Integration

¹ http://safety.fhwa.dot.gov/rsdp/downloads/rsdp_usrsdca_final.pdf

² <http://safety.fhwa.dot.gov/hsip/resources/fhwasa11043/#t1>

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Model	Applicability	Key Components	Levels
FHWA Corridor TPM Model³	Corridor management programs/initiatives	<ul style="list-style-type: none"> Performance Management Processes (goals/objectives, performance measures, target setting, resource allocation, performance monitoring and reporting, management and operations, integration into long-term planning and programming) Technology/Tools (data collection/availability, data sharing/standardization, analysis tools/capabilities, availability of data for corridor uses) Institutional/Governance (mobilization of partners, organizational structure/ leadership/ direction, organizational funding, modal partner collaboration, planning partner collaboration) 	<ul style="list-style-type: none"> 1-None/Limited 2 3 4 5 6-Optimized
FHWA Traffic Incident Management (TIM) Assessment⁴	Incident management programs/functions	<ul style="list-style-type: none"> Formal incident management program Multi-agency TIM teams TIM performance measures Policies and procedures for incident clearance Data collection/integration/ sharing Traveler information 	<ul style="list-style-type: none"> Low – Little to no activity Medium – some level of activity/practice with fair to good results High – Outstanding activity, high level of interagency cooperation
FHWA Infrastructure Voluntary Evaluation Sustainability Tool (INVEST) Assessment Tools⁵	Sustainability assessment for system planning, operations and maintenance and projects	<ul style="list-style-type: none"> Very broad scope touching on multiple aspects of sustainability within different contexts 	<ul style="list-style-type: none"> Bronze Silver Gold Platinum <p>(based on % of possible points scored)</p>

³ <http://www.fhwa.dot.gov/TPM/resources/corridor/hif13058.pdf>

⁴ http://ops.fhwa.dot.gov/eto_tim_pse/docs/09timsaguide/index.htm

⁵ <https://www.sustainablehighways.org/1/home.html>

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Model	Applicability	Key Components	Levels
NCHRP Report 666: Target-Setting Methods and Data Management to Support Performance-Based Resource Allocation by Transportation Agencies⁶	State DOT data governance functions – to support performance-based resource allocation and target setting	<ul style="list-style-type: none">• Technology/Tools• People/Awareness• Institutional/Governance	<ul style="list-style-type: none">• Ad-Hoc• Aware• Planning• Defined• Managed• Integrated• Continuous Improvement
Transportation Asset Management (TAM) Gap Assessment	Transportation asset management functions	<ul style="list-style-type: none">• Policy Goals and Objectives• TAM Practices• Planning, Programming, and Project Delivery• Data Management• Information Systems• Transparency and Outreach• Results• Workforce Capacity and Development	<ul style="list-style-type: none">• 1-Initial• 2-Awakening• 3- Structured• 4-Proficient• 5-Best Practice

⁶ http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_666.pdf

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Model	Applicability	Key Components	Levels
SHRP-2/AASHTO System Operations and Management Institutional Capability Maturity Model⁷	State DOT system operations functions	<ul style="list-style-type: none"> • Business processes – including formal scoping planning, programming, and budgeting; • Systems and technology – including systems architecture, standards, interoperability, and standardization and documentation; • Performance measurement – including measures definition, data acquisition, analysis, and utilization; • Culture – including technical understanding, leadership, policy commitment, outreach, and program authority; • Organization and workforce – including organizational structure, staff capacity, development, and retention; and • Collaboration – including relationships with public safety agencies, local governments, MPOs, and the private sector. 	<ul style="list-style-type: none"> • Level 1 – ad hoc, informal and champion-driven, not mainstreamed • Level 2 – basic applications and processes, core technologies and processes under development, limited internal accountability and uneven alignment with partners • Level 3 – standardized and managed applications, TSM&O technical and business processes developed, documented, and integrated into DOT; partnerships aligned • Level 4 – TSM&O is a core, sustainable program, continuous improvement with top level management status and formal partnerships

NCHRP Report 814: Data to Support Transportation Agency Business Needs: A Self-Assessment Guide (2015)

This research involved interviews and focus groups with DOTs and MPOs to understand data challenges, and reviews of the literature to identify and document successful agency practices that can be pursued to advance agency data management capabilities. A comprehensive data management self-assessment tool was produced, covering five key elements: Data Strategy and Governance, Life Cycle Data Management (including collection, storage, documentation and delivery), Data Architecture and Integration, Data Collaboration, and Data Quality Management (see Figure A-1.) A companion guidance document was prepared including a data improvement catalog with relevant practice examples for data improvement strategies within each assessment element.

