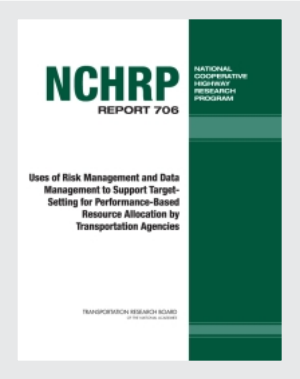

Uses of Risk Management and Data Management to Support Target-Setting for Performance-Based Resource Allocation by Transportation Agencies

DETAILS

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NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

NCHRP REPORT 706

Uses of Risk Management and Data Management to Support Target-Setting for Performance-Based Resource Allocation by Transportation Agencies

CAMBRIDGE SYSTEMATICS, INC.
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TRANSPORTATION RESEARCH BOARD

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NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

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FOREWORD

By Andrew C. Lemer
Staff Officer
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NCHRP Report 706 describes how risk management and data management may be used by transportation agencies to support management target-setting for performance-based resource allocation. As the final product of a second phase of NCHRP Project 08-70, "Target-Setting Methods and Data Management to Support Performance-Based Resource Allocation by Transportation Agencies," this report supplements *NCHRP Report 666* published in 2010. Transportation agencies at all levels of government are embracing performance measurement to improve agency efficiency and accountability. Setting performance targets generally entails balancing competing objectives and dealing with political implications in a context of uncertainties about economic conditions, fiscal constraints, climate conditions, customer demands, and more. Good data on the transportation system and its performance provides the information managers need to set targets, but good management depends on clear understanding of the risks that future conditions will differ significantly from what today's best information suggests. Performance targets and consequent resource-allocation decisions established with such understanding are more likely to ensure that the agency and the transportation system perform well. This report presents advice and illustrative case studies, in the form of primers, on using risk management and data management practices in support of performance-based resource allocation, and specifically performance-target setting. The information will be useful to senior agency managers seeking to develop and improve their performance-management practices.

DOTs and other transportation agencies are increasingly using performance measurement to guide their resource allocation decisions for operations, asset management, capital investment, planning, and policy development. Much work has been done on defining and applying performance measures, but relatively little attention has been given to the specific problem of setting performance targets. Setting targets within the context of a DOT generally entails balancing competing objectives and considering the perspectives of multiple stakeholder groups. Unless performance targets are set with sound and defensible bases, and with the concurrence of key decision makers and stakeholders, the effectiveness of performance measurement as a management tool to improve agency efficiency and accountability is almost certain to be compromised.

This report is the product of an extension of NCHRP Project 08-70, initially undertaken to develop a more comprehensive set of methods for establishing performance targets to guide resource allocation decisions in all aspects of DOT management, from planning and policy development to project implementation and operations. The research was designed to draw on a range of private- and public-sector examples to extract lessons that would be instructive and adaptable to transportation agencies. Because effective performance

measurement relies on good data, the research was designed also to describe data management systems and institutional relationships that can support DOT use of performance-based resource allocation.

The specific objectives of the research were to (1) describe a comprehensive framework and set of methods (a) to analyze opportunities to improve the multiple-objective performance of transportation systems within the context of broader societal goals and (b) to set specific performance targets to guide agency policies, plans, and programs; (2) detail the factors that influence target setting and the success of performance-based resource allocation systems and explain how agencies may successfully design, implement, and use such systems; and (3) analyze the data and information needs, data acquisition and management systems, and institutional relationships required to support successful performance-based resource allocation systems. Case studies of organizations that use performance-based resource allocation and other examples illustrate methods for presenting performance information to decision makers and other stakeholders and decision-support systems that can provide this information.

A team led by Cambridge Systematics conducted the research. The work started with a review of current private- and public-sector practices in using performance-based resource-allocation to investigate the key elements of the performance-measurement and resource-allocation processes and the tools, data-management systems, and institutional relationships needed to support these elements. The research team next sought to describe factors likely to influence the setting of performance targets in transportation agencies, such as agency scope and organization; agencies' use of forecasting; availability, precision, and reliability of data within the agency; agencies' experience using benefit-cost analysis and other evaluation methodology; and stakeholders' perceptions and expectations. Data management systems and institutional relationships to support performance-based resource allocation were given particular attention in the research. *NCHRP Report 666: Target-Setting Methods and Data Management to Support Performance-Based Resource Allocation by Transportation Agencies,* published in 2010, presented guidance and case-study reports on how agencies can use performance target setting as a factor affecting resource allocation and on data management practices to support such efforts. A web-only document supplementing *NCHRP Report 666* is available at http://144.171.11.40/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=2147.

Recognizing that performance target setting must be done within a context of uncertainties about economic conditions, fiscal constraints, climate conditions, customer demands, and more, the NCHRP project panel asked the research team to undertake further case studies and analysis of the particular ways that agencies can use risk management in performance-based resource allocation and target setting, and supportive data sharing, tools, and integration practices. This report presents primers on using risk management and data management practices supplementing *NCHRP Report 666*. The first primer describes a process for transportation agencies to systematically assess and address risks and provides examples from case studies, organized by the steps of the process, to illustrate how state DOTs are using risk management to support funding decisions. The second primer addresses information technology issues and challenges regarding data sharing, and integration.

CONTENTS

Note: Many of the photographs, figures, and tables in this report have been converted from color to grayscale for printing. The electronic version of the report (posted on the Web at www.trb.org) retains the color versions.

PART 1

Applications of Risk Management to Support Performance-Based Resource Allocation

CHAPTER 1

Introduction

NCHRP 8-70 research, which led to *NCHRP Report 666: Target-Setting Methods and Data Management to Support Performance-Based Resource Allocation by Transportation Agencies,* described a comprehensive framework and methods to set specific performance targets to guide agency policies, plans, and programs. It also detailed factors that influence target-setting and the success of performance-based resource allocation (PBRA) systems, explaining how agencies may successfully design, implement, and use such systems. Finally, it addressed the data and information needs, data acquisition and management systems, and institutional relationships required to support successful PBRA systems.

Research in NCHRP 8-70 highlighted the significant uncertainties agencies face from frequent changes of important variables outside their control, such as cost inflation, changing political leadership and their priorities, and revenues available for agency programs. These uncertainties pose risks that asset-allocation decisions will be rendered inappropriate when external variables change. Some organizations in both the private and public sectors utilize risk analysis to assess whether certain resource-allocation choices and consequent system and agency performance are more susceptible to these uncertainties. Such risk analysis has been found to be helpful, but is not currently in common use among transportation agencies.

Based on this work, the NCHRP 8-70 Project Panel identified the need for further research on how risk analysis may best be used by transportation agencies to support PBRA. This primer addresses that need and serves as an introduction to the topic.

The guidance provided in this report is consistent with, but different than, the risk management approaches being explored as part of NCHRP 20-24(74). That research effort is addressing risks related to internal operations and program and project delivery. In contrast, this document focuses on the application of risk management techniques to support funding decisions, such as by helping to prioritize which projects should be delivered.

This section provides an introduction to PBRA, which is described in greater detail in Volume I of *NCHRP Report 666.* Following that is a brief summary of the five case studies discussed in more detail throughout the primer.

The remainder of this document describes a process for transportation agencies to systematically assess and address risks. It also provides several examples, organized by the steps of the process, that illustrate how state departments of transportation (DOTs) are using risk management to support funding decisions.

1.1 Introduction to Performance-Based Resource Allocation

Despite uneven implementation among state departments of transportation (DOTs), performance management has been evolving steadily into an effective business process that links organizational goals and objectives to resources and results. Performance measures, and their attendant targets, are the lynchpin in this process. They are the link connecting goals to specific investments. The methods by which the measures and targets are established, including underlying data support systems, play a critical role in the overall success of a public agency or private company.

Performance-based resource allocation takes place within an overall Performance Management Framework, depicted in Figure 1.1.1, which is comprised of the following six basic elements:

Establish Goals and Objectives. Performance-based resource allocation decisions are anchored in a set of policy goals and objectives that identify an organization's desired direction and reflect the environment within which its business is conducted. For example, many state DOTs have well-defined goals for the transportation system, including infrastructure condition, level of service and safety, as well as goals reflecting

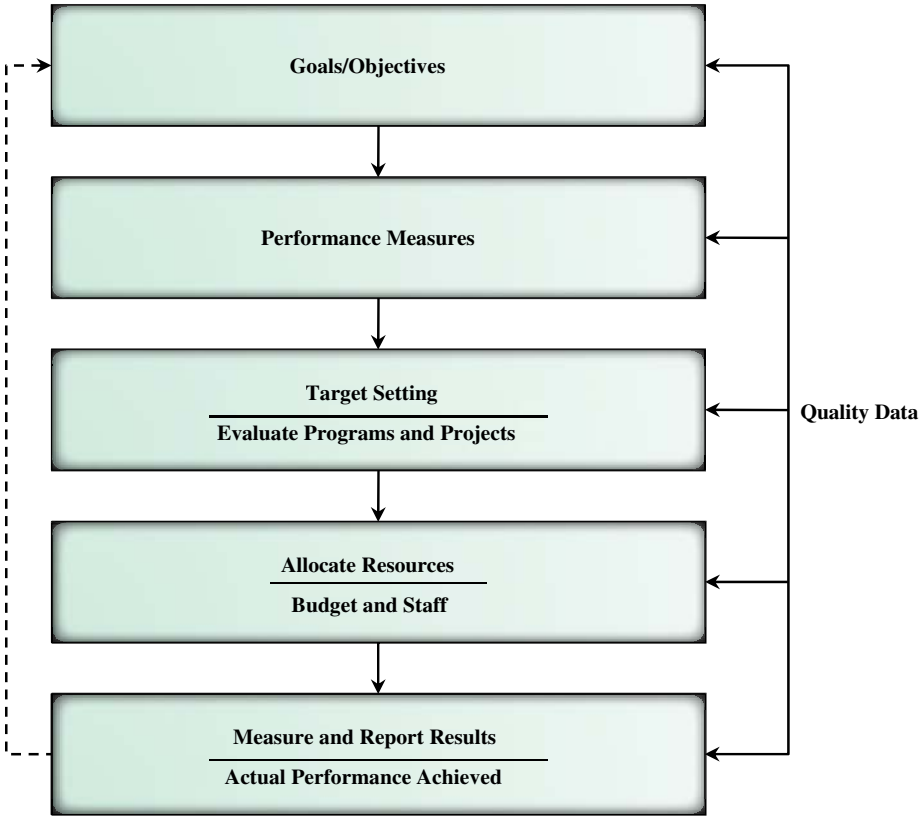


Figure 1.1.1. Performance management framework.

economic, environmental, and community values. Likewise, the private sector frequently establishes policy goals to guide production of products and services while defining the environmental and community context for its investment decisions.

Select Performance Measures. Performance measures are a set of metrics used by organizations to monitor progress toward achieving a goal or objective. The criteria for selecting measures often include

- Feasibility,
- Policy sensitivity,
- Ease of understanding, and
- Usefulness in actual decision making.

Identify Targets. Targets are a quantifiable point in time at which an organization achieves all or a portion of its goals. These points set a performance level for each organizational measure, such as achieving a 25 percent reduction in highway fatalities by 2030. The methods used to set such a target include

- Establish Performance Management Framework,
- Evaluate the factors influencing target-setting,
- Select the appropriate method(s) for target-setting,
- Establish methods for achieving targets,
- Track progress toward targets, and
- Adjust targets over time.

Allocate Resources. The allocation of resources (time and money) is guided by the integration of the preceding steps into an organization's planning, programming, and project development process. To the extent possible, each investment category is linked to a goal/objective, a set of performance measures, and a target. Specific investment proposals are defined in relation to specific targets.

Measure and Record Results. The data for each performance measure must be regularly collected and periodically analyzed. The analysis should indicate how close the organization is to achieving its targets and identify the actions necessary to improve results. Many public- and private-sector organizations have tracking systems in place to monitor performance allowing senior staff to make periodic budget adjustments.

Create Data Management Systems to Ensure Quality Data. "Good" data is the foundation of performance management. Effective decision making in each element of the performance management framework requires that data be collected, cleaned, accessed, analyzed, and displayed. The

organizational functions that produce these requirements are called data management systems. There are two key dimensions to creating and sustaining these systems. The two areas are equally important and must be synchronized within an organization to ensure the generation and use of accurate, timely, and appropriate data. The first area centers on the technical challenges associated with data systems, including development and maintenance of hardware and software, and the specifications for data collection, analysis, archiving, and reporting. The second area focuses on the institutional issues associated with data stewardship and data governance.

1.2 Selected Case Studies

Georgia DOT Pavement and Bridge Preservation Risk Assessment

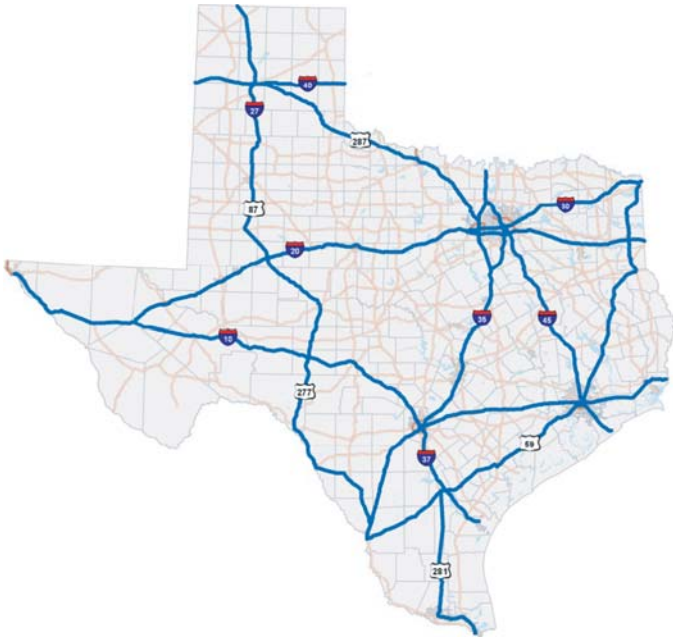
The Georgia Department of Transportation (GDOT) is developing an approach for incorporating risk considerations into the prioritization of pavement and bridge preservation projects. The intent of this effort is to move away from a "worst-first" resource allocation approach to a "most-at-risk" approach. The new approach considers both the current condition of an asset and the risk associated with its failure. GDOT is implementing this new process with the overall goal of better informing transportation investment decisions. The GDOT Office of Organizational Performance Management (OPM) initiated the risk management work as part of its responsibility for administrating the agency's transportation asset management program.

Minnesota DOT Bridge Programming Risk Assessment

The Minnesota Department of Transportation (Mn/DOT) Bridge Office has undertaken a process that applies risk management philosophy to programming of bridge rehabilitation and replacement projects. The primary goal of this process is to develop a communication tool that would help managers more easily explain the factors that Mn/DOT considers in programming bridge rehabilitation and replacement projects, considering the risk of an interruption to service. This process was developed at the request of the Mn/DOT Commissioner early in 2008, and is part of a larger effort to integrate risk assessment and management into the agency.

Texas DOT Statewide Freight Resiliency Plan

The Texas Department of Transportation (TxDOT) has developed a Statewide Freight Resiliency (SFR) Plan that identifies key freight infrastructure corridors and strategies to ensure a resilient freight transportation network in Texas.



Source: TranSystems.

Figure 1.1.2. Primary highway routes in Texas.

TxDOT adopted the following definition of freight transportation resiliency: "the ability for the system to absorb the consequences of disruptions, to reduce the impacts of disruptions, and to maintain freight mobility."[1]

The SFR Plan is primarily focused on the key highway routes for freight traveling through Texas (Figure 1.1.2) and the potential mode shift to highways or the shift from one highway to another following a moderate-to-major disruption on/at the state's highways, rail system, ports, or airports. By identifying prioritized infrastructure enhancements on the portion of the network that is vital for freight movements, TxDOT intends that the SFR Plan will help build a stronger case for increased transportation funding.

Washington State DOT Bridge Retrofit Risk Assessment

Washington's Department of Emergency Management, National Guard, Department of Transportation (WSDOT), and others in the state helped determine a network of lifeline routes across the state, critical in the event of major natural or manmade disasters. These include routes to military bases, airports, and all interstate routes. As part of a separate effort, researchers have found that particular silts in Washington

[1]Ta, C., A. V. Goodchild, and K. Pitera. "Structuring a Definition of Resilience for the Freight Transportation System." In *Transportation Research Record: Journal of the Transportation Research Board,* No. 2097, Transportation Research Board of the National Academies, Washington, D.C., 2009, pp. 19–25.

could liquefy in the event of a major earthquake, and many of the state's bridges are not designed to withstand this. In response, several divisions at WSDOT, including planners, bridge engineers, and materials engineers, have begun working together to identify ways to evaluate bridge projects by weighing the risks of failure and impacts against other potential projects.