⁷ <http://www.aashtotsmoguidance.org/>

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Implementing a Transportation Agency Data Self-Assessment NCHRP 08-92

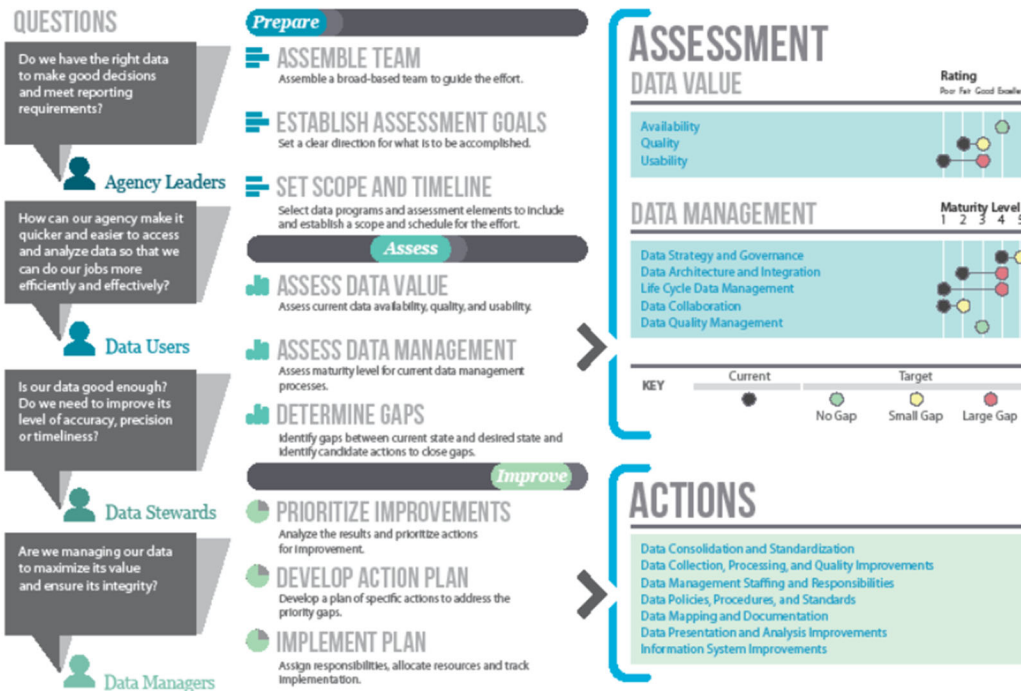


Figure A-1. NCHRP Report 814: Implementing a Transportation Agency Self-Assessment

AASHTO Asset Management Gap Analysis Tool

Link: <http://www.tam-portal.com/resource/aashto-transportation-asset-management-gap-analysis-tool-users-guide/>

The Transportation Asset Management (TAM) Gap Assessment tool, developed as part of NCHRP Project 8-90 is intended to be used by State DOTs to target improvements to asset management functions. This model includes many performance management components, since TAM can be viewed as an application of TPM for life cycle management of pavements, bridges and other transportation infrastructure assets. The gap assessment covers eight major areas that include formulation of policies, goals and objectives, development of performance measures and targets, collection and analysis of data, use of decision support tools, leadership, data-driven prioritization and investment strategies, and workforce capacity.

United States Roadway Safety Data Capabilities Assessment (2012)

Link: https://safety.fhwa.dot.gov/rsdp/downloads/rsdp_usrsdca_final.pdf

In one of the more established transportation data assessments conducted to date, the FHWA conducted a capabilities assessment for each State, the District of Columbia, and Puerto Rico on the collection, management, and use of roadway safety data. This effort was completed as a component of the Roadway Safety Data Program (RSDP). The stated purpose of this project was, “to develop, pilot, and conduct a

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consistent and thorough roadway safety data capabilities assessment and to gain insight from the States to develop a National Roadway Safety Data Action Plan (NRSDAP).” Based upon the state purpose there were three primary objectives:

- To develop and carry out a consistent, repeatable, and systematic process to assess State’s roadway safety data capabilities.
- To understand what States capability goals are, and to help them identify critical gaps and potential solutions to achieve their data goals.
- To set future research and programmatic goals to further the evolving state of practice for data-driven highway safety planning.

Within the area of safety, the capability assessment being carried out focused upon four areas and employed a five-level capability maturity model (CMM). The four focus areas were segmented further into element areas. The four focus areas completed within the capability assessment were as follows:

- **Roadway Inventory Data Collection / Technical Standards** - What roadway inventory data are collected? How are they collected? What standards must they meet?
- **Data Analysis Tools and Uses** - How does roadway safety data relate to analysis process including tools such as HSM, IHSDM, Safety Analyst, etc.?
- **Data Management** - What policies and procedures exist for collection, maintenance, usage, and updating of roadway safety data?
- **Data Interoperability and Expandability** - How does roadway inventory data relate to other data including, but not limited to, crash data, citation data, etc.? Can the existing data be expanded as new technologies and tools are developed in the future?

In carrying out the capabilities assessment the project team used questionnaires and interviews to identify the current capability of each State in the four areas / element levels. The States were heavily involved in the process, and were responsible for both confirming their current capability levels and establishing their target capability levels for each element level. As noted within the final report, the project team averaged the findings of each State to identify national gaps in capability. Consistent gaps from a national perspective center on data management policies and technology, the completeness of the roadway inventory, and use of data for countermeasure selection.

The assessment was based on the CMM framework originally developed by the Carnegie Mellon Software Engineering Institute (SEI) for assessment of software development practices. The maturity framework allowed each State to assess capability levels for each element and for the roadway safety data program as a whole. It included the following five maturity levels:

1. **Initial/Ad-hoc** - The organization does not possess a stable implementation environment and the safety data collection, management (entering/coding, processing, and evaluating) and maintenance process is ‘ad hoc’ with no interconnection within the organization. There is no plan for interoperability or expandability.
2. **Repeatable** - The results of previous projects and the demands of the current project drive activities and actions. Individual managers decide what to do on a case-by-case basis during individual projects.
3. **Defined** - The organization documents the process rather than on a per-project basis. The organization's standards tie to an adopted strategy and this guidance determines project outcomes.

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4. **Managed** - Process management initializes and supervises individual projects. Through performance management, processes are predictable, and the organization is able to develop rules and conditions regarding the quality of the products and processes.
5. **Optimizing** - The whole organization focuses on continuous improvement. The organization possesses the means to detect weaknesses and to strengthen areas of concern proactively.

A questionnaire was used to assign one of the five levels to each assessment element. The questionnaire was divided into each of the 4 main areas with each section containing a series of background questions, questions related to each associated data capability elements and a glossary of associated terms. The questions provided were a mix of check box, fill in the blank and open-ended questions depending upon the type of information that was being sought by the review team. Worth noting is that the questionnaire was completed at the state level by a series of safety stakeholders and evaluated by the lead member of the assessment team assigned to that state. The state was subsequently provided an opportunity to review the assessment score and provide feedback for each element / area. Ultimately the data captured was used by the state safety stakeholders to 1) establish target goals for each data capability element, and 2) develop an action plan to aid in achieving the stated goals.

Results for each state were summarized in Figure A-2 below.