California DOT Seismic Safety Retrofit Program

There are more than 12,000 bridges in the California State Highway System, plus an additional 11,500 city and county bridges. The California Department of Transportation (Caltrans) established a prioritization process in 1988 to bring California's bridges up to seismic safety standards, which was refined following the 1989 Loma Prieta earthquake. However, since it was not possible or necessary to retrofit all structures to eliminate all damage, Caltrans used the following process so that the most critical structures were retrofitted first:

1. Identify all structures potentially needing retrofitting to ensure that they were safe from collapse during earthquakes;
2. Identify complex or vital transportation lifeline structures;
3. Prioritize all structures requiring retrofitting, based on an algorithm that considers a weighted combination of hazards, impacts, and vulnerability of bridges; and
4. Group structures into logical projects, focusing on highest priority structures and considering geographic proximity.

CHAPTER 2

Risk Management Process

Building on research conducted for NCHRP 20-74, Developing an Asset Management Framework for the Interstate Highway System; NCHRP 20-24(74), Executive Strategies for Risk Management by State Departments of Transportation; NCHRP 20-59(17), Guide to Risk Management of Multimodal Transportation Infrastructure; and other recent work, Figure 1.2.1 illustrates a risk management process for transportation agencies. The process is applicable to a broad range of applications (across modes, assets, and other areas) as a means to inform resource allocation decisions.

The following sections are designed to guide practitioners step by step through the risk management process. They provide a definition of each step, a discussion of its general application, and examples, issues, and lessons learned from a series of case studies.

2.1 Establish Risk Tolerances

Since risk management is largely consequence driven, the first step in the process involves establishing an agency's tolerance level (or consequence threshold) for a given risk. An agency's tolerance level is determined by establishing the level of liability, or consequences, that it can absorb before additional resources would be required. It is also in this step that an agency begins to assess the tradeoffs between its risk program and its other capital, maintenance, and operations programs.

Establishing risk tolerances is generally a policy decision, but should be transparent. As described in *NCHRP Report 525: Surface Transportation Security*, "Volume 15, Costing Asset Protection: An All Hazards Guide for Transportation Agencies (CAPTA)," this step is best suited to the strategic, high-level planning undertaken at the executive level. Using budgetary discretion, risk tolerances should also reflect the agency's priorities and asset characteristics.

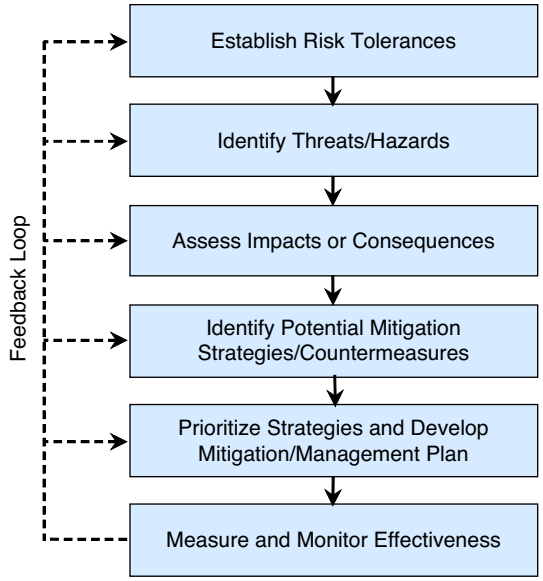
For example, the risk tolerances in the Mn/DOT and GDOT case studies are defined by an asset condition threshold (for pavements and/or bridges) that triggers major rehabilitation or reconstruction. This type of threshold provides a basis for identifying, evaluating, prioritizing, and managing risks in subsequent steps of the risk management framework. To support the bridge programming risk assessment at Mn/DOT, the agency sets performance targets for the percent of the system of bridges in good, satisfactory, fair, and poor condition. These goals are based on the assumptions that bridges have a 75-year life, all bridges have a similar deterioration curve, and Mn/DOT has funding available to replace approximately 2 percent of the system bridges each year. Funding targets are recommended for each Area Transportation Partnership (ATP)[2] based on output of system needs for bridge rehabilitation and replacement in order to meet the established bridge condition targets.

Similarly, GDOT has established the following service-level statements related to the condition of the state's bridges:

- Maintain interstate, U.S. route, state route, and off-system state-owned bridges such that they can carry all legal loads;
- Maintain interstate bridges such that they, at a minimum, have decks that are in good condition;
- Maintain U.S. route bridges such that they, at a minimum, have decks that are in satisfactory condition; and
- Maintain state route and off-system, state-owned bridges such that they, at a minimum, have decks that are in fair condition.

For pavements, GDOT developed an inspection protocol called the Computerized Pavement Condition Evaluation System (COPACES) where pavements are assigned a condition rating (referred to as the PACES rating) based on a combination of distress type and severity. These ratings are used to define when a segment of pavement is a candidate for

[2]There are eight ATPs in Minnesota (one for each Mn/DOT district area). Every year, the ATPs develop an Annual Transportation Improvement Program (ATIP) that covers a minimum 4-year period.



Source: Adapted from *NCHRP Report 632: An Asset Management Framework for the Interstate Highway System.*

Figure 1.2.1. Risk management framework for resource allocation.

rehabilitation or replacement. In general, a roadway is recommended for resurfacing when its PACES rating falls below 70. Interstates, however, have higher condition targets. The condition target for interstates with greater than 50,000 average daily traffic (ADT) is 80, while the target for the remaining interstates is 75. The developers of the PACES rating established these thresholds based on historical data that suggests they are optimal triggers for resurfacing.

The risk tolerance in TxDOT's Statewide Freight Mobility Plan was defined as a moderate-to-major duration event causing a change in freight travel patterns. This definition was developed in consultation with freight carriers, shippers, and other stakeholders in the state. Stakeholders indicated that during short-term or minor disruptions lasting a few hours to a few days, drivers would likely just "wait it out," while a disruption lasting several weeks or more would change how they operate. The Texas SFR Plan also characterizes risk tolerance in the context of a spectrum of events: recurring, episodic, or catastrophic. Freight shippers and carriers are aware of, and prepare for, recurring events, such as routine traffic congestion or icy road conditions. At the other end of the spectrum, catastrophic events result in extraordinary loss of life and property with national-level impacts that exceed capabilities of normal resources. Episodic events, the focus of the Texas SFR Plan, involve unpredictable occurrences that are manageable with available resources. The goal of the Texas SFR Plan is to prepare the freight transportation system that keeps freight moving and minimizes potential economic loss during an episodic event of moderate-to-major magnitude.

Last, risk tolerance was implicit in the goals developed for the Caltrans Bridge Seismic Safety Retrofit Program, as follows:

- **No collapse**—The prevention of direct injury or death to individuals who are on or near a structure; and
- **No major damage**—The prevention of indirect injury due to the closure of a structure critical to a transportation system that supports emergency response to a large-scale civil disaster.

Within the context of these goals, Caltrans developed a risk algorithm to categorize and prioritize the state's bridges.

2.2 Identify Threats/Hazards

The second step in the risk management framework involves identifying and categorizing the risks that could cause or contribute to unplanned or undesired circumstances. For a transportation agency, these risks range from small-scale threats impacting the quality of service provided to the traveling public, to large-scale threats that can result in loss of life. The identification of relevant threats and hazards, and their respective magnitudes, probabilities, and spatial distribution, are typically based on historical data, experience, and judgment.

The risks faced by transportation agencies come from a variety of sources, and it is possible to categorize them in a number of different ways. As an example, Table 1.2.1 categorizes risks into internal and external threats. Internal risks are those within an agency's control, often internalized in the day-to-day business practices of a transportation agency. External risks are those over which an agency has little or no control. External risks can be the result of either the natural environment or human actions. The five case studies described throughout this document focus on external risks. For more information on addressing internal risks, refer to NCHRP 20-24(74).

Mn/DOT's risk management process provides an example of the types of specific risks that can be considered. The agency has identified the following threats and hazards:

- Risk of service loss, such as bridge posting or closing, due to advanced deterioration of portions of structures,
- Risk of structure damage or destruction due to stream erosion or storms,
- Risk of damage or collapse of structures that are vulnerable to sudden fatigue cracking or other localized failure,
- Risk of sudden damage to a bridge caused by passage of a heavy vehicle that exceeds the safe load capacity of the structure,

Table 1.2.1. Transportation agency risk environment from broad (Level 1) to specific (Level 3).

Level 1	Level 2	Level 3
Internal Risks	Organizational management	Agency goals and priorities Available revenues
	Project and service delivery	Design development Schedule adjustments Cost of materials Program budgets
External Risks	Political	Leadership change Laws and regulations
	Environmental	Weather events
	Structural	Advanced deterioration Fatigue cracking
	Social	Terrorist attack Asset usage (e.g., traffic volumes, fleet composition, and driver error)

Source: Adapted from *NCHRP Report 632: An Asset-Management Framework for the Interstate Highway System* and ICF International, Executive Strategies for Risk Management by State Departments of Transportation, May 2011.

- Risk of sudden damage to a structure caused by attempted passage underneath a bridge, of a vehicle whose height exceeds the available vertical clearance, and
- Risk of service interruption caused by a driver's loss of control of a vehicle, and the resultant crash.

These threats and hazards were developed and refined by an expert panel. Since they are condition based, Mn/DOT estimates probability based on known occurrence of maintenance, inspection, repair, or replacement service interruptions. As condition degrades, the probability of a service interruption increases; therefore, the factors are scaled based on condition.

For the Texas SFR Plan, TxDOT developed a hazard identification and assessment methodology to identify state-level hazards to which the freight transportation system is most vulnerable. The purpose of the hazard assessment was to locate areas of vulnerability in each freight corridor to effectively understand how to eliminate or reduce risk associated with a hazard. As shown in Table 1.2.2, the Texas SFR Plan evaluated potential external threats resulting from 10 different

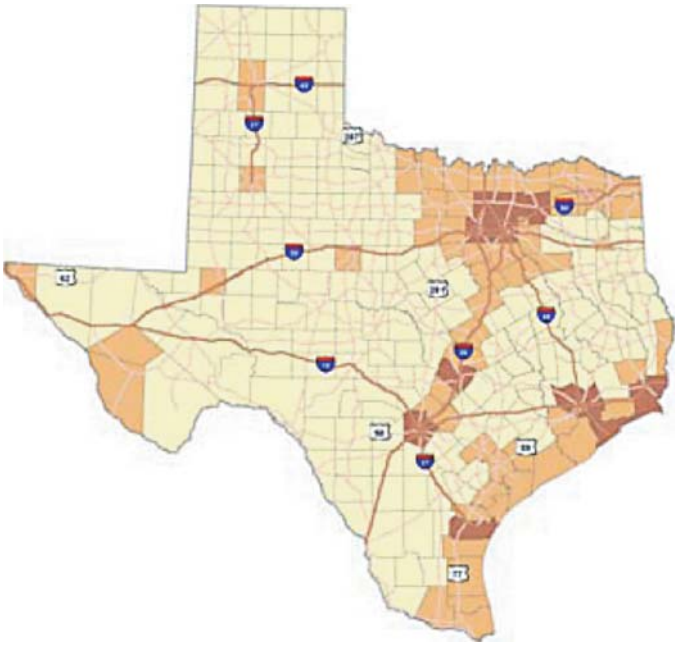
Table 1.2.2. Texas freight system hazard impact summary.

Hazard Type	Frequency of Occurrence	Warning Time	Potential Severity	Hazard Rating for Freight in Texas
Earthquake	Unlikely	None	Substantial	2
Flood	Highly Likely	Minimal	Substantial	3
Hurricane	Likely	Well in advance	Major	3
Landslide	Occasional	Minimal	Minor	2
Manmade	Occasional	Minimal	Major	3
Tornado	Likely	Advance	Major	1
Volcano	Unlikely	Well in advance	Minor	0*
Wildfire	Occasional	Advance	Minor	1
Wind	Likely	Advance	Limited	1
Winter Storm	Occasional	Advance	Limited	1

Notes: Hazard rating is based on a 1–3 scale, with 1 being the lowest and 3 being the highest.

*Since there are no volcanos in Texas, this is zero.

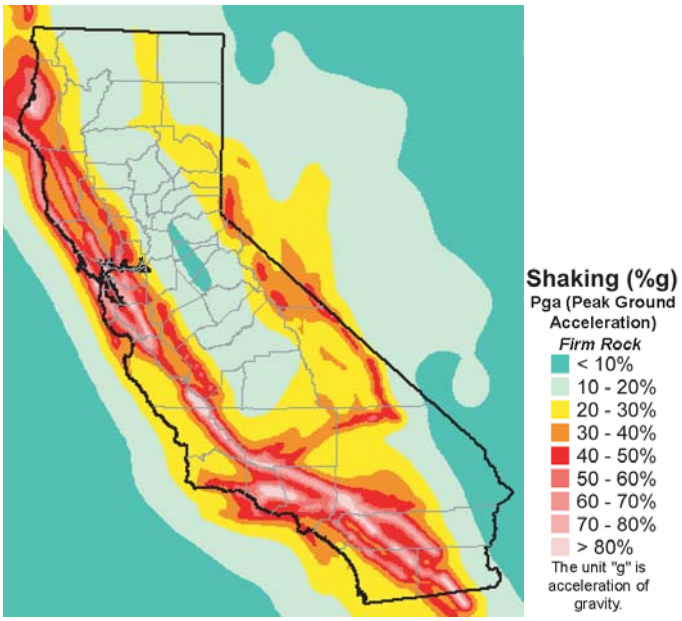
Source: TranSystems.



Note: The overall combined risk represents the overall vulnerability of the freight transportation system to each of the hazards identified in Texas.

Source: TranSystems derived from Texas Hazard Mitigation Package and USGS.

Figure 1.2.2. Overall combined risk of hazard locations in Texas.



Source: California Geological Survey, April 2003.

Figure 1.2.3. Probabilistic seismic hazards assessment in California.

natural and manmade threats. For each of these threats, TxDOT developed hazard ratings by assessing the frequency of occurrence, warning time, and potential severity. To assess the potential threat of each hazard type, TxDOT used data from the Texas Division of Emergency Management[3] and the Texas Hazard Mitigation Package[4] to map the locations of historic occurrences and potential vulnerability by county (Figure 1.2.2). Using this information, the Texas SFR Plan evaluated the hazards from the perspective of potential impact to the freight transportation system to assign a rating for each hazard type (summarized in Table 1.2.2).

The seismic retrofit program in California used a risk algorithm that included a weighted combination of bridge hazards, vulnerabilities, and impacts. Caltrans defined hazards to be the major factors that affect seismic performance: soil conditions, peak rock acceleration, and duration. Vulnerabilities pertained to physical attributes of each bridge, such as year constructed, abutment type, skew, and other design elements.

Caltrans started the bridge prioritization process by looking at the physical details of about 25,000 bridges. Bridges that were already current, simple spans that were not at risk, culverts, and short multiple-span bridges in low seismic risk areas (Figure 1.2.3) were eliminated from the program.

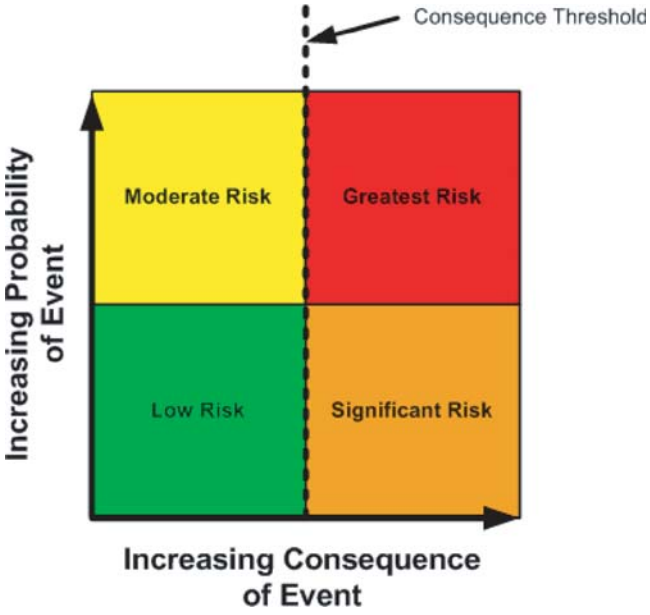
2.3 Assess Impacts or Consequences

Risk assessment is a function of the likelihood of an event (probability of occurrence, as estimated in the previous step) and the associated consequences (whether positive or negative) of the event's occurrence. Consequences are determined by estimating the level, duration, and nature of an incident's impact. In the risk matrix shown in Figure 1.2.4, the vertical axis represents the probability (from low to high) of a particular threat/hazard materializing, and the horizontal axis represents the consequence (from low to high) of the materialized threat/hazard. From a risk management standpoint, it is undesirable to be in a high-hazard, high-exposure situation as represented by the upper right corner in Figure 1.2.4. The consequence threshold, defined in the first step of the framework, allows agencies to identify the most critical risks that require a higher degree of attention.

Some agencies, such as GDOT and Mn/DOT, use asset condition as a surrogate for the probability of an event. For example, GDOT's program for pavements focuses on pavement condition ratings. As a pavement's condition worsens, the likelihood of its failure increases. GDOT has developed a pavement risk matrix for use in evaluating the consequences of failure. This matrix considers functional class, annual average daily traffic (AADT), truck percent, and county population served. Generally speaking, as the function of a road increases

[3]Texas Division of Emergency Management, *State of Texas Hazard Mitigation Plan 2010–2013,* ftp://ftp.txdps.state.tx.us/dem/mitigation/txHazMitPlan.pdf

[4]Texas Hazard Mitigation Package, http://www.thmp.info/



Source: Adapted from *NCHRP Report 632: An Asset-Management Framework for the Interstate Highway System.*

Figure 1.2.4. Sample risk prioritization matrix.