State / Jurisdiction	Area 1: Data Collection				Area 2: Data Analysis								Area 3: Data Management			Area 4: Data Interoperability		
	IA	IB	IC	ID	2A: Network Screening			2B	2C	2D	2E	3A	3B	3C	4A	4B	4C	
	Completeness	Timeliness	Accuracy	Uniformity	Data	Method	Coverage	Diagnosis	Counter-measure Selection	Evaluation	Accessibility	People	Policies	Technology	Interoperability	Expandability	Linkage	
1	2	4	5	4	4	4	3	4	3	4	5	4	2	3	3	4	4	
2	2	4	5	5	3	4	3	3	2	4	5	3	2	2	3	5	5	
3	2	3	4	4	3	2	3	4	2	3	5	4	2	2	3	4	3	
4	2	4	3	5	3	3	3	4	2	4	4	3	2	2	3	4	4	
5	4	4	5	4	5	5	5	5	5	5	5	4	3	4	4	4	4	
6	3	3	4	5	2	3	4	4	2	2	2	2	2	3	2	3	3	
7	4	3	4	4	5	5	4	4	3	4	5	3	3	4	3	4	4	
8	4	2	4	5	3	2	3	4	3	4	5	3	2	4	3	4	4	
9	4	3	4	3	4	5	3	4	2	4	4	4	3	3	3	3	4	
10	2	3	3	3	3	3	2	4	2	4	5	3	2	3	3	4	4	
11	3	4	4	2	3	3	3	4	2	4	4	4	3	4	3	4	5	
12	3	4	4	5	4	5	3	4	3	4	4	4	3	4	4	4	4	
13	2	3	3	4	4	5	3	4	3	4	5	5	3	4	4	4	4	
14	2	3	4	5	4	4	4	4	4	4	4	3	3	3	4	4	5	
15	2	5	3	4	3	2	5	4	3	1	5	1	1	2	3	4	3	
16	3	4	4	5	3	5	5	5	4	4	5	2	1	3	3	4	4	
17	4	5	4	5	5	3	5	4	4	4	5	5	3	5	4	5	4	
18	4	4	4	4	3	2	2	3	2	1	4	3	4	2	2	2	2	
19	3	4	4	4	4	4	3	3	3	4	5	3	2	3	4	2	4	
20	2	3	5	5	5	3	5	4	4	4	5	3	2	3	4	4	5	
21	2	4	5	3	3	3	4	3	2	4	5	4	3	3	3	4	4	
22	2	1	4	2	2	2	3	4	2	2	1	2	2	1	2	3	2	
23	3	3	3	1	3	3	1	3	3	3	3	2	3	3	3	3	4	
24	2	4	4	5	4	2	3	5	3	3	4	2	2	3	3	4	3	

Figure A-2. FHWA Roadway Safety Data Capabilities Assessment State Results

Weights reflecting the importance of each assessment element were established, providing the mechanism for rolling up results across elements to provide an average score for each state. The weights established are shown in the table below.

National averages for each assessment element were computed (as shown in Figure A-3 below), allowing for identification of universal areas of concern, and areas where additional assistance from FHWA may be needed.

Developing National Performance Management Data Strategies to Address Data Gaps, Standards and Quality

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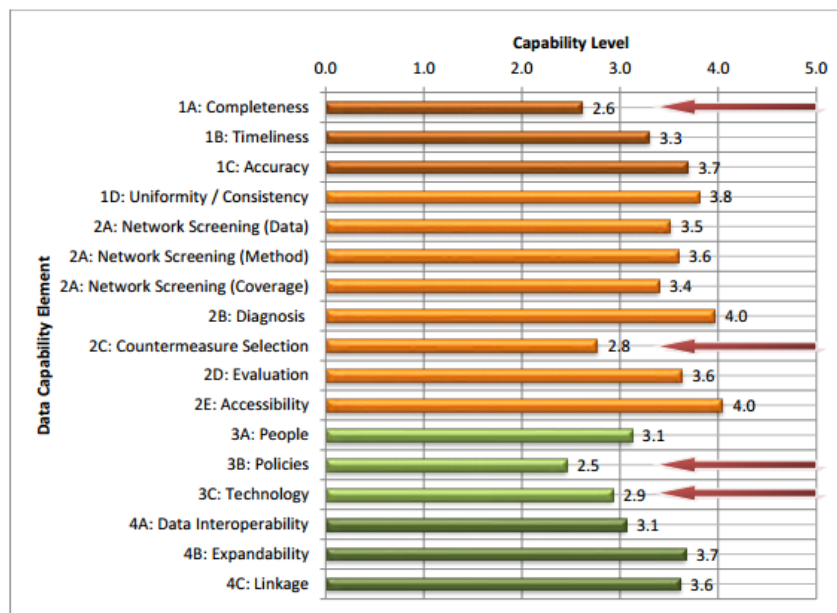


Figure A-3. FHWA Roadway Safety Data Capabilities Assessment Summary Results

To assist states with linking the assessment results to an action plan for data improvement, the following template was included:

ACTION ITEM TABLE					
Item #	Action Item	Responsible Department	Dependency (prior action)	Completion Date	Status
STRATEGY LEVEL ONE: Roadway Data Collection/Technical Standards					
Element 1A: Data Collection (Completeness)					
Current: The State maintains low-level detail (i.e., limited elements) for roadway segments for some or all State-owned roads. No other data categories are maintained (e.g., intersections, curves, etc.) The inventory files have a moderate to large amount of missing or blank fields.					
State-identified goal:					
1.1A.1	Ensure that the inventory includes all state-maintained roads		None	mm/dd/yyyy	Xxx
1.1A.2	Ensure that the inventory includes all state and local-maintained roads.			mm/dd/yyyy	xxx
1.1A.3	---etc---				
Element 1B: Data Collection (Timeliness)					
Current: The State has no standardized procedure for updating the inventory files. Changes to the files are only made when they come to the attention of the file maintainer.					
State-identified goal:					
1.1B.1	Develop a standard method for updating roadway inventory files.		1.1A.1	mm/dd/yyyy	xxx
1.1B.2	Develop a voluntary notification method so that the field can alert the inventory file maintainer of changes.			Projected: mm/dd/yyyy	xxx

Figure A-4. FHWA Roadway Safety Data Capabilities Assessment Template

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Updated Assessment – Safety Performance Management (under development)

The RDSP assessment tools are currently undergoing revision; the new version will include a section that is specifically related to safety performance management. The safety performance management section defines assessment elements based on a framework of performance management activities and specific areas of concern.

Performance management activities are:

1. **Establish measures** - includes adopting a set of safety performance measures consistent with the national measures (but may include others); ensuring that adequate data exists to track the measures.
2. **Establish targets** – includes implementing an evidence-based, data-driven process for setting targets. This requires assembling trend data and other data on influencing factors, developing analysis capabilities to understand past trends and project future performance, coordinating with partner agencies (state DOT, MPO, SHSO), and defining a business process and schedule for producing and approving targets.
3. **Develop plans and programs to meet performance targets** – includes identification, prioritization and selection of countermeasures based on likely performance impacts, and evaluation of program-level performance impacts to assess consistency with targets.
4. **Monitor and adjust** – includes establishment of monitoring systems that track system-level performance results, as well as project-level results; use of performance results to adjust programs; and use of project-level results to improve future predictive capabilities.
5. **Report and communicate** - involves establishment of coordinated data management and reporting processes across state DOTs, MPOs and SHSOs to disseminate performance information, meet internal and external reporting requirements and ensure consistency and minimize duplication of effort.

Areas of concern to be included in the assessment are:

- **Data Adequacy for Transportation Safety Performance Management** – do State DOTs and MPOs have the right data for Safety PM – and is it of sufficient quality (considering accuracy, completeness, consistency, etc.)?
- **Analysis Capabilities for Transportation Safety Performance Management** – do State DOTs and MPOs have the analytical tools and skills to conduct analysis that supports safety performance management?
- **Organizational Processes**– do State DOTs and MPOs have established decision making processes, workflows, communication and collaboration mechanisms for making use of performance data to coordinate on targets, allocate resources and develop plans and programs?

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Specific characteristics of data adequacy are listed in Table A-3 below.

Table A-3. Safety Performance Management Assessment Elements – Data Adequacy

Data Type	Characteristic of Interest	Safety Performance Management Need
Serious Injuries	Uniformity/Consistency with the definition in MMUCC 4 th Edition	1-Establish Measures
Serious Injuries	Uniformity/Consistency – across jurisdictions providing data to the state database	1-Establish Measures
Serious injuries	Uniformity/Consistency – across historical data sets	1-Establish Measures
Serious injuries and Fatalities	Completeness – availability of historical data	1-Establish Measures
Serious injuries and Fatalities	Completeness –coverage of both state-maintained and other public roads	1-Establish Measures
Serious injuries and Fatalities	Accuracy – quality checked and verified	1-Establish Measures
Serious Injuries - nonmotorized	Uniformity/Consistency of nonmotorized person type within crash data – based on ANSI D16.1 (2007)	1-Establish Measures
Vehicle Miles of Travel - Statewide	Accuracy – estimated based on sufficient samples using sound methodology	1-Establish Measures
Vehicle Miles of Travel for MPO areas (MPAs)	Accuracy – estimated based on sufficient samples using sound methodology	1-Establish Measures (for MPOs that choose to set separate targets)
Road Inventory – MIRE (including AADT)	Completeness – availability for analysis	3-Develop Plans and Programs
Serious injuries and Fatalities	Timeliness – elapsed time from crash to availability of data for analysis and reporting	2-Establish Targets 4-Monitoring and Reporting
Serious injuries and Fatalities	Linkage – ability to filter by UZA and MPA boundaries (current and historical)	2-Establish Targets (UZA –if State elects to set separate urban/rural targets; MPA – for MPOs that choose to set separate targets)