(e.g., interstates that carry high volumes of traffic and serve heavily populated areas) the risk of it going out of service increases. GDOT has rated each combination of these four variables on a scale of 0.00 to 1.00. Table 1.2.3 illustrates these risk factors. Each segment of roadway is assigned a base risk unit of 1.00. This value is then adjusted using the factors illustrated in the table. The existing pavement condition rating for each pavement segment is then divided by the resulting risk factor. These modified condition ratings (referred to as adjusted PACES ratings) are the basis for prioritizing roadways (as described in a later step).

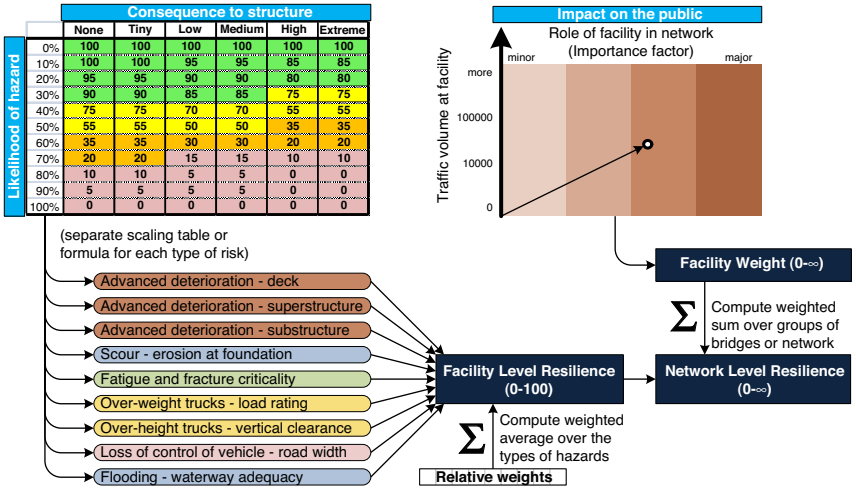
Following a similar approach for bridges, GDOT uses a combination of functional class, traffic volume, and detour length (the length of the alternative route) to assess the consequence of a bridge going out of service.

In the example of Mn/DOT's bridge programming risk assessment, the likelihood of risks occurring, and impacts and consequences of those risks, are combined into a single indicator of bridge resilience. To estimate the resilience of each bridge, Mn/DOT develops a scaling table for each hazard based on the likelihood of the hazard occurring and the consequence

Table 1.2.3. GDOT pavement risk matrix.

		AADT							Truck %		County Population							
Functional Class	**Base Unit**	**> 100K**	**50-99K**	**35-50K**	**25-35K**	**15-25K**	**7-15K**	**< 7K**	**> 12%**	**< 12%**	**> 600K**	**300-600K**	**200-300K**	**100-200K**	**50-100K**	**< 50 K**	**Total Risk Factor**	**Adjusted PACES**
Interstates																		
Urban	1.00	0.60	0.50	0.40	0.30	0.20	0.10	0.00	0.50	0.30	0.50	0.40	0.40	0.30	0.20	0.10		
Rural	1.00	0.40	0.30	0.20	0.10	0.00	0.00	0.00	0.50	0.30	0.30	0.20	0.15	0.10	0.00	0.00		
Freeways																		
Urban freeways and expressways	1.00	0.30	0.20	0.10	0.00	0.00	0.00	0.00	0.30	0.10	0.40	0.35	0.30	0.20	0.10	0.05		
Arterials																		
Urban principal arterials	1.00	0.30	0.20	0.10	0.00	0.00	0.00	0.00	0.30	0.20	0.40	0.35	0.30	0.20	0.20	0.10		
Urban minor arterials	1.00	0.20	0.10	0.00	0.00	0.00	0.00	0.00	0.30	0.10	0.30	02.0	0.20	0.10	0.10	0.00		
Rural principal arterials	1.00	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.30	0.10	0.20	0.10	0.10	0.00	0.00	0.00		
Rural minor arterials	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.30	0.10	0.10	0.00	0.00	0.00	0.00	0.00		
Collectors																		
Urban collector	1.00	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.10	0.30	0.25	0.20	0.10	0.10	0.00		
Rural major collector	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.10	0.20	0.15	0.10	0.00	0.00	0.00		
Rural minor collector	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.10	0.10	0.05	0.00	0.00	0.00	0.00		
Local																		
Urban local road	1.00																	
Rural local road	1.00																	

Source: Georgia DOT

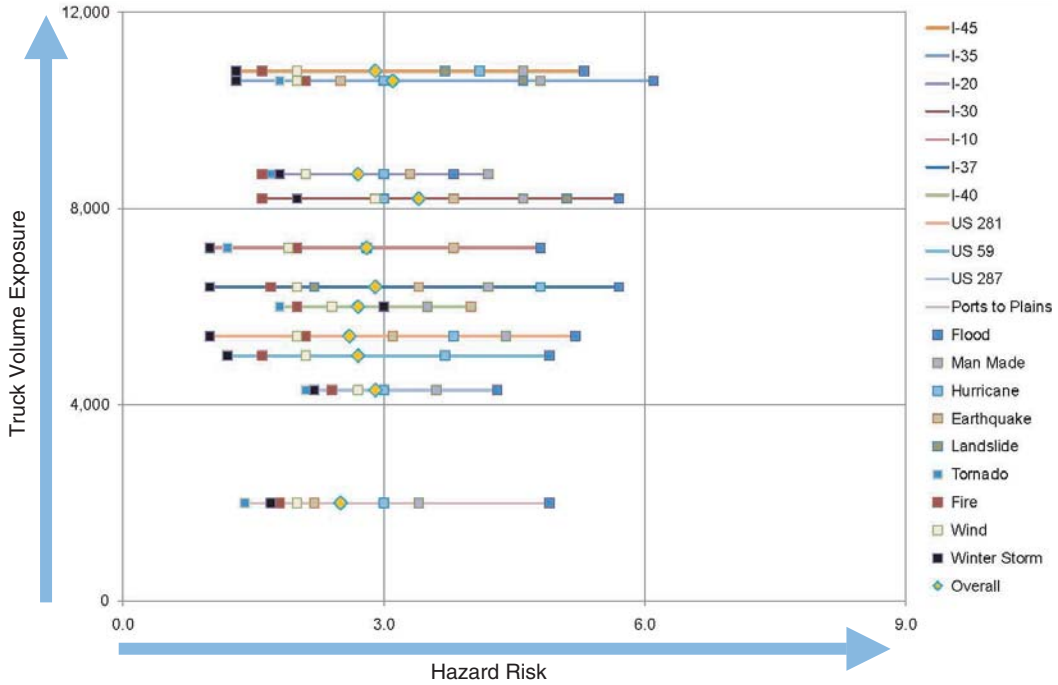


Source: Mn/DOT.

Figure 1.2.5. Mn/DOT bridge programming risk assessment quantifying risks, impacts, and consequences.

to the structure, as shown on the left in Figure 1.2.5. The potential impact of each bridge's resilience on the public is then characterized by traffic volume and by the role of the bridge in the network, represented as a function of structure length, detour length, and traffic volume and network importance. Network-level resilience is thus a function of facility-level resilience and facility weight summed across the network.

After assessing the hazards in the state by county (developed in the previous step of the risk management framework), TxDOT evaluated the hazard risk for each primary freight corridor. Ratings for each corridor were calculated by summing the individual hazard ratings for each county through which the corridor passes and weighting by the length of the corridor in that county. Ultimately, TxDOT evaluated corridor-based results by plotting truck volumes versus hazard rating to measure the robustness of the primary and secondary corridors and the potential impact to freight flows (Figure 1.2.6). Plotting the corridors in this manner allows further assessment



Source: TranSystems.

Figure 1.2.6. Texas statewide highway corridors risk vs. exposure.

of their relative risk to prioritize freight resiliency planning in the various corridors (additional discussion on corridor prioritization is discussed in a later step).

For the bridge seismic retrofit program, Caltrans used the following series of criteria to estimate the potential impact of bridge failure:

- ADT on structure;
- ADT under/over structure;
- Leased airspace (residential, office);
- Leased airspace (parking, storage, etc.);
- Facility crossed
- Facility carried;
- Detour length; and
- Essential utilities.

Caltrans assigned each criterion a weight to calculate a total "impact factor" used in the bridge prioritization algorithm (discussed in more detail in a later step).

2.4 Identify Potential Mitigation Strategies/Countermeasures

Once the impacts of the risks are understood, transportation agencies can begin to develop strategies to mitigate the impact of these risks. The NCHRP 20-24(74) literature review outlines four basic countermeasures to address risk as follows:

- Avoid—Make adjustments to eliminate the possibility of the risk occurring or causing impact;
- Transfer—Shift the risk to another party more capable of mitigating or managing the risk, thereby protecting the organization from the financial impact of the risk;
- Mitigate—Develop strategies to decrease either the likelihood of the risk occurring, the impact of the risk, or both; and
- Accept—Implement none of the three strategies above, accepting the likelihood and consequences of the risk as is.

Given the distinction between the level of agency control involved in mitigating internal and external risks, it is not surprising that agencies have placed more focus on developing internal risk management strategies. As an example, WSDOT incorporated risk management concepts into its Cost Estimate and Validation Process (CEVP) and Cost Risk Assessment (CRA) to reduce the risk associated with project schedule and cost estimates for large and complex projects. Caltrans and the FTA pioneered the use of formal risk assessment practice to minimize specific risk to project delivery due to cost overruns. Although the history of approaches for addressing external risks is considerably shorter, several recent manmade and natural disasters have underscored the importance of developing potential risk mitigation strategies to address both internal and external threats. Examples from the risk management case studies are summarized below.

Since GDOT's risk management approach focuses on system preservation, its strategies focus mainly on mitigation (e.g., conducting regular inspections and performing maintenance and rehabilitation work in a timely manner) and acceptance (e.g., focusing resources on assets with a higher consequence of risk and accepting risks in other locations).

Mn/DOT has identified a set of mitigation strategies for each of the bridge threats and hazards that are either in use or could be deployed. Examples of mitigation strategies include increased inspection frequency, load posting, scour monitoring during high-water events, preventative maintenance strategies, and reactionary maintenance strategies. Some of the scaling factors (developed in the previous step) are reduced due to the mitigation strategies; other strategies are output recommendations from risk-based bridge programming suggestions (e.g., bridge rehabilitation projects).

For their bridge retrofit program, the mitigation strategies that Caltrans selected were site specific and structure dependent, as determined by factors such as nearest active earthquake fault, type of geology beneath the bridge, and the original bridge design. Some retrofitting strategies involved placing steel shells around columns, strengthening footings and piles, adding infill walls, extending bearing seat widths, and installing isolation bearings. Caltrans utilized peer review panels of independent seismic and structural experts to review earthquake-strengthening strategies on major, complex retrofit projects.

The corridor-based analysis conducted for the Texas SFR Plan found the overall freight transportation system in the state to be robust and redundant. However, the plan identified several strategies that TxDOT can implement in a continued effort to improve freight resilience in Texas[5]

- **Strategy 1: Support planning for a resilient, well-maintained freight transportation network** by incorporating freight resiliency into traditional transportation planning and programming and including other modes in planning efforts to increase awareness of systemwide needs;
- **Strategy 2: Prioritize infrastructure enhancements to improve the freight resilience of Texas highways** by utilizing corridor assessments to identify operational bottlenecks and physical constraints, and investigating ways to fund improvements needed for other modes;
- **Strategy 3: Improve access to data, information, and people needed for effective resiliency planning** by understanding baseline data and continuing to build information

[5]TranSystems and RJ Rivera Associates, *Statewide Freight Resiliency Plan,* prepared for the Texas Department of Transportation, February 2011.

databases, defining local issues and needs, and recruiting key players to boost effectiveness of planning; and
- **Strategy 4: Communicate before, during, and after events** by providing up to date, comprehensive status reports; holding coordination meetings among critical sector groups, and engaging the private sector.

The Texas SFR Plan also acknowledged that while it is important to evaluate the potential risk to the state's freight network from all potential hazards, most response and recovery strategies are not hazard specific.

2.5 Prioritize Strategies and Develop Mitigation/Management Plan

Agencies can establish risk mitigation priorities by comparing the results of the consequence analysis to the estimated costs of the mitigation strategies and countermeasures identified in the previous step. Overall, prioritizing strategies helps to inform resource allocation decisions by identifying programs and projects with the greatest return on investment.

For example, GDOT has developed a Bridge Prioritization Formula to identify which bridges are candidates for rehabilitation or replacement. The prioritization formula is based on the following main elements:

- National Bridge Inventory (NBI) rating (measure of overall bridge strength),
- Average daily traffic,
- Detour length,
- Bridge condition, and
- Overall risk factor.

Additional elements (timber components, reduced weight limits, repairs, vertical clearance, etc.) also contribute to the prioritization score, but are weighted less than the above factors. Although the bridge prioritization formula takes into consideration the risk factors for bridge projects, GDOT does not use it as a standalone tool for decision making.

GDOT recently began an effort to refine its approach for prioritizing pavement projects based on the modified pavement condition rating described previously. GDOT plans to apply the new approach initially to the Georgia Interstate System.

Mn/DOT's bridge programming risk assessment process culminates in developing a priority score for each bridge. As shown in Figure 1.2.7, the priority score is developed based on a benefit/cost ratio, computed using an improvement to perfect resilience as the benefit (identified in the previous step), and using deck area as a proxy for cost.

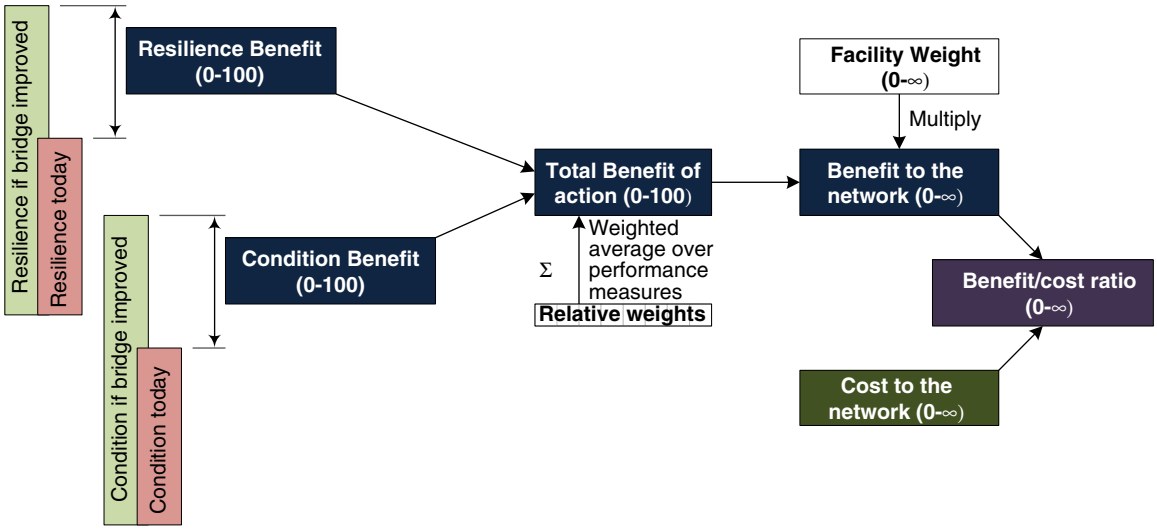
$$Priority = \frac{(100 - resilence) \times FacilityWeight}{DeckArea}$$

Facility weight is calculated as

$$Weight = \prod_i F_i \times (W \times K \times ADT + (1 - W) \times DeckArea)$$

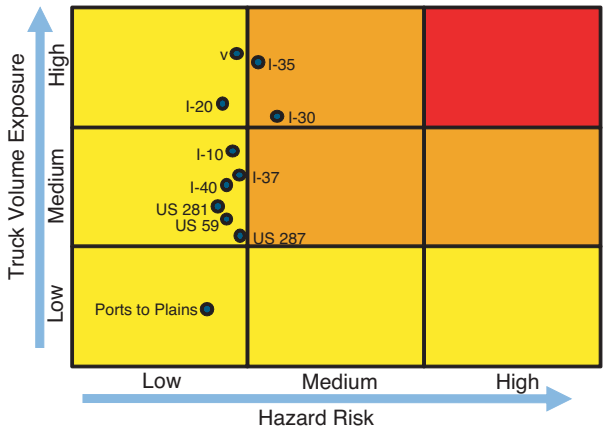
Where

$\Pi_i F_i$ is the product of a set of importance factors,
ADT is daily traffic summed over all roadways on and under the bridge,
DeckArea is the bridge deck area in square feet,



Source: Mn/DOT.

Figure 1.2.7. Developing a priority score.



Source: Adapted from the Texas Statewide Freight Resiliency Plan.

Figure 1.2.8. Texas statewide highway corridors' risk vs. exposure.

K is a constant to equalize the contribution of ADT and deck area,
W is the relative weight given to ADT.

ADT includes roadways passing under bridges as well because drivers on those roadways also are exposed to many of the hazards.