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Data Type	Characteristic of Interest	Safety Performance Management Need
Serious injuries and Fatalities	Linkage – ability to link with roadway data	3-Develop Plans and Programs
UZA Boundaries	Completeness – availability of boundaries for past years (where changes have occurred)	2-Establish Targets (UZA –if State elects to set separate urban/rural targets)
MPA Boundaries	Completeness – availability of boundaries for past years (where changes have occurred)	1-Establish Measures 2-Establish Targets (for MPOs that choose to set separate targets)

Creating an Effective Program to Advance Transportation System Management and Operations: Primer

Link: <https://ops.fhwa.dot.gov/publications/fhwahop12003/fhwahop12003.pdf>

This document presents a maturity model for the practice of transportation system management and operations. It defines four levels of maturity across six dimensions:

- Business Processes
- Systems and Technology
- Performance Measurement
- Culture
- Organization/Workforce
- Collaboration

For each dimension, the model identifies steps that agencies can take to move from one level to the next. The Performance Measurement dimension covers measures definition, data acquisition, analysis, and utilization. Capability levels for this dimension are:

- Level 1: No regular performance measurement related to TSM&O
- Level 2: TSM&O strategies measurement largely via outputs, with limited after-action analyses
- Level 3: Outcome measures identified and consistently used for TSM&O strategies improvement
- Level 4: Mission-related outputs/outcomes data routinely utilized for management, reported internally and externally, and archived

The Systems and Technology dimension covers systems architecture, standards, interoperability, and standardization and documentation. Capability levels for this dimension are:

- Level 1: Ad hoc approaches outside systematic systems engineering
- Level 2: Systems Engineering employed and consistently used for ConOps, architecture and systems development

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- Level 3: Systems and technology standardized, documented and trained statewide, and new technology incorporated
- Level 4: Systems and technology routinely upgraded and utilized to improve efficiency performance

Appendix B. Stakeholder Interview Guide

NCHRP Project 08-108: Developing National Performance Management Data Strategies to Address Data Gaps, Standards, and Quality

Project Overview

The goal of this project is to develop guidance for DOTs, MPOs and local transportation agencies for improving how data is used for Transportation Performance Management. The project will:

- Examine leading practices regarding data utilization to support TPM including specifying, defining, obtaining, storing, managing, analyzing, using, sharing, presenting, and communicating data.
- Identify contributing factors, both positive and negative, to the effective use of data to support transportation performance management. These factors may be current, emerging and projected.
- Present conclusions, cross-cutting themes, lessons, and strategies for overcoming shortcomings based on examples that will assist practitioners and decision makers to better utilize data to support transportation performance management,
- Prepare an approach (building on prior research) to assist transportation agencies in implementing a self-assessment on data utilization by identifying the critical building blocks for transportation practitioners to improve their efforts to specify, define, obtain, store, manage, analyze, use, share, present, and communicate data to support transportation performance management. This assessment will complement the existing assessment tools that are already available (e.g. the FHWA TPM TAP tool; the NCHRP Project 08-92 Data Self-Assessment Tool, etc.) – and will likely use a checklist format.

Project Scope

The scope of this project is broad, covering all phases of the TPM process:

- Establishing performance objectives and measures (focusing on the MAP-21/FAST Act measures, with some coverage of other common transportation system performance measures);
- Developing performance targets;
- Identifying strategies and actions to improve performance and achieve targets – and incorporating these into plans and programs;
- Reporting and communicating transportation system performance for both internal and external audiences; and
- Monitoring progress and making course corrections as needed

It will also cover multiple performance areas and data types, but will emphasize those included in the MAP-21/FAST Act:

- Highway safety;
- Pavement and bridge infrastructure condition; and
- System performance for passenger and freight movement.