TxDOT identified relative priorities among the state's primary freight corridors by plotting the risk assessment results on a risk versus exposure plot shown in Figure 1.2.8. None of the freight corridors in Texas fall in the high-risk category and only two corridors, I-35 and I-30, fall in the medium-risk category. Four highway corridors, I-45, I-35, I-20, and I-30, fall in the high-exposure category, while a majority of the corridors fall in the medium-exposure category. Using this risk versus exposure plot, the Texas SFR Plan concludes that I-35 and I-30 should receive the highest priority for corridor improvements, because they have the highest risk and exposure combination of all Texas highway corridors.

Caltrans used an algorithm to prioritize retrofits to the state's bridges based on risk. This algorithm, developed in 1988, was revised during the course of the program. The revised algorithm used in 1992 was defined as follows:

$$Risk = (Vulnerability \times Hazard \times Impact) \times [(0.27 \times Vulnerability) + (0.33 \times Hazard) + (0.40 \times Impact)]$$

Each variable in the algorithm is defined by adding the weighted global utility function values from all criteria that define that variable (Table 1.2.4). Recall that the vulnerability and hazard variables were developed in Step 2 of the risk management framework, and the impact variable was calculated in Step 3.

2.6 Measure and Monitor Effectiveness

A successful risk monitoring process will systematically track risks, invite the identification of new risks, and capture lessons learned from subsequent efforts. Given the preventative nature of risk management, monitoring efforts typically included aspects of implementation (e.g., monitoring the percent of program implemented and making improvements to the risk assessment process) in addition to performance assessment.

Table 1.2.4. Risk criteria for Caltrans bridge prioritization algorithm.

Criterion	Weight	Criterion	Weight
Hazard		**Impact**	
Soil conditions	33%	ADT on structure	28%
Peak rock acceleration	38%	Leased airspace (residential, office)	15%
Duration	29%	Leased airspace (parking, storage, etc.)	7%
Vulnerability		ADT under/over structure	12%
Year constructed	25%	Facility crossed	7%
Outriggers, shared columns	22%	Facility carried	7%
Abutment type	8%	Detour length	14%
Skew	12%	Essential utilities	10%
Potential for drop-type failure	16.5%		
Bent redundancy	16.5%		

Source: Caltrans.

For example, at Mn/DOT, continuous monitoring of effectiveness is accomplished through annual review of the established bridge condition performance measures. Similarly, GDOT conducts regular inspections and periodically reviews its prioritization formulas to make changes and refinements as necessary.

The Texas SFR Plan recognizes that measuring and monitoring the system's resiliency is an ongoing, internal function for TxDOT and that continuous feedback and documenting lessons learned after real events will improve the plan and ensure its relevance. In the absence of an event, TxDOT recognizes the importance of evaluating resilience regularly and incorporating feedback into SFR Plan updates.

While many of the DOT case studies highlighted in this primer are newly developing or refining their risk management programs to support resource allocation, Caltrans is nearing completion of its retrofit program. As described in earlier steps of the framework, Caltrans refined their bridge prioritization algorithm over time such that it evolved into a highly complex system—a clear example of the iterative nature of the risk management process.

CHAPTER 3

Risk Management Implementation

As illustrated by the various case study examples presented throughout this primer, each agency's approach to risk management for resource allocation is specific to its unique needs and applications. Likewise, each agency will face different challenges for continued implementation and refinement over time. In the context of their unique programs, this section summarizes each DOT's risk management implementation considerations and next steps.

3.1 GDOT Pavement and Bridge Preservation Risk Assessment

From a technical perspective, GDOT is testing the pavement risk factors to ensure their overall validity. It also is evaluating the potential for enhancing the process for application to its Interstate Highway System. The bridge risk factors were incorporated into GDOT's latest programming cycle. In both cases, the intent of the resulting priority scores (which combine condition with risk) is to serve as one input into the decision-making process. They are combined with other factors such as legislative requirements for the equitable distribution of funds, proximity to other planned projects, and engineering judgment. The intent of GDOT's asset management (and risk management) program is to inform—rather than dictate—resource allocation decisions.

From an institutional perspective, GDOT is working to address the paradigm shift of moving from a worst-first to a most-at-risk approach. For example, it is likely that a risk-based approach will lead to GDOT letting certain low-risk assets deteriorate to a point that is lower than would have been tolerated under a worst-first approach. This, in turn, may lead to GDOT lowering its overall condition targets, which would be significant internally because GDOT historically prides itself on the overall condition of its assets relative to other agencies throughout the United States. GDOT attributes its early successes in steering the culture away from a worst-first mentality to two things: (1) obtaining buy-in from top management (in this case, GDOT's Chief Engineer/Deputy Commission), and (2) creating a sense of ownership among its technical ranks by asking the agency's pavement, bridge, and maintenance experts to provide details for the new process.

Looking ahead, GDOT also plans to focus on two areas that will further the implementation of its asset management and risk management efforts. The first is to develop an approach for informing the allocation of funds across program areas (e.g., pavement versus bridge versus roadway expansion) through tradeoff analysis. The second is to develop data governance standards for its condition and performance data. For example, identify each data element required to calculate each metric, and then, for each element, determine a standard definition, a data owner, a QA/QC process, a data storage protocol, etc. This work will set the stage for a central repository that provides GDOT staff with ready access to timely and quality performance data.

3.2 Mn/DOT's Bridge Programming Risk Assessment

Risk assessment and management is being implemented at Mn/DOT due to leadership from the commissioner, who has hired a risk expert to incorporate these principles into the agency's overall decision-making process. It is expected that this assessment will be used to inform decisions about project selection. The exact process of incorporating the new risk model with the existing Mn/DOT Decision Matrix for prioritizing projects still must be determined.

Agencywide, risk management implementation is going to be an organic process to ensure risk practices are used where valuable and scalable. Although the vision is to successfully integrate risk management throughout Mn/DOT, implementation has been mindful of both need and demand for

the service from internal customers. One tool for this is the Mn/DOT Risk Management Workshop. These workshops have increased the department's ability to move forward with difficult projects, program goals, decisions, and initiatives. In just under 2 years, over 40 diverse risk management workshops have helped generate cooperation and communication for a variety of topics and decisions.

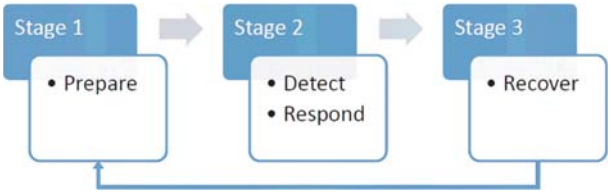
3.3 TxDOT's Statewide Freight Resiliency Plan

Considering the complexity involved in developing a resiliency plan, TxDOT is proceeding with a three-staged approach to risk management, as shown in Figure 1.3.1. The SFR Plan completed in February 2011 focused on Stage 1, an assessment of the freight system's preparedness from the perspective of TxDOT as the managing organization. The results of the Stage 1 plan indicate that the overall freight transportation system in Texas is prepared for an event, but there are physical and institutional improvements that could provide higher levels of resiliency. As a result, TxDOT's Transportation Planning and Programming Division could use the SFR Plan to inform the planning process and to advocate for additional funding for freight-related improvements in the state. Assessing the robustness and resiliency of the freight network informs decisionmakers by providing a risk-based assessment of the state's transportation needs.

In the stages to follow, Stage 2 will focus on communication and plan implementation during response to an actual event and its recovery. Stage 3 incorporates a continuous feedback loop to update the plan on a regular basis to keep it relevant and effective over time.

3.4 Washington State's Bridge Retrofit Risk Assessment

WSDOT's approach for programming bridge retrofits and reconstruction is still in its nascent stages, and has yet to be specifically defined. Looking ahead, WSDOT hopes to use research from this and other studies to further develop its approach and move away from a "one design fits all" approach to bridge reconstruction. In particular, WSDOT hopes to develop a risk assessment procedure that considers tradeoffs between different program areas and that incorporates flexibility in design standards.



Source: TranSystems.

Figure 1.3.1. Texas SFR plan stages.

3.5 Caltrans' Bridge Seismic Safety Retrofit Program

As the program comes to a close and after evaluating the program in retrospect, Caltrans identified several lessons learned from the program with implications for next steps.

- The mandate resulted in a funding priority for the program over other programs; a tighter financial constraint could have resulted in a different overall process, prioritization scheme, or set of mitigation strategies.
- Retrofitting as part of the program was exempt from the state environmental impact report (EIR) requirements in order to expedite the process. In some cases, replacement may have been a cheaper construction alternative but was not selected since it would have been subject to the more time-consuming and costly EIR requirements.
- The availability of additional data for the bridges that were screened for potential seismic vulnerabilities would have reduced the up-front analysis time and cost for the retrofit program. Caltrans is currently working to expand its bridge database.
- Some retrofit projects were incorporated into widening or other highway improvement projects. This often increased efficiency, but sometimes made the project subject to EIR requirements.

3.6 Summary of Common Themes

Taken collectively, the experiences at the five agencies described above help to illustrate a number of common themes related to the development and implementation of a risk management process. These include

- When developing a risk management process, there is a need to work closely with, and gather input from, all involved parties within the agency (e.g., bridge engineers, the asset management group) and/or external to the agency (system users, peer reviewers, etc.);
- Agencies have, or desire to, fit risk assessment and management within existing performance-based planning and programming processes, with the culmination of the process being a factor or adjustment to existing prioritization scores and therefore influencing the programming process;

- Agencies want to evolve into performing tradeoffs between different assets within their risk management process, but this has not yet been implemented among the interviewed agencies;
- During the risk management process, it is important to consider both the individual facility (often through asset-specific estimates of the likelihood of a risk) and its potential impact on the entire system (other through a systems-level view of the consequences of a risk occurring); and
- Although the risk management approaches reviewed for this study all align generally with the generic risk management process described in this primer, the details vary significantly based on the individual needs of the implementing agency.

PART 2

Use of Information Technology Tools and Data Management Practices to Support Data Sharing and Integration in Transportation Agencies

CHAPTER 1

Introduction

This primer provides guidance to state transportation agencies on the use of information technology (IT) tools within a data management framework to

- Support performance-based resource allocation (PBRA) in a transportation agency;
- Support data sharing and access; and
- Manage data security, data privacy, and other IT issues that impact data sharing.

Data systems are used as a source of information for decision-makers at all levels, and any risks associated with the use of data must be addressed. The primer covers risk management approaches for data programs and also discusses how data is used to support risk management programs within a transportation agency in general.

This primer addresses IT issues and challenges that impact data sharing and integration, and therefore decision making, especially for PBRA decisions. It demonstrates how IT tools and techniques can be used to support and strengthen data management and risk management programs in transportation agencies. The ultimate goal is for transportation agencies to use this primer to identify the IT tools, methods, and practices that best meet their needs for establishing and maintaining comprehensive data management programs.

The research conducted to complete this primer consisted of interviews with the following six state DOTs and two other agencies, as well as follow-up correspondence related to particular issues:

1. Alaska Department of Transportation and Public Facilities: Program Development Division;
2. Colorado Department of Transportation: Division of Transportation Development, Traffic Analysis Unit;
3. Hennepin County, Minnesota: Public Works Administration;
4. Metropolitan Transportation Commission (Bay Area of California): 511 Program and Information Technology Office;
5. Michigan Department of Transportation: Bureau of Transportation Planning, Asset Management Section;
6. Minnesota Department of Transportation: Office of Policy Analysis, Research, and Innovation, *TIS Risk Assessment Final Report,* 11/17/2009;
7. Virginia Department of Transportation: Office of Knowledge Management, Operations Planning Division and Information Technology Division; and
8. Washington State Department of Transportation: Enterprise Risk Management Office.

CHAPTER 2

IT Issues that Impact Data Sharing and Data Integration

Several IT issues were identified during the course of the case study research for NCHRP 8-70 (*NCHRP Report 666*) as either having a positive or negative impact on decision making at transportation agencies. There are several potential solutions available including IT tools and procedures as discussed in this primer. For the purposes of this primer, the IT issues are grouped into the following nine data process categories:

- Collection,
- Archiving/storage,
- Processing,
- Analysis,
- Reporting/dissemination,
- Sharing,
- Access,
- Institutional issues, and
- New technology.

These issues are described in Table 2.2.1. The table shows an issue number, description of issue, benefits, challenges, and severity of impact of the issue. Some issues also provide solutions for the IT challenges. These solutions are identified with an issue number from Table 2.2.1.

The research from the eight case studies and additional Web-based and other research indicates that certain issues play a more critical role than others in impacting business decisions (including PBRA).

Each issue was assigned a "severity-of-impact" value of high, medium, or low, based on the information provided by the agencies in the case studies. Assigning a severity-of-impact value to each IT issue helps prioritize the issues that present the most significant challenges and warrant focused attention in this primer. These impacts either can provide benefits or present challenges for transportation agencies. Examples from the case studies are discussed for each issue to further explain the potential impact to agencies.

2.1 High Impact

An issue was determined to have a high impact for several reasons. The issue may have a high (negative) impact on an organization because it results in significant costs in staff and resources to implement. Alternatively, it may require a low cost to implement, but results in a significant (positive) return on investment (ROI) regarding productivity and timeliness in delivery of data and information.

These high-value/low-cost issues are considered "low-hanging fruit." They would yield significant benefits to the agency or particular business unit and might be solutions that agencies would choose to implement first, as part of a data management program. Several high-impact issues identified in Table 2.2.1 in the categories of sharing, processing, analysis, access, institutional, and new technology are discussed in the following paragraphs.

Sharing

Issue: Establish Common Location Referencing (#23)

Many state transportation agencies use various types of location referencing methods in their road network linear referencing systems. Some of the methods may include route-milepoint, distance from origin, and latitude/longitude locations. These diverse methods of documenting locations across multiple agencies, or within the same agency, present challenges when trying to integrate data from multiple systems.

The challenges associated with this issue can be illustrated by the Alaska Department of Transportation and Public Facilities (ADOT&PF) case study. ADOT&PF currently uses a route-milepoint scheme to identify locations on the Alaska road network. This linear referencing system is used for location of attribute data in the Highway Analysis System (HAS), including data used for traffic and crash analysis, as well as for Highway Performance Monitoring System (HPMS) reporting. HAS is a legacy system and does not have the capability for data

Table 2.2.1. IT issues that impact data sharing and integration.

Issue No.	Issues Related to Data Sharing/Integration	Benefits	Challenges	Impacts (Potential Cost in Terms of Money, Time, Resources) to Agency Internally (I), to External Stakeholders (E), or to Both (B)	Severity of Impact, Either Positive or Negative – High, Medium, Low
	COLLECTION				
1	Collect "right" data for "right business use."	Supports business need for a specific business unit.	Need to determine how to collect the right data to get it to the right people at the right time.	I	Medium
2	Integration of real-time data with traditional traffic data systems.	Increases richness and completeness of traffic datasets	Need to determine how/when/where to use real-time data to supplement traditional traffic data collection methods.	I	Medium
3	Collection and integration of local road data with on-state system road network.	Provides for a comprehensive road network to support agency geodatabase.	Data providers for local road networks not required to use/follow same data collection standards and definitions as state transportation agencies.	B—It may not be feasible for external data providers to accommodate certain data collection requirements (i.e., level of granularity) based on the type of equipment used by them and/or limited staff to complete data collection activities in the required timeframe.	Medium
4	Level of granularity (more detailed versus less detailed).	Increases level of accuracy of data used to support decision making.	Increased cost for data collected with increased data accuracy (data collected at 1-mile interval versus 1-foot interval).	I	Medium
5	Collection of data across jurisdictional boundaries.	Provides comprehensive transportation network on a regional, state, and national basis.	Consolidation of data and level of detail at boundary lines, county to county, state to state, and at international borders may be difficult.	B— May impact external stakeholders too, if some of data provided externally.	Low
	ARCHIVING/STORAGE				
6	Costs associated with data archiving and need for storage of large data files.	Archives provide a historical repository of data for trends analysis and forecasting for investment purposes.	Need to determine what data to keep and how many years of data are needed. Need ability to store large files (i.e. 4-6 GB of data) and to post the files to the network.	I	Medium
7	Maintain archive in-house or externally.	Although costs of external archiving may be more expensive, outsourcing this function can alleviate the strain on limited internal agency resources.	• Costs to house data externally may be more expensive, and data must be accessible when needed by internal business units. • Additional hardware and software may need to be procured to serve as the archive repository.	B—Impact depends on whether the archive is housed internally or externally.	Medium
	PROCESSING				
8	Resources needed to process volume of data collected through outsourcing.	Data can be collected in shorter timeframe.	Processing of data collected through outsourcing may require increase in internal staff to process the data.	I	Low
9	Redundant data kept in duplicate systems because of data silos.	There were no benefits identified with maintaining data in silo systems.	Produces inefficient business processes, which may require duplicate data collection, QA/QC, and analysis, resulting in potentially conflicting results in reporting functions.	I	High

Table 2.2.1. (Continued).