Interview Purpose

The purpose of the stakeholder interviews is to obtain input from target users of guidance on what types of guidance is most needed, and to receive feedback on a draft section for the guidance.

Target users of the guidance to be produced are staff who have responsibilities for coordinating, planning and managing data development activities for:

- Performance management and reporting;
- Pavement and bridge management;
- Safety planning and management;
- Passenger and freight mobility planning and management; and
- Traffic operations planning and management

Interview Participation Guidelines

We would like each interview to include at least one individual who is broadly knowledgeable about data challenges related to performance measurement and management, and 1-2 additional individuals who specialize in data collection, analysis, visualization, and/or communication within a specific performance area (safety, pavement, bridge, congestion/system reliability, or freight.) We will discuss selection of these specialists with the agency contact prior to scheduling the interview in order to obtain a broad set of perspectives across all of the agencies included in the interviews.

The ideal group size for the interview would be 2-3 individuals. We are requesting a 90 minute interview slot. If this poses scheduling difficulties, we can set up a 60 minute slot and schedule a follow up if needed.

Information on the draft framework for the guidance and an example section has been provided separately. *We request that each interview participant take 15-20 minutes to review these materials prior to the interview.*

Questionnaire

Overview

There are five questions:

- Question 1 asks about your background – so that we can focus the discussion around your areas of responsibility and expertise.
- Question 2 asks about the challenges you are facing so that we can prioritize what material to include in the guidance
- Question 3 asks about your success stories – to identify possible examples to include in the guidance and identify success factors to emphasize
- Question 4 asks about where you see the gaps are with respect to existing guidance for TPM and data
- Question 5 asks for your feedback on the sample vignette that we sent out

For purposes of this interview, we define “TPM” or “Transportation Performance Management” to include:

- Measuring transportation system performance – for pavements, bridges, safety, congestion/mobility, freight, etc.
- Developing performance targets;
- Identifying strategies and actions to improve performance and achieve targets – and incorporating these into plans and programs;
- Reporting and communicating transportation system performance for both internal and external audiences; and
- Monitoring progress and making course corrections as needed.

Thus, we are interested in the entire cycle of activities –deciding on measures, specifying what data are needed, collecting and processing data, using data to make decisions, and communicating results.

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1. About You (for each interview participant)

a. Job title and name of Division/bureau/section/office/unit

Respondent 1:

Respondent 2:

Respondent 3:

b. Current areas of responsibility related to transportation performance management

Respondent 1:

Respondent 2:

Respondent 3:

c. In which TPM areas do you have a good working knowledge of performance measures and associated data issues? (from your current or prior positions):

☐ Pavement

☐ Bridge

☐ Safety

☐ Mobility/System Performance

☐ Freight

☐ Transit

☐ Air Quality

☐ Other:

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2. Data Challenges

- a. First, rate each of the following types of data challenges with respect to their impact on your agency's ability to obtain, manage and make effective use of transportation system performance data (for safety, infrastructure condition, mobility/congestion, etc.)? Rate each on a scale of 1 to 3.

Then, provide examples for those you rated as 3-Major Impact.

3-Major Impact means that it has created major roadblocks to your ability to move forward and required management intervention. **2-Some impact** means that it has slowed you down some but hasn't required management intervention. **1-No impact** means that it has not affected you.

Data Challenge	1-No Impact	2-Some Impact	3-Major Impact
Not having the right data to provide meaningful insight into performance	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<i>Example:</i>			
Poor or uneven data quality that limits our trust in the data that we have	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<i>Example:</i>			
Insufficient documentation about data sources, derivations or meaning (metadata)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<i>Example:</i>			
Difficulty getting agreement on what data to collect at what level of detail; or how (e.g. private sources, new collection technologies, etc.)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<i>Example:</i>			
Concerns about sharing data (within the agency and/or externally) – due to fear that it may be misinterpreted or that limitations would be exposed	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<i>Example:</i>			
Difficulty developing a coordinated data strategy within the agency and/or with partners (e.g. state DOT/MPO/localities)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