Issue No.	Issues Related to Data Sharing/Integration	Benefits	Challenges	Impacts (Potential Cost in Terms of Money, Time, Resources) to Agency Internally (I), to External Stakeholders (E), or to Both (B)	Severity of Impact, Either Positive or Negative – High, Medium, Low
10	Gain support from staff for replacing manual business processes with automated processes.	Increased efficiency and productivity using automated methods to replace manual methods.	Staff may be reluctant to change from doing things "the way they've always been done."	I	Medium
11	Conversion of legacy data and information systems is time-consuming and costly.	Conversion processes provide an opportunity to cleanse data that may not be reviewed otherwise.	Conversion of data and information systems usually requires a period of parallel processing to ensure that conversions of data and application systems are done correctly.	I	Medium
12	Need to identify update cycles required to refresh datasets.	Updating data on standard cycles helps to ensure that the most recent data is available for decision making.	Datasets provided from external sources may not be refreshed or updated in a timely manner.	B— Impact depends on whether data is provided internally or externally.	Low
	ANALYSIS **Data Quality**				
13	Need to identify and develop new automated analysis tools and procedures.	Increased efficiency and productivity of staff responsible for analysis of data for particular systems (i.e., traffic, crash, road inventory, GIS, etc.).	Automated analysis tools may need to be developed to replace manual methods and procedures. There may be some resistance on the part of staff to replace existing procedures with automated methods. Development of new tools can be time-consuming and costly initially, but ultimately can produce increased efficiency and productivity of staff	I	Medium
14	Need to determine and document each of the following attributes to ensure delivery of highest quality data: accuracy, timeliness, completeness, validity, coverage, accessibility, currency.	Clearly documented definitions and standards applied to each of these data quality components helps to ensure that the highest quality data is available for decision-making.	Need to identify which business units in the agency are responsible for determining each of these components of data quality. Is it primarily the IT office, or the business unit that is responsible for data quality?	I	High
	Use of Metadata				
15	Need to develop and maintain metadata corresponding to data and information systems.	Helps to ensure that the data is used for the right purpose.	It is time-consuming to develop and maintain up-to-date metadata.	I	Medium
16	Need to determine best method for dissemination of metadata and who (which office) is responsible for this function?	All stakeholders for a data system benefit from the widespread easy access to metadata through the use of tools such as Web links, knowledge management systems, etc.	Metadata standards and definitions need to be developed and methods for delivery identified to ensure that the metadata is available to **all** stakeholders.	B—Developed internally and disseminated externally.	Medium

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Table 2.2.1. (Continued).

Issue No.	Issues Related to Data Sharing/Integration	Benefits	Challenges	Impacts (Potential Cost in Terms of Money, Time, Resources) to Agency Internally (I), to External Stakeholders (E), or to Both (B)	Severity of Impact, Either Positive or Negative – High, Medium, Low
	REPORTING				
17	Need to identify whether reports are to be generated daily, weekly, monthly, or annually to support business needs. This may require a change in current business practices.	Establishing and publishing reporting deadlines across the organization can help with this issue.	Business processes in various offices may need to be modified to accommodate changes in reporting deadlines and requirements regarding the types of reports and methods of delivery of reports.	I	Low
18	Need to identify the best methods and tools to deliver reports.	Use of technology such as dashboards can improve timeliness in delivery of reports and the ability to use reports to support decision-making.	Reports may need to be produced in multiple formats, such as Excel spreadsheets, graphs, charts, tables, and through different means, via Web link, or visual methods using PowerPoint presentations, use of dashboards, etc., resulting in additional costs to the agency in procuring these tools.	I	Medium
	DISSEMINATION				
19	Need to define what is considered "timely" dissemination of information: daily, weekly, monthly, annually, other?	Establishing deadlines and timeframes for delivery of data and information helps to ensure that data is available when needed.	Limited staff resources may find it challenging to provide data in a timely manner to all stakeholders when needed.	I	Low
20	Need to select the best tools and methods for delivery of data and information to internal and external customers.	User-friendly tools instill confidence in the use of the data and information by the users.	Delivery methods and tools used for internal and external customers may vary, such as dashboards (for internal) and Web links or wireless (for external). This may result in additional costs and required training for staff in the use of each of these tools.	B—Can impact external customers too if training is required in use of reports and tools.	Medium
	SHARING				
21	Need to balance data sharing needs of all stakeholders: federal, state, local, private.	Ensures that agency resources are aligned to meet the needs of stakeholders regarding data and information in a timely manner.	Data requirements and needs for all stakeholders differ and should be clearly identified and documented.	B	Medium
22	Data sharing standards of all stakeholders may not be compatible with your agency standards.	Providing a copy of your agency data catalog or data definitions and standards can help address this issue.	Data conversion may be required to prepare data for delivery according to external stakeholder needs.	B	High
23	Data sharing across all modes of transportation needs to rely on a common georeferenced dataset, with standard data definitions and dataset formats.	Use of a common georeferenced database system supports sharing of data across multiple modes of transportation.	Development of a common georeferenced dataset may require development of an enterprise geodatabase and acceptance by all users regarding the level of accuracy of the linear referencing system used.	B	High

Table 2.2.1. (Continued).

Issue No.	Issues Related to Data Sharing/Integration	Benefits	Challenges	Impacts (Potential Cost in Terms of Money, Time, Resources) to Agency Internally (I), to External Stakeholders (E), or to Both (B)	Severity of Impact, Either Positive or Negative – High, Medium, Low
24	Need to address reluctance on the part of data providers to share data and information without knowing who will use the data and how it will be used.	Use of metadata can help to address this issue.	Different business units within an agency or the agency itself may be reluctant to provide data and information to external users without clearly identifying the intended use of the data and information.	I	Low
25	Need to establish cooperative data sharing agreements between agency and external partners.	Clearly identifies expectations regarding quality and timeliness of data delivery for all data sharing partners.	Requires give-and-take on the part of all data sharing partners to provide data usable and mutually beneficial to all data partners.	B	High
26	Data sharing may be difficult across organizations because money and skilled personnel are not always available across all jurisdictions.	Use of cost-sharing methods for data collection (such as pooled fund efforts) can decrease the financial burden on any particular data partner.	Limited money and staff resources may inhibit data sharing across multiple jurisdictions.	B	High
27	Need to integrate publicly produced and privately purchased data products.	Use of external data products (whether free or at a cost) can increase the richness and completeness of agency datasets.	Certain business offices within the organization may be reluctant to purchase data products from external sources due to additional costs or lack of quality control over the data delivered.	I	Medium
	ACCESS				
28	Data Security—data systems must have authorized access for internal and external users; procedures have to be established to determine who/when/ under what circumstances access is granted.	Access controls protect against unauthorized access and use of data by internal and external sources.	IT offices often need to coordinate this effort with business units to approve access to various data systems.	I	Low
29	Data Privacy—privacy of individuals/organizations must be upheld according to federal/state/local laws.	Agency policies and standards regarding what is considered public vs. private information helps to protect the privacy rights of individuals, and limits risks to the agency from potential litigation.	Need to balance the need of the public's right to know with privacy laws.	B—Internal users may have full access to data, while external users have limited access to data.	High
	INSTITUTIONAL				
	Data Management Policies/Procedures				
30	Need strong executive leadership to support data management programs.	Strong leadership supports data management through establishing data governance policies and standards for collection, processing, and use of data across the organization.	Changes in leadership may impact continuity of support for data management programs.	I	High
31	Need to develop shared datasets and business terminology definitions between data program managers and all departments/business units, including IT office.	Standard business terminology dictionary supports development of applications and data systems that are transferable across all business units and transferable to external users of the application systems.	Requires close coordination between IT office and business units to develop what is considered the "standard business terminology" dictionary.	I	Medium

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32	Data is needed to support before-and-after analysis regarding return on investment (ROI) to agency to support future investment strategies.	Helps to justify future investments in business programs and in the risk management process.	Requires archiving of data for before-and-after analyses processes.	I	Medium
33	Different financial, legal, and technical environments exist at individual agencies that may participate in data sharing agreements.	No benefits identified for this issue.	Careful consideration must be given to the differences between agencies (technical environments, legal, financial resources, etc.) when establishing data sharing agreements.	B	Low
	Governance				
34	Differences of opinions may exist between IT offices and business units regarding the roles and responsibilities for defining data definitions, standards, and policies for the use of data and information.	No benefits identified for these types of institutional barriers.	• Clearly identifying roles and responsibilities of IT offices, business units, and stakeholders may take a significant investment in time and resources. • The development of a data governance framework may be required to address this issue. • There is not a one-size-fits-all model for data governance; the model must be scaled and adapted to the size of the organization. • Need to identify the data champions in the organization.	I	High
35	State standards or agency standards and policies may dictate contracting methods that prohibit the use of certain hardware, software, communication protocols.	Establishment of standards and policies for use of agency hardware/software helps to protect the agency data systems from unauthorized access/use, and helps to streamline application system development, which must comply with the agency's preferred architecture and database model designs.	Information systems developers and business data owners must have access to, and become familiar with, the state standards and policies governing the use of hardware, software, communication devices, and protocols that may be used to share and integrate data at the agency.	I	Medium
	Data Business Plans				
36	Need to demonstrate the link between agency mission and goals, the business units, and application systems, which support the business units.	• Ensures that agency data systems are aligned with its mission & goals, in order to support the core business functions of the agency. • Helps to manage risks to the agency associated with data programs.	• Need to develop a data business plan framework with input from the IT office and business units working in partnership to develop the framework that supports agency mission and goals. • Data business plans may take several years to implement and may require a phased implementation approach. • Requires involvement of multiple internal and external stakeholders.	B	High

Table 2.2.1. (Continued).

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37	Need business terminology dictionary to facilitate sharing of data and information internally and externally.	Helps IT developers to understand business terminology of the agency when developing applications to support business needs. This may result in eliminating duplicate data definitions across multiple application systems.	Requires close coordination from both the IT office and business units to participate in development of the business terminology dictionary.	I	Medium
	Maturity Models				
38	Need to use maturity models to assess overall progress of agency's data governance evolution, which ultimately impacts the agency's ability to share and integrate data and information systems with other internal or external data sources.	Helps the agency to assess their progress in the evolution of data governance.	Need to develop the maturity model that best suits or is the best fit for the agency. This may require the help of external consultants if internal staff is not trained in developing data governance maturity models.	I	High
	Risk Management				
39	Need to identify risks to an agency associated with the loss of data.	Helps to prevent loss of mission-critical data and information used for policy making and decision making.	Persons from all business units and the IT office need to participate in the risk management process.	I	High
40	Need to develop risk management plan and routinely (e.g., annually) re-evaluate the plan.	Identifies persons/offices responsible for addressing risks to data and information on behalf of the agency.	This may require additional tasks to be assigned to already limited staff resources to support the risk management activities identified in the risk management plan.	I	High
	NEW TECHNOLOGY				
41	Need to continually evaluate when/where/how to integrate new technology through a data management program.	Keeps the agency at the forefront in the use of new technology to support business operations.	This on-going evaluation carried out as part of a Data Management Program for the agency, will require time and dedicated resources to accomplish.	I	High
42	Need to assess impact to agency through the integration of the following types of new technology:				
	a) Business intelligence (BI) tools (dashboards, scorecards)	• Useful for sharing data and information from an executive-level overview perspective. • Has capabilities to access data stored in many formats including databases, spreadsheets, reports. • Provides agencywide access to staff for monitoring goals, targets, and performance of core business programs.	• Commercial dashboards often have to be customized for use in an agency. • In some cases, there may not be **any** commercial dashboards available that meet an agency's needs. In this case, the agency may develop the dashboard in-house, or, use consultant services. • Training usually required for staff maintaining the information on the dashboards and/or scorecards and also for general staff using these BI tools.	I	High

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Table 2.2.1. (Continued).

Issue No.	Issues Related to Data Sharing/Integration	Benefits	Challenges	Impacts (Potential Cost in Terms of Money, Time, Resources) to Agency Internally (I), to External Stakeholders (E), or to Both (B)	Severity of Impact, Either Positive or Negative – High, Medium, Low
	b) Knowledge management (KM) systems	KM systems can be used to • Provide easy and quick access to data, information, reports in a variety of formats to support business needs; • Provide automated versioning control for documents; • Serve as repository of information on lessons learned; • Contain contact information for data stewards, data business owners for specific data systems; provide links to data dictionaries, data catalogs; and • Provide information on data governance policies and procedures.	• Agency needs to determine basic functions required in their KM system so they scale the KM system to meet their needs. • Some KM systems are more costly than others, and an agency may not need all features offered by some of the more expensive solutions.	I	Medium
	c) Extensible Markup Language (XML) for data sharing and storage	• Easy to use for formatting files for transfer of data; • Offers automated security protocols for data; • May be more economical means of data transfer compared to File Transfer Protocol (FTP) servers.	No challenges were identified with the use of XML.	N/A	High
	d) Wireless technology for data collection, dissemination	• Use of Smart Phone apps for instance, for GPS data collection, may be less costly than the use of commercial GPS data collectors.	• Transmission of data/information with Smart Phones relies on the use of cellular network towers, which may be limited or non-existent in remote areas.	B—Coordination may be required between internal agency and external data providers regarding the use/transmission of data using wireless technology and the applications used, such as Smart Phone apps.	Medium
	e) Automatic vehicle location (AVL) systems for transit data collection	• Provides real-time departure/arrival information for transit vehicles, such as buses. Data can then be used for real-time trip planning. • AVL systems also are used with snowplow operations to track GPS locations of equipment and amount of time needed for snow removal in a geographic area. • AVL systems used with snowplows also are capable of tracking the temperature of the road and the speed of the vehicle.	No challenges were noted with the use of AVL systems.	I	Medium

Table 2.2.1. (Continued).

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	f) Global positioning system (GPS) data collection	Provides increased accuracy of location data in real-time, which can be used in applications that support dynamic routing of vehicles, and for updating agency's linear referencing system and GIS.	• Cost of GPS data collection devices and supplemental equipment varies and may be a factor in determining which equipment to procure. • Commercial GPS data collectors rely on satellites, which may be unavailable from time to time, or have limited transmission capabilities in remote areas. • GPS data requires transfer from GPS device to another device such as a PC/laptop for post-processing of the data, which includes data validation, differential corrections, etc. Differential corrections are used to improve the GPS location data.	B—Type of data collection equipment and format of data to be collected needs to be coordinated between external data collectors and agencies needing/using the data.	High
	g) Closed-circuit television cameras (CCTV) for data collection	• Supports emergency operations during extreme weather conditions or other types of emergencies impacting flow of traffic. • Provides real-time data including travel time, speed, incidents, and weather for a geographic region in the range of the camera.	• Telecommunication relays from cameras may be intermittent during a 24-hour period, based on weather or other factors. • Cameras may be costly to procure, install, and maintain. Therefore, their deployment location should be carefully selected to maximize collection of data/information in the most critical areas.	I	Medium
	h) Non-intrusive technology (such as Minnesota GuideStar) for traffic data collection including infrared, magnetic, radar, Doppler microwave, pulse ultrasonic, passive acoustic, and video.	Can be used effectively for collection of speed data	No challenges were identified with the use of non-intrusive technologies, except perhaps cost, compared with the use of traditional tubes across a particular section of road for traffic volume data collection.	I—Cost of non-intrusive technology may be more than traditional data collection methods using road tubes.	Medium

analysis within a geographic information system (GIS) environment. Therefore, ADOT&PF's Program Development Division is developing an enterprise geodatabase that will eventually replace the HAS system and will be used to support their business needs including highway safety and traffic analysis, traveler information, and asset management.

This enterprise geodatabase will need to integrate road networks for all functional classifications of roads required for reporting. Projects are underway to collect this additional linear referenced data for integration into the geodatabase. The database model is being designed with the flexibility to integrate data from additional road networks, as needed. When the geodatabase is implemented, it will be the source of location data for a new Traffic Data System and Crash Data System, as well as support existing department business programs.

This example illustrates the challenges associated with developing a location geodatabase, that must have the capability to integrate new road networks and to update existing networks to meet the needs of all stakeholders. ADOT&PF will continue to encourage internal and external stakeholders to use this database as the source for their location needs.

Solution

Implementing a geodatabase containing a comprehensive network of state and local roads will encourage stakeholders to use it for their location data needs. Outreach to stakeholders to solicit contributions to this single geographic road network will help ensure it contains the most accurate location data available.

Providing a means for data sharing partners to transmit local road data and multiple types of roadway attribute data through a File Transfer Protocol (FTP) server, or via a Web portal, encourages their use and continued contribution to the master dataset.

Six state DOTs were surveyed for this primer and many of them indicated that there is an office that maintains GIS maps and databases that are used by other offices within the agency and by external users (via a Web portal). They also indicated that GIS and associated data are transmitted through the use of extensible markup language (XML) formats or FTP processes.

Issue: Variety of Data Standards and Skill Sets Used at Multiple Agencies (#22 & #26)

Another critical issue having a high impact on data sharing with external partners is that independent agencies each have their own set of standards used for data collection, processing, and reporting. There also are a variety of skill levels among staff at individual agencies, and certain staff may have more advanced technical training than others in the maintenance of data programs. Others may have more experience or knowledge in the tools used for integration and sharing of data, which can present challenges when exchanging data between agencies.

Solution

Although state agencies cannot dictate the required standards and skill sets of personnel at other agencies, data sharing agreements and memorandums of understanding (Issue #25) can be used to facilitate the exchange of data and information. These types of documents are used to specify data file format requirements, data definitions, data collection requirements, and any quality assurance/quality control (QA/QC) procedures required for datasets. They also can be used to document required update cycles for delivery of refreshed data to participating agencies.

Processing

Issue: Silo Systems (#9)

One of the most notable high-impact issues identified by transportation agencies is the existence of silo systems. These are data systems, which are most likely legacy systems, built to address business needs in separate business areas of the agency.

Although many of these systems support certain business needs, they lack the ability to meet the majority of business needs for the agency. The use of silo systems often results in duplicate data being maintained across multiple systems, which requires continued costs to maintain separate data systems. Integrating these silo systems into an enterprise database has the potential to reduce maintenance costs.

Solution

One of the most effective methods identified for addressing the existence of silos is the development of enterprise databases. The implementation of an enterprise database usually relies on participation from the business units and IT offices. This ensures that the enterprise data warehouse meets the needs of each individual business unit as well as the agency as a whole. An enterprise data warehouse architecture includes links to data marts, which are used to distribute reports and predefined datasets to users.

At Hennepin County in Minnesota, enterprise data is maintained for use by other departments within the county, including the Public Works Administration. This department uses accounting, payroll, GIS, and global positioning system (GPS) data to support their business operations in the county. This includes performance-based management, which evaluates the performance of county programs from four perspectives—financial, customer satisfaction, internal processes, and learning and growth.

Analysis

Issue: Ensure Data Quality (#14)

Another issue identified as having a high impact on staff and resources is the necessity for access to quality data. This includes having the staff and business processes in place to ensure that data, especially data used for target-setting and performance measures, is of the highest quality. The quality of data can be assessed in terms of the following seven attributes:

- Accuracy—degree to which data are free from error,
- Completeness—degree to which data values exist in the data system,
- Timeliness—degree to which data are available when required,
- Validity—degree to which data are in the domain of acceptable data values,
- Coverage—degree to which sample data accurately represent the entire set of data,

- Accessibility—degree to which data are easily retrievable, and
- Currency—indicates how current the data must be in order to meet business needs (e.g., is a daily, monthly, annual update sufficient?).

The challenge is to ensure that data quality is maintained consistently throughout an organization, even though the determination for acceptable levels of data quality may vary across business units.

There are also temporal issues to be considered, which may impact the determination of data quality. Particularly regarding currency, some datasets may need to be developed for future use (such as GIS datasets), while others are no longer used and may need to be deleted or replaced with databases that offer more advanced query, analysis, and reporting capabilities.

Solution

A method for addressing data quality issues across the enterprise is to document clear definitions and standards for each of the seven attributes as they pertain to particular data systems. Data catalogs can be used to document this information and the catalogs can be made accessible through the use of an enterprise knowledge management (KM) system.

Michigan DOT has a structured data management program that includes data policies and standards, and data dictionaries for the many applications systems that are used to support business operations. In order to provide the highest quality data and information, a concerted effort is made to evaluate what data are (and will be) collected to meet business needs.

Some data may be used to develop performance measures for the department. In this case, all parties responsible for the collection and use of the data have to agree on what type of data will be used to monitor the performance measure before it is implemented. This requires close coordination among business units, which supports the goal to "collect data once, and use it many times."

Access

Issue: Data Privacy (#29)

Several agencies identified that protecting the privacy of citizens regarding the collection and distribution of data is a high priority. For example, much of the data collected as part of crash data programs at state transportation agencies includes the collection of data that is considered sensitive or private.

The case study at the Metropolitan Transportation Commission (MTC) in the California Bay Area illustrates the challenges regarding maintaining privacy when a transit agency is collecting travel-time data from an electronic toll tag system. In this case, the primary purpose of collecting data using toll tags is to capture when a toll tag appeared at a location. Any information about the driver that may be linked to the toll tag (including name, address, and telephone number) is not needed to track travel times of a particular vehicle. This type of data must be protected from unauthorized use.

Citizens also may use the traveler 511 system in the Bay Area for personalized trip planning services, with the "My 511" option in the system. Use of this service requires setting up a customer account with information including a phone number and a location. Again, this information may be considered as sensitive or private and must be protected from unauthorized or unlawful use.

Solution

The privacy of individuals can be maintained using business processes and software that encrypts the data at the source of data collection. This is the method used by the 511 Program at MTC. The toll tag ID is encrypted and the data is destroyed within a 24-hour period.

Institutional

Issue: Need Strong Executive Leadership to Support Data Management Programs (#30)

One of the most significant institutional issues impacting the success of data management programs at transportation agencies is the need for strong executive leadership and support for an overall data management program/data governance framework. This includes the need for policies, directives, and procedures that are sanctioned from the highest levels of the organization regarding how data is to be collected, used, and managed within the organization.

Solution

There are several approaches that have been, and can be, used to solicit strong executive support for data management programs in both the private and public sector. One of the most effective is the use of IT tools such as executive dashboards that demonstrate how the agency's business programs are performing when compared to established performance goals and targets. The use of dashboards is an effective and understandable method of relaying this type of information to executives. It is the responsibility of the various offices within the agency to explain, via presentations or other methods, how the information available on the dashboards relies to a great extent on access to timely, accurate, complete, and high-quality data.

Depending upon the level of detailed information needed by leadership, business data models also can be used to clearly show how the collection, processing, and reporting of data to

such entities as FHWA results in a significant apportionment of highway funds to the state highway agencies on an annual basis. Demonstrating the ROI resulting from strong data programs is another effective method for gaining strong executive leadership support for data management programs.

Issue: Need to Use Maturity Models to Assess Overall Progress of Agency's Data Governance Evolution (#38)

Agencies that are in the process of developing or implementing data governance programs also need the ability to assess their progress as they evolve from being ungoverned to fully governed, regarding their data programs. They need a tool to assess where they currently are, compared to where they started and where they need to be, in order to obtain the highest level of data governance.

Solution

The use of data maturity models is the recommended solution for assessing how well the agency is progressing in achieving various levels of data governance within the organization. It is important to scale the maturity model to the needs of the organization and to focus on the most critical institutional, technical, and resource issues that may (or will) impact the implementation of data governance. An example of a Data Management Maturity Model Matrix can be found in Table 2.1 of *NCHRP Report 666: Target-Setting Methods and Data Management to Support Performance-Based Resource Allocation by Transportation Agencies.*

Issue: Identify Risks Regarding Data Systems and Establish Risk Management Programs (#39 & #40)

An issue that could require significant investment in resources is the development of a risk management program. This includes identification of potential risks and development of strategies to address those risks. This requires participation from multiple business units and the IT office to assess risks regarding systems in each business area. The IT office also may evaluate risks differently than the business units; this is also an issue that needs to be resolved. For example, the IT office may tend to focus more on potential risks pertaining to the agency IT infrastructure. This includes securing the intranet and hardware and software from loss of service due to power disruption or equipment failure. The business units, however, may focus their risk management efforts on the potential failure of infrastructure assets, such as bridges or pavements in a state DOT. Each of these types of risks is important and should be addressed as part of an agency's risk management program.

Solution

Risk management plays an important role in evaluating and addressing several of the IT challenges discussed in this report. Therefore, risk management is discussed as a standalone issue in Part 2, Chapter 3 of this primer.

Issue: Identify Roles of IT Offices and Business Units for Data Stewardship (#34)

A common institutional issue that exists in many agencies is the difference in opinions over the roles and responsibilities of the IT offices and the business units for maintaining and supporting data systems. Without clearly defined roles for all data stewards and business data owners, duplicate processes may be developed for sharing and integration of data, especially data used for PBRA. This can result in the delay of timely delivery of data and information to decisionmakers when needed.

Solution

A data governance framework and data governance maturity model can be used to address this issue. Establishing clearly defined roles for data stewards, business data owners and communities of interest (COIs), which are the stakeholders who share a common interest in a particular type of data (e.g., safety, traffic, crash, 511, and GIS), helps to address this issue.

More information on data governance and the data governance maturity model can be found in Volume 2, Chapter 2, Section 2.1 of *NCHRP Report 666.*

In addition to establishing data governance models, an organization should consider implementing the appropriate technical infrastructure, using business intelligence tools, to support data governance. This could include KM systems that are used to store information and archive best practices relating to stewardship for application systems.

Issue: Need to Demonstrate the Link Between Agency Mission and Supporting Data Programs (#36)

There is a need to clearly communicate how an agency's ability to achieve its mission and goals rely on data systems that provide information for decision-making purposes. Many decisions, including PBRA, are based on available data and information from data support systems. Attention to investment in data systems becomes a higher priority once management is aware of the relationship between the data systems and their importance in supporting business operations.

Solution

Development of a data business plan framework can be used to address this issue. The framework not only ensures that the data systems are aligned to support agency goals and business processes, but it also helps to identify the data systems that need to be addressed as part of a risk management program.

More information on the use of a data business plan framework can be found in Volume 1, Chapter 4, Sections 4.2 and 4.3 and Volume 2, Chapter 2, Section 2.1 of *NCHRP Report 666*.

New Technology

Issue: Need to Identify Best Approaches for Integrating New Technology Tools and Procedures (#41 & #42)

The use of IT tools and procedures has a significant impact on data sharing and integration. Although several benefits can be derived from the use of such tools, challenges often exist with the use of particular types of technology.

These challenges include the need for customization of certain tools to make them usable at an agency. Additional training also may be required for staff in the use of the new IT tools and there may be additional costs for procurement of hardware and software needed to implement a particular technology tool.

The benefits and challenges identified by the case study research for each of these IT tools and procedures are summarized in Table 2.2.1.

Solution

Several types of IT tools and techniques are available to facilitate sharing and exchange of data and information. This includes GIS tools used for display of maps and the use of business intelligence tools, such as dashboards and scorecards, and KM systems for storing and sharing data and information.

For the purpose of identifying a unique proposed solution, the following discussion explains how GPS, GIS, and wireless technology are used as part of a study involving sharing and exchange of data to support electronic freight management.

Research for this primer included investigation of the Cross-Town Improvement Project (C-TIP) in the Kansas City metropolitan area. C-TIP is under the direction of the FHWA Office of Freight Management and Operations.

In this example, the sharing of data and information between the motor carriers and the railroad terminals in the Kansas City metropolitan area relies on a sophisticated network of smart phones (iPhone), cellular network relay towers, satellites, and roadway sensors that collect traffic volume data. Real-time routing information is provided using GPS location data and GIS databases.

C-TIP, still under development, identifies four main components in its Concept of Operations (2009). The component of the system that includes the use of wireless technology is the wireless drayage updating (WDU) component. According to the proposed system design, motor carriers can receive information about pending load assignments, pickup and delivery instructions, and traffic congestion information through the use of a truck-mounted driver interface device (T-MDID), which is an iPhone.[6]

The following scenario, illustrated in Figure 2.2.1, including process steps, depicts how the C-TIP system can be used to relay information for moving containers between two railroad terminals.[7]

The C-TIP system illustrates how the integration of different types of technology and tools can be used to improve timely delivery of freight containers between multimodal terminals and helps to eliminate empty container trips across town. The system integrates the use of real-time traffic information, GIS mapping tools for routing, and GPS technology for location of trucks and containers. The system takes advantage of wireless communication through the use of iPhones for relaying information to/from the motor carriers and the railroad terminals and dispatchers.

Overall, this system looks promising. There are some human and technical challenges, however, associated with the use of the system.[8]

These challenges include the following:

- Validating the dynamic route guidance (DRG) and real-time traffic monitoring (RTTM) output,
- Providing useable output to drivers,
- Getting truckers to trust the dynamic routing recommendations, and
- Accommodating human behavior variables.

In spite of these challenges, the C-TIP system provides continued opportunities for improved transportation of freight in the Kansas City metropolitan area through the use of integrated technology tools.

2.2 Medium Impact

A medium-impact value issue indicates that some additional investment in resources and new applications may be needed; however, the ROI in productivity and ability of the organization to meet its business needs justifies the investment.

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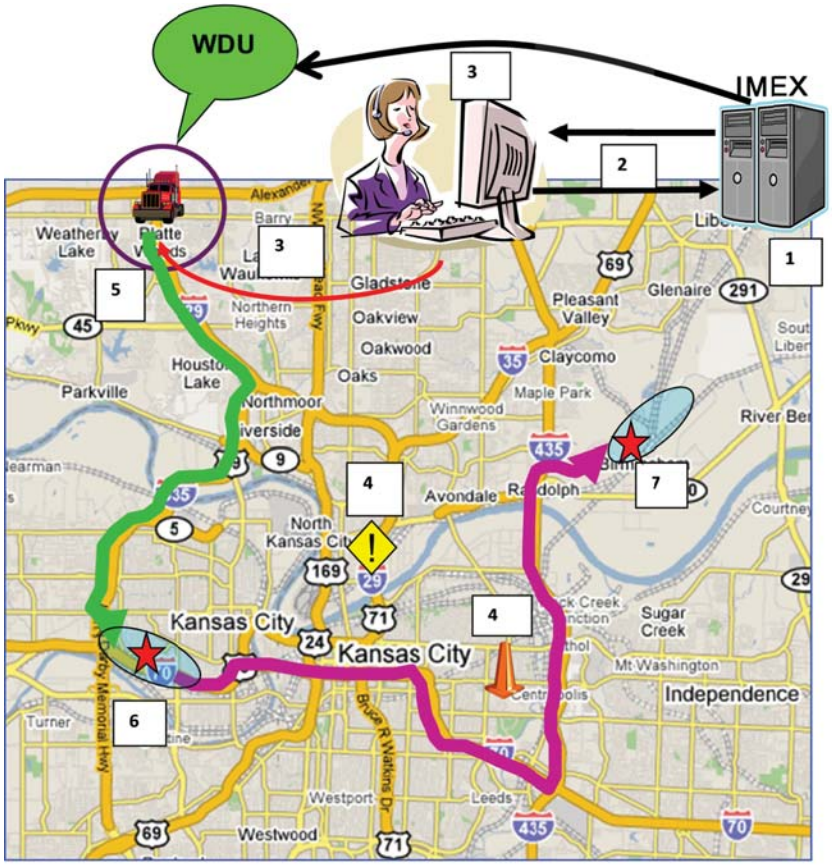
[6]http://www.ctip-us.com/ctip_files/CTIP Scope Statement_V6.pdf

[7]Randy Butler, Transportation Specialist, FHWA Office of Freight Management and Operations, Talking Freight Webinar, November 17, 2010.

[8]Paul Belella, Delcan, Talking Freight Webinar, November 17, 2010.



Process Steps

1. Information is relayed to an Intermodal Move Exchange (IMEX) server to coordinate pickup and delivery of containers from railroads, terminal operators, and trucking companies. IMEX acts as a clearinghouse where railroads and terminal operators post transportation needs and trucking companies can indicate hauling capacity and daily load assignments.
2. The IMEX produces work orders for truck carriers to move containers, which are sent over the network to a dispatcher.
3. Truck carriers query and receive information either through a dispatcher or the WDU component. The WDU forwards travel-time information to the trucks.
4. Real-Time traffic information is collected from roadway sensors and relayed to drayage operators through the WDU. The information is sent to the T-MDID device (iPhone) in the truck.
5. The drayage operator begins the trip using the real-time traffic information and the dynamic routing component of C-TIP.
6. The drayage operator picks up container(s) at railroad terminal #1 to transport the shipment to railroad terminal #2.
7. Drayage operator then proceeds to railroad terminal #2 to deliver the container(s).

Figure 2.2.1. C-TIP freight movement.

The issues in the medium-impact-level range are relative to other issues identified by the case studies that may have a higher or lower impact level on the agency. The medium-impact-level issues include the categories of collection, archiving/storage, processing, analysis, reporting/dissemination, sharing, and institutional, and are described in the following paragraphs.

Collection

Issue: Collect Right Data for Right Business Use (#1)

Several agencies are faced with the challenge of collecting the right data and using it for the right purpose. Clear expectations must be identified for the intended use of data to justify the cost of data collection programs. Many state DOT data collection programs exist to support operations of the agency and to meet federal and/or state legislative mandates. This may result in duplicate data collection efforts across multiple business units within the agency, in order to satisfy legislative requirements that pertain to planning (HPMS), safety (Fatality Analysis Reporting System, or FARS), environmental, and other programs. The right data also are needed to support development of performance measures and, subsequently, PBRA.

Virginia Department of Transportation (VDOT), like many state DOTs, has found that they are "data rich, information poor." The agency must find a way to process the abundance of data collected and translate data into information that is available on an enterprise basis for use in making business decisions.

Solution, Part 1: Evaluate What Data Need to be Collected for Business Needs, Prior to Beginning Data Collection Efforts

Michigan DOT begins the process of defining data collection that is used for performance measures by asking the following questions:

- For what is the data being used?
- What is really being measured with the data?
- What is the quality and meaning of the data?

Any data collection program should be organized to ensure that the primary business needs for the use of the data are met. Caution should be exercised in adding additional data collection requirements with stricter levels of accuracy because this may increase the time and cost of the data collection process.

Before beginning this process, evaluating the data collection needs of the organization and the best approach for managing data collection will help to ensure more efficient management of resources. The databases that store the data also should be designed with consideration for how the data will be used. This will help to align the data systems to support the business operations of the organization.