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Data Challenge	1-No Impact	2-Some Impact	3-Major Impact
<i>Example:</i>			
Lack of institutional capacity to ensure data is transformed into information that decision-makers can routinely use to support their actions	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<i>Example:</i>			
Lack of ability to integrate or aggregate data from different sources due to incompatible location referencing, linkage elements or inconsistent definitions	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<i>Example:</i>			
Lack of analysis tools or staff capabilities to predict future performance under varying assumptions (e.g. scenario analysis)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<i>Example:</i>			
Limited access to needed skill sets – e.g. database design, data integration, report development, data visualization, interpretation and communication (the “so what” behind the data)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<i>Example:</i>			
Information technology issues – e.g. lack of sufficient hardware/software for data storage and management; restrictive policies related to cloud storage or using software as a service.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<i>Example:</i>			

- b. What other challenges (not included above) has your agency faced that has impacted your TPM capabilities? What would you like to be able to do but haven't yet been able to do because of these challenges?

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- c. Is your agency facing any challenges related to meeting multiple (federal and state) performance reporting deadlines? How are you tackling these challenges – e.g. adjusting data collection/processing schedules; outsourcing some of the work, etc.?

3. Data Utilization Success Stories

- a. Can you provide an example where your agency has been particularly successful in making effective use of data for TPM – for example, implementing useful performance reports/websites, implementing performance-driven project selection methods, setting data-driven performance targets that drive resource allocation?
- b. What was the most critical things that were done to make this effort a success? What advice would you give to other agencies who might want to do something similar?

4. Input on What Guidance is Most Needed

- a. What sources of guidance have you found to be most helpful to get ideas for collecting, managing, analyzing and using data for TPM? If possible, provide names of websites, reports, online forums, conferences, peer exchanges, or other sources.
- b. What type of guidance would you like to see that is currently not available? For example:
 - ☐ Guidance related to particular aspects of TPM – e.g. performance reporting, target setting, performance monitoring, performance diagnostics, performance prediction, project/strategy prioritization and selection, etc.? (Specify:)
 - ☐ Guidance related to particular performance areas or data sources? (Specify:)
 - ☐ Guidance geared to particular job functions or roles in your organization? (Specify:)
 - ☐ Guidance geared to addressing particular issues or challenges? (Which ones:)
- c. Is there anything else that you'd like to suggest about what guidance is needed – related to not only the content of the guidance but style or format?
- d. Who in your agency would most benefit from this type of guidance? (Provide examples of specific people and their roles)

5. Feedback on draft framework “vignette”

- a. Prior to this interview, you were provided with a brief “vignette” that was developed to illustrate how the guidance might be structured. What was your general reaction to this vignette – is it a useful way to communicate techniques and success factors for making effective use of data for TPM?
- b. What aspects are most useful? What should be added? What isn’t needed?
- c. Which of the following ideas for vignettes would be of most interest to you?
 - ☐ **Target Setting.** Developing performance targets for bridge or pavement condition, and system performance.
 - ☐ **Performance Reporting.** Producing pavement performance measures for incorporation in HPMS – integrating state and local data for the National Highway System (NHS)
 - ☐ **Performance Dashboard.** Producing a performance dashboard to strengthen agency accountability
 - ☐ **Performance Diagnostics.** Analyzing trend data for non-motorized fatalities and serious injuries to establish a baseline and identify key explanatory factors
 - ☐ **Scenario Analysis.** Conducting scenario analysis for a corridor to assess options for improving travel time reliability
 - ☐ **Performance Improvement – Network Screening.** Developing a network screening process to identify locations for development of candidate projects
 - ☐ **Performance Improvement Selection – Project Ranking.** Creating a project ranking process aligned with established performance measures and targets
 - ☐ **Performance Improvement Selection - Operations.** Using real time traffic information for incident response and targeting of operational improvements
 - ☐ **Performance Monitoring.** Producing a quarterly performance tracking report that helps agency managers understand progress and identify what levers they can pull to get performance back on track with respect to targets
 - ☐ **Other:**

- d. Would you be willing to provide feedback on guidance materials developed in the next phase of this project?

THANK YOU!!