Solution, Part 2: Develop/Maintain/Distribute Good Metadata (#15 & #16)

One of the most effective methods that can be used to ensure that the right data is used for the right purpose is to develop metadata for datasets. This is an example of how an IT issue can be used to provide a solution to address other issues. Metadata includes a description of the data fields for a dataset, the date of last update, and the intended uses for the data. The metadata also needs to be accessible to all stakeholders as needed.

Issue: Level of granularity (#4)

The level of granularity or precision level that is needed for data collection programs may vary across business units within a state transportation agency. For instance, although a 1-mile increment unit may be sufficient for road inventory data collection programs, pavement management programs may require 1/10-mile segments to be used for data collection in order to meet federal or other reporting requirements.

Solution

There are many approaches that can be used to address this issue of the level of granularity needed for a particular data collection program. One of the best approaches is to combine the processes used at Hennepin County in Minnesota and the processes used at Michigan DOT for roadway location data.

Hennepin County evaluates the level of granularity needed on a case-by-case basis. The precision level required by surveyors, for instance, is not the same as that required for snowplow operators. Snowplowing operations may be able to use aerial photography to meet their location needs and to determine the resource allocations needed to complete snowplowing operations. However, if data is collected at a more detailed level for use by surveyors and is made available through a GIS, the data still could be used to support snowplow operations.

Michigan DOT provides an alternative solution for addressing the issue of level of granularity by making this decision at the design stage for their databases. In designing their GIS database used in the Asset Management Section of the Bureau of Transportation Planning, a specific precision level is used for the roadway network data layer, which also allows data collectors to segment the linear network road layer according to the data attribute being collected. This design provides flexibility in the use of multiple data layers within a GIS framework.

Issue: Integration of Real-Time Data and Local Road Data (#2, #3)

All state DOTs are required under federal regulations to report data that documents the extent, conditions, and performance of the public road network in the state on an annual cycle to FHWA. This is for the HPMS report. This includes information on the mileage, pavement conditions, traffic volumes, vehicle classification, and weight data as some of its primary components. The states maintain various databases for HPMS reporting. These databases include the higher functionally classified roads, such as interstates, state roads, and principal arterial roads. However, states do not always have up-to-date local road data since much of it is provided by local government sources. The ability to integrate this type of data from external sources is cumbersome because local entities do not have the same data collection requirements or cycles as the state transportation agencies. Much of the local road data is not typically in a format that allows for easy transfer or integration with state datasets, and to facilitate the use of this data requires the development of additional conversion programs.

A similar data integration challenge exists with the use of real-time traffic data collected from Intelligent Transportation System (ITS) programs. One of the primary challenges associated with the use of real-time data is to determine how much data to archive for future use. Unless the real-time data is archived, it is unavailable for further analysis. If it is archived, it usually needs to be processed further to combine data collected at 15-minute intervals into a value representing 1-hour intervals. The format of the data also has to be converted to a format that can be integrated with a state's traffic database. Decisions also have to be made regarding how long to keep the archived data and opinions on this may vary from office to office within a state DOT based on the business uses of real-time data.

Solution

Designing databases with flexibility to allow for easy integration of external datasets can help to ensure that data from local governments and other external sources can be effectively integrated when it becomes available. Entering into data sharing agreements that establish specific data definitions and requirements also encourages the exchange and use of such data.

Integrating real-time data requires coordination between the state DOT IT office, the internal users of the real-time data, and the transportation management centers that collect the data. Data sharing agreements, which include detailed system requirements for data collection, storage, QA/QC, and processing, are needed to ensure that the data is available to supplement traditional traffic data collection programs. Archives need to be maintained to store the data and access to the archive should be provided to users as needed.

Archiving/Storage

Issue: Costs Associated With Archiving/Storage (#6)

Archiving and storage of data is also an issue that each state DOT must address since much of an agency's historical data is used as a source for trends analysis (i.e., comparing travel volume trends) and for evaluating future investments in agency programs that support business needs.

Many agencies rely on external data archive services and some use their own internal archive systems for storing data. The costs vary depending upon the archive method used and access to the data also must be maintained so that it is available when needed.

Solution: Determine Whether to Maintain Archive Internally or Externally (#7)

Such decisions are best made on the basis of a thorough benefit-cost evaluation of the hardware and software requirements for data archiving and storage using an internal or external archive. The amount of data and other archive requirements should be scaled to the needs of the organization and will affect the evaluation.

Other options for data storage also may be explored, such as the use of cloud and/or Web-based services, especially if implementation of these options does not require the procurement of additional hardware or software.

Processing

Issue: Conversion of Legacy System Data (#11)

Another issue that impacts resources at state agencies is the need to convert legacy data from existing systems for use in new applications. This can be illustrated in the development of enterprise databases at a state transportation agency.

Much of the data that is needed for incorporation into the enterprise database may reside within legacy systems typically used for traffic, pavement, and bridge management.

Resources from IT offices and business units must be applied to develop software that is used to extract data from existing systems and convert the data for use in the new applications.

Solution

Business units and the IT office must work together to establish clear data definitions and file formats for the new data systems. This can be accomplished through the use of internal

work groups that define the needs and uses for data systems from the perspectives of the business units and IT office.

To ensure that the conversions work properly, the necessary conversion programs can be developed by programmers in the IT office and system testing can be conducted by the business units.

Issue: Need Staff to Support and Participate in Replacing Manual Processes with Automated Processes (#10)

Some issues that impact data sharing and integration are not symptomatic of the use of a particular technology tool or procedure, but are instead embedded in the culture of the organization. It may be difficult at times to convince employees to replace manual processes that they have been using for many years and are costly in terms of full-time equivalent (FTE) hours. This is true even if the new business processes that rely on new technology increase productivity and shorten processing cycles.

Solution

Identify stakeholders to participate in work groups for various data systems. These may be business data owners and data stewards for particular systems such as road inventory, traffic, pavement, bridge, and asset management systems. Providing training opportunities to staff in the use of new technology and tools also encourages their support of letting go of "doing things the way they've always been done." The work groups are used to identify potential solutions and best approaches for implementing improved business processes. These work groups can be implemented through the use of a data business plan, as was done at the Minnesota Department of Transportation (Mn/DOT). Mn/DOT used work groups to identify the gaps and needs regarding their data systems. The work groups were part of a data assessment process to determine the health of existing data systems.

The states that have begun the implementation of data business plans, or are currently using them, are already experiencing the benefits derived by gaining support and input from stakeholders who contribute information about business needs for particular data systems. At Mn/DOT, the data business plan development resulted in recommendations for improved business processes and development of data systems that support traveler safety, infrastructure preservation, and mobility.

Analysis

Issue: Need Automated Analysis Tools and Procedures (#13)

Many agencies still rely on a combination of manual review processes and some automated tools to evaluate and analyze data. Manual review and analysis, to some degree, is a useful method depending upon the amount of data to be analyzed and the resources available to perform the analysis. However, any QA/QC of data that relies primarily on manual methods has the potential for introduction of human error. The evaluation process also can take longer to complete when multiple staff and/or offices are involved in the analysis processes. This may delay reporting of data and information, especially data that is used to support PBRA, to decisionmakers at all levels of the organization.

An example of this issue is demonstrated by the Colorado Department of Transportation (CDOT) case study. In the Traffic Analysis Unit (TAU) there are a number of manuals, paper tracking, and electronic software systems used to analyze and manage daily, monthly, and annual year-end traffic statistics, as well as to store continuous and short-duration count raw traffic data. Traffic data at CDOT is currently dispersed over a number of different databases and systems. Although CDOT is still able to meet its traffic reporting requirements, there is the potential for improvement in the use of automated tools to support traffic analysis, including the use of GIS tools.

Solution

Several automated tools can be used to enhance analysis and processing of data, including data used for performance measurement. Analytical tools include GIS mapping tools, which can be used to identify anomalies in data. Excel spreadsheets also can be used to produce tabular reports to identify erroneous data that may be outside a given tolerance range. CDOT is continuing to improve access to its traffic data for internal and external stakeholders through the development of a GIS with a front-end portal that allows users to access and use traffic data to meet their own business needs.

Reporting/Dissemination

Issue: Need Automated Tools to Deliver/ Disseminate Data Information in Timely and User-Friendly Manner (#18 & #20)

In some cases, it may be a challenge to identify the best IT tools to distribute reports and disseminate data and information. The decision to select one type of technology over another depends a great deal on the audience using the data and information. If the audience is more technically inclined, tabular reports, charts, or raw data files may be appropriate.

However, in other cases, it may be more useful to provide information on an interactive GIS map where users can select a specific location on the map to generate reports regarding traffic counts or locations of construction projects within a specific travel corridor.

Solution

Clearly identify the target audience for the use of data and information. Is it executives who are making decisions about PBRA? If so, dashboards and scorecards may be the more appropriate choice for disseminating information than providing raw data files. However, if the audience includes software developers, then raw data files may be exactly what is needed to perform system testing for new applications.

The IT tool selected should be user-friendly for the intended audience.

A variety of automated tools and services are available to facilitate the dissemination of data and information. Some of the more commonly used options identified by the case study participants are listed below and are included in Table 2.2.1.

- FTP servers can be used for transmission of large, raw data files;
- Wireless networks can be used for collection and relay of data, as was illustrated by the use of wireless technology to support freight management in the Kansas City metropolitan area;
- Closed-circuit television cameras (CCTC) can be used to relay traffic- and weather-related information to the public;
- Cloud computing services can be used for file transmission and sharing of large data files;
- Electronic dashboards and scorecards can be used to relay information about Key Performance Indicators (KPIs) to executives and decisionmakers in an organization;
- XML file formats can be used to facilitate sharing of data and is the preferred format for file transmission at several agencies, including the 511 Program at MTC and Hennepin County Public Works Administration in Minnesota; and
- Automatic vehicle location (AVL) systems can be used to collect and transmit information about GPS locations of vehicles, which is particularly useful in monitoring arrival/departure times for transit operations and is used effectively to manage snowplow operations in Hennepin County.

Sharing

Issue: Need to Balance Data Needs of All Stakeholders (#21)

Transportation agencies routinely face the challenges of balancing needs of all internal and external stakeholders. The stakeholders are the users of data and information for various data systems. These groups include federal, state, and local governments, as well as the general public and the private sector.

Data and information are needed to comply with legislative mandates and are used to support statewide transportation improvement programs and manage agency assets. An abundance of transportation data also is used for research to identify best practices in managing all modes of transportation, including highway, rail, transit, air, and marine transportation.

Limited resources are available to meet the needs of all of these groups, and therefore, agencies must increasingly rely on improved business processes and automated tools to address the competing needs of all of the stakeholder groups.

Solution

The solution to address this need involves a combination of the use of business intelligence tools including data business plans, KM systems, risk management programs, and the right combination of IT tools.

The implementation of each of these solutions has a medium level of impact to the organization. These solutions require a certain amount of dedicated resources to develop and implement compared to other issues identified through the case studies.

Data business plans can be used effectively to clearly identify which data programs and data systems are used to support the business functions of an organization. These plans also are used to identify data management policies and standards and data governance structures that are used to manage the collection and dissemination of data and information.

Data governance also can be used to identify the data stewards, data business owners, and COIs for particular data programs. The COIs are comprised of the multiple offices and agencies who share a common interest in the use of the data.

Data business plans and data governance can both be effective methods in addressing the needs of all stakeholders as illustrated by the case studies from ADOT&PF and VDOT's Systems Operations Directorate. Each of these agencies are defining COIs that can be used to identify data and information needs from the stakeholder's perspective.

KM systems are another option for documenting and archiving information about stakeholder needs associated with specific data systems. KM systems can also contain contact information about the business data owners, data stewards, and COIs who work with a particular kind of data, such as traffic, crash, pavement, bridge, environmental, rail, and transit data.

VDOT has implemented an Office of Knowledge Management that stays very involved in coordinating outreach to the COIs for two specific areas: (1) work planning and tracking, and (2) ITS assets. VDOT is able to use the COIs to define the needs of the stakeholders and evaluate the processes and technology that can be used to address their needs.

Issue: Need to Integrate Publicly Produced, Privately Purchased Data Products (#27)

Certain business offices within an organization may be reluctant to use free sources of data or to purchase data from external data sources, due to costs or lack of quality control over the data delivered. External data products also may require additional internal agency processing before the data is ready for integration into internal database systems.

Solution

When external sources of data are used to supplement data collection activities for a state transportation agency, the collection requirements should be very detailed and include data definitions, file formats, and any QA/QC procedures that must be applied to the data.

Well-defined internal QA/QC procedures will serve as a secondary validation to ensure that the data provided is in accordance with the requirements of the organization.

An abundance of free public data is available for use by state transportation agencies—including traffic and weather data—from federal, state, and local sources. Consideration should be given to the use of free data sources to improve the completeness and richness of state transportation databases. Data sharing agreements can be used to document the procedures for the exchange of free data between public agencies.

Institutional

Issue: Need to Develop Shared Datasets Based on Use of Business Terminology Definitions (#31 & #37)

There is a need in state transportation agencies to develop and maintain data that is shareable across many business units. This usually requires coordination between the IT office or division and the other divisions and offices within the agency.

Traditionally, the roles of the IT staff were to develop data systems on behalf of the business units and to implement and train the business areas in the use of these systems. Business units are now more involved in the development of applications to meet their business needs.

They have staff that is very knowledgeable in the use of IT tools and motivated to use this knowledge to support their business operations. In some cases, the business units may develop their own applications to meet their business needs. A more comprehensive understanding of how data systems are used in the business areas of the organization is needed by IT offices.

Solution

An understanding of the business terms used to describe data is important to specifying datasets. These business terms can be documented in a business terminology data dictionary maintained by data business owners and accessible for use by IT developers, describing also how data are defined and used by specific divisions or offices. Such a dictionary will help developers ensure that applications meet the business needs of data users.

At Michigan DOT, streamlined data definitions are used across multiple application systems instead of creating new data definitions for similar uses. For example, a particular type of traffic data collection device would not need to be a new data field in a system but could be included as one of the valid values for a data field known as "traffic data collection device."

Issue: Data Needed to Support ROI Analysis (#32)

Data is needed in state transportation agencies for ROI analysis and investments in particular projects and programs that support business operations.

With current anticipated budget shortfalls from federal and state sources, it is imperative that data is available to support ROI analysis and decision-making regarding investments in transportation programs, including PBRA.

Historical and current data are needed for this comparative analysis. A data archive can be used to store the historical data required. ROI analysis also requires access to financial data to complete the cost analysis component for various investments, including the procurement of hardware/software to support business operations.

Data is also needed to document the tangible and intangible benefits regarding investments in particular projects and programs. Justification for development and maintenance of such programs as highway safety improvement programs, statewide transportation improvement programs, and traffic monitoring programs, usually require documenting the tangible and intangible benefits of each program, compared with the costs of developing and maintaining those programs.

Tangible benefits include costs savings through the use of automated data collection devices and development of enterprise databases that provide data and information in a timely, efficient manner.

Intangible benefits include the ability of the agency to meet federal and/or state legislative requirements within deadlines, or to maintain the confidence level of the public regarding access to, and use of, state transportation systems including highway, rail, and transit systems.

Solution

A data catalog can be developed to identify data systems used in the organization by various business units. The catalog can include data fields and data definitions by data system. Access to the data catalog through a KM system, or internal

intranet site can help to quickly identify where to find data that is useful for ROI analysis.

Issue: State Statute or Agency Policies May Dictate Contracting Methods that Prohibit Procurement and Use of Certain Hardware/Software (#35)

State level legislative requirements that prohibit the use of certain hardware or software clearly will limit the ability of state transportation agencies to procure a product that may best suit their business needs. Such limiting policies typically are intended to ensure that data and information are reliably secured and maintained to be available when needed to support business decisions.

Solution

A sound business case may justify a request for exceptions to restrictive legislation or policies. The business case will document the benefits, costs, and risks associated with the hardware and software sought. Demonstrating that other agencies or state programs will not be exposed to significant risk, including descriptions of security protocols to be adopted, and presenting examples of successful applications in other states or federal agencies can be very effective arguments for why the exception should be made.

2.3 Low Impact

A low-impact value indicates that this IT issue was not identified as a high priority by the majority of the agencies in the case studies. These issues usually have limited impact on agency resources or require little or no cost to implement.

In some cases, the low-impact issues are beyond the control of the agency, and therefore cannot be addressed by investments in particular programs or data systems at an agency. The low-level impact issues include the categories of institutional, access, sharing, reporting/dissemination, collection, and processing. These issues are discussed in the following paragraphs.

Institutional

Issue: Different Financial, Legal, Technical Environments Exist Across Multiple Agencies (#33)

There are differences that exist in the financial, legal, and technical environments across agencies and organizations that share and exchange data. These differences may limit the ability of some agencies to procure certain hardware and software based on policies or legislation, or due to fiscal constraints. Also, organizations may prohibit the release of data and information to other agencies that is considered to be private or confidential. Technology environments vary widely from agency to agency, which can inhibit the exchange of data and information. Although many of these issues are beyond the control of individual agencies, there are solutions that can be used to address them.

Solution

Develop data sharing agreements between agencies that exchange data and information, to ensure that data is provided within the financial, legal, and technical requirements of each agency.

The data sharing agreements should include, at a minimum, the following items:

- Costs of data collection and processing, if there is a cost incurred, for delivery of data from one agency or organization to another;
- Legal requirements regarding the use of the data; and
- Specific technical requirements regarding the integration of the source data into other data environments (i.e., does the data have to be converted into a different format, or does the data require special software to process it within a GIS environment?).

For state transportation agencies that provide data and information in compliance with federal and/or other state legislative requirements, data sharing agreements are not necessary; however, data file format requirements and delivery methods must be defined clearly.

This includes whether data is to be uploaded to a specific Web portal, such as the User Profile and Access Control System (UPACS), which is used for submitting HPMS data to FHWA, and any data file format specifications.

Access

Issue: Need to Assign Authorized Access to Data Application Systems (#28)

There is a need to identify clearly who within the business units and IT offices at state transportation agencies are authorized to query, update, process, and use data from particular applications.

This is usually easily identifiable, based on a person's job function in the organization. Human resource officers, for instance, would have access to certain employee or financial information that should not be shared with everyone in the agency.

This issue has a low level of impact because it typically does not require procurement of additional hardware or software

to make these types of business decisions. Managers are usually responsible for submitting forms authorizing their employees to have access to particular data systems.

Solution

Assigning authorized access to data systems that support business operations is usually the function of business line managers and supervisors. Those persons responsible for establishing the user logins and passwords normally reside in the IT office or division of the agency.

The IT office also has a responsibility to report any unauthorized access to, or use of, data to the business owner of the data, or to others as outlined according to department policy, for resolution of the issue.

Sharing

Issue: Some Reluctance May Exist for Sharing Data if the Purpose of its Use is Unknown (#24)

The possibility always exists with the sharing and exchange of data that it may be used for purposes for which it was not intended. This is typically not a major issue in sharing and exchange of data between state and local transportation agencies.

If a state DOT exchanges and shares traffic data with and between local governments and metropolitan planning organizations (MPOs) for instance, what the data is used for is usually clearly identified by each agency. In this case, the data is most likely used to support statewide transportation planning and urban and regional transportation planning programs.

Solution

Data sharing agreements can be used to document any data that is made available by one agency for use by other agencies or organizations. Metadata also should be provided with datasets, to describe the intent for the use of the data. It is incumbent upon the receiving agency to use the data as intended and to clearly identify when it may, or may not, be using the data according to its original intent.

Reporting/Dissemination

Issue: Need to Establish Reporting Distribution and Data Dissemination Cycles (#17 & #19)

Inconsistency in reporting of data and information, on varying cycles, by a state transportation agency can impact its credibility with all stakeholders including federal, state, and local partners, as well as the private sector and the public.

There is a need to clearly identify the methods to be used for distributing reports, as well as the timeframes to be used for disseminating information and data to internal and external stakeholders.

Solution

A data management plan is an effective method for documenting policies, standards, and procedures used for the release of reports, data, and information to any internal and external users, including specifying if reports are to be distributed on a weekly, monthly, or annual cycle. Additional information on developing data management plans can be found in Volume 2, Chapter 2 of *NCHRP Report 666.*

Collection

Issue: Need to Collect Data Across Jurisdictional Boundaries (#5)

Since state transportation agencies often are required to submit data that has been aggregated at a statewide level, they may need to integrate data that crosses jurisdictional boundaries, such as counties or regions within the state.

Border states often participate in national or regional programs that require the exchange of data across state or national boundaries. One example of this case is the exchange of GIS and roadway network data between the states on the southern U.S. border and Mexico. The GIS data is used for many purposes including planning, design, and construction of roads and bridges near and at border crossings.

Solution

Integrated database systems, such as GIS, can be used to store, process, and display data across jurisdictional boundaries. GIS data models can be developed to allow for multiple data layers to be integrated within the GIS. Although each data layer can be linked to a specific jurisdiction (region, county, city), GIS allow the user to integrate data for use on a statewide level.

Processing

Issue: Resources Needed to Process Large Volumes of Data Collected Through Outsourcing (#8) and According to Specific Update Cycles (#12)

As transportation agencies rely more on external sources of data, to enhance the completeness and richness of their own datasets they will need to have enough resources to

process the data internally in order to provide information when needed.

Solution

The incorporation of automated tools for QA/QC of external datasets can reduce the amount of time and, in some cases, the number of resources needed, to manually review and process data. By saving processing time in one area, resources can be reallocated to other areas to handle large volumes of data.

Even with the use of automated QA/QC tools, there still may be minimal resources available to handle the volume of data received. In this case, data archiving may be an option to preserve the data for future processing at a time when additional resources are more readily available.

Summary—IT Issues

Each of the IT issues that impact data sharing and integration have been discussed in this section. The issues were examined in terms of their impact to the organization, based on a high-, medium-, or low-level of impact.

Some of the issues discussed actually provided positive impacts and presented solutions to address other IT issues. Examples were presented to illustrate how these issues impact the organizations interviewed.

CHAPTER 3

Risk Management

Risk management programs are used by organizations to identify and prioritize risks and to develop strategies to deal with those risks. Many different types of risks can impact an agency's ability to provide services and conduct business, including the ability to make PBRA decisions.

Risk management programs provide a vital link between data systems, planning and programming, and target-setting in transportation agencies. Risk assessment is part of the risk management process. This assessment includes access to data, which is used to develop performance measures and to perform cost/benefit analysis. Ultimately, risk assessment supports the link between data systems and planning, programming, and target-setting as illustrated in Figure 2.3.1.

This relationship is an iterative one that requires continuous evaluation of data and performance measures and a refinement and adjustment of risk priorities. This allows for adapting to changing strategic needs that support target-setting and transportation planning and programming.

The next examples illustrate how risk management programs are used at two state transportation agencies in Washington and Minnesota.

3.1 Washington State Department of Transportation

The Washington State Department of Transportation (WSDOT) uses risk management as part of project development in accordance with the following policy:

> It is the policy of the Washington State Department of Transportation (WSDOT) to conduct risk-based estimating workshops for all projects over $10 million (total of preliminary engineering, right of way, and construction).[9]

WSDOT has established an Enterprise Risk Management Office that is responsible for coordinating the risk management program at WSDOT. This office has developed a multi-step process that is used to facilitate risk management at WSDOT. The risk management steps are as follows:

1. Risk management planning—systematic process of deciding how to approach, plan, and execute risks;
2. Identification of risk events—determine which risks might affect the project;
3. Qualitative risk analysis—assess likelihood of risks and prioritize risks;
4. Quantitative risk analysis—numerically estimate probability that a project will meet its costs and time objectives;
5. Risk response planning—develop options to reduce threats to project objectives; and
6. Risk monitoring and control—track identified risks, monitor residual risks, identify new risks.[10]

WSDOT's enterprise risk management program examines the use of data, especially for developing performance measures, and evaluates its use for achieving agency strategic objectives.

This link between data and risk management is a critical one, especially when data is needed to support planning and programming and target-setting, and the necessary information may not be available because of intermittent network interruptions or catastrophic events. Risk management helps to identify when, where, and how these types of events may occur. This allows for the development of strategies to deal with any potential risks to agency assets—including data program assets.

As part of the risk management process at WSDOT, a priority rating system is used. This includes performance measures defined for such issues as crash frequencies, pavement ratings, and potential factors that impact risks to the infrastructure. The department uses a robust database with geometric and pavement conditions to define and assess performance measures that rely on location data.

[9] http://www.wsdot.wa.gov/publications/fulltext/cevp/1053policy.pdf

[10] http://www.wsdot.wa.gov/Design/SAEO

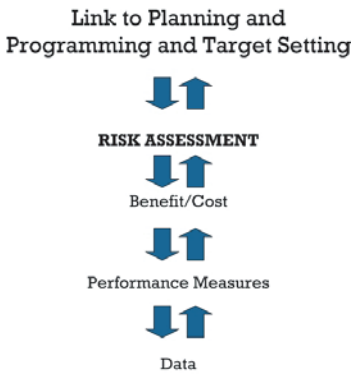


Figure 2.3.1. Data, risk management link to planning and programming and target-setting.

To address safety issues, the risk analysis process includes prioritizing areas of the state (such as corridors or specific highways that have the potential for improvements) that can result in reduced crashes and/or fatalities.

Additional risk analysis is performed by the region offices to assess what types of solutions can be implemented to address these issues. Potential solutions can then be incorporated into project plans.

One of the critical steps of this risk assessment process includes evaluating the costs of any proposed improvements. This type of analysis is referred to as a cradle analysis. The costs of improvements are compared with the ROI, which, in this case, includes evaluating whether the investment will reduce crashes and/or save lives.

3.2 Minnesota Department of Transportation

Mn/DOT, like WSDOT, has strong executive level support for their risk management program. Mn/DOT's Office of Policy Analysis, Research, and Innovation is responsible for coordinating risk management with Mn/DOT districts and for developing a corporate risk management model. The purpose of this office is to provide innovation for moving strategic initiatives forward faster.

The risk management program focuses on risk tolerance as well as the level of decision-making, and asks questions such as "how do you make tradeoffs with data and decision-making?" They want to build consistency in the definition of risk.

The risk management approach involves a process of "go deep, go wide, and be accountable" for risk management, as follows:

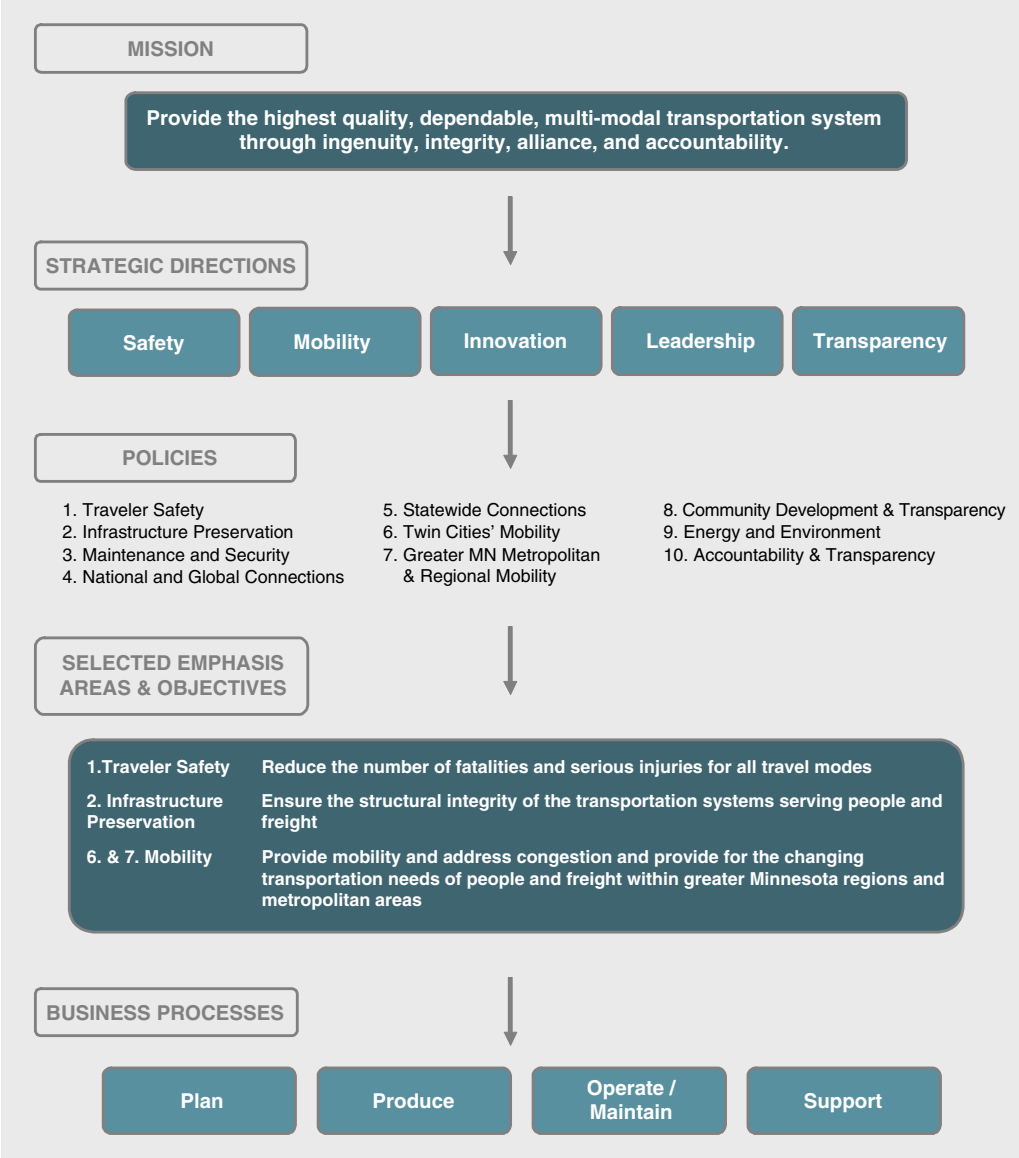
- Go deep—The risk manager facilitates risk management plans for a variety of issues and conducts hands-on risk management workshops.
- Go wide—Mn/DOT evaluates how the risk management process is used in each district. A risk profile was created for each district and a statewide meeting was held to examine the diversity of risks identified within each district. This process involves examining the relationship between performance measures and data, and how they are used in the districts. The data and performance measures are used as a means to judge and forecast risks. This includes assessing risks for the area of safety, and looking at assets that are not tangible (e.g., mobility). They are striving for consistency in the approach to risk management among districts.
- Be accountable—This process includes tracking decisions and risk-level impacts, district and statewide program risk levels, and risk management at the project level. This is an effort that is still evolving at Mn/DOT.

In addition to assessing risks at the district level, there is also a corporate risk tolerance level defined for Mn/DOT's investment plan. The investment plan needs to be auditable, and must account for data, performance measures, and risks. It needs to answer the question: "are we doing everything we can to manage risk?" This requires having the right type of data to assess the risks.

Mn/DOT has been proactive in developing a data business plan, including a framework (Figure 2.3.2) that helps the department to ensure that they continue to maintain the data systems that are needed to meet business needs and assess risks to the agency due to loss of data from any of their core data systems.

Mn/DOT uses a risk management model that is similar in many ways to the one used at WSDOT. The Mn/DOT risk management process includes the following steps:

1. Create vision of success by documenting the issues and gathering background information.
2. Gather data and performance measures.
3. Brainstorm the risks—this is the facilitation process.
4. Evaluate the timeframe for seeing the vision implemented. The longer the timeframe, the greater the risk.
5. For each risk, look at what the likelihood is that this event will occur.
6. Account for everyone's interest and opinions (including stating that they do not know, or are not sure of how likely it is that a particular event will occur).
7. Assess (based on scale of 1 to 5) how big an impact it will have if an event occurs.
8. Prioritize the risks and gain consensus on the list of risks.
9. Evaluate what to do about the risks.
10. Develop strategies to deal with the risks.
11. Evaluate how effective the strategy will be. Will it really help? This evaluation helps drive implementation plans and policy plans.



Source: *Mn/DOT Draft Data Business Plan*, May 2009.

Figure 2.3.2. Mn/DOT data business plan framework.

Mn/DOT also uses a risk assessment matrix to document potential risks to the agency in each of its strategic areas, including safety, mobility, innovation, leadership, and transparency.

A sample risk assessment matrix, or risk register, is provided (Table 2.3.1) to illustrate how risk statements are identified for particular risk areas, including safety, travel time, pavement management, bridge management, and others. Mn/DOT uses Excel spreadsheets as the primary IT tool to develop their risk registers.

This matrix includes the following components:

- Risk area;
- Risk statement that identifies the risk;
- Probability that the risk will occur;
- Impact of the risk on a scale of 1 to 5 (ranging from 1, which indicates little noticeable impacts on the system and the public is generally unaware, to 5, which indicates catastrophic impacts to overall system performance and the public is aware and upset with Mn/DOT); and
- Risk score, which is calculated by multiplying the probability times the value of the impact.

The highest scores indicate the areas with the greatest risks. This can be used to guide policy decisions regarding program investments to address these risks.

A similar risk assessment approach was used in determining whether to replace the existing Transportation Information

Table 2.3.1. Mn/DOT risk matrix.

Risk Area	Risk Statement -Try and Be Specific. Use Information, Performance Indicators and Measures to Identify.	PROBABILITY - Assume NO Change, and 10 years	IMPACT on District System, Public Trust and Confidence, QOL (1-5)	Score (function, do not fill)
Safety	The District's Safety approach is not effective or is not properly resourced for reducing fatalities and crashes, which results in an inability to manage behavior, and infrastructure problems.	95%	4	3.8
Other Infrastructure	Other infrastructure, Culverts, Drainage, Signs, etc. are not being managed or maintained and are at the bottom of the investment list, and that results in catastrophic failures and safety concerns. Rest Areas	95%	4	3.8
Local Priorities	The District is seen as not funding enough local priorities, which results in a negative relationship with our local partners/stakeholder's and impacts overall programming in the form of earmarks and discretionary funding and outcry.	95%	3.5	3.325
Pavements	Non-principals Pavements continue to exist at 20% "poor condition" in the District, which results in public trust and confidence issues and impacts to the public's QOL.	75%	4	3
Travel Time	Overall travel in segments on IRC in the District increases by 15% VMT in the next ten years on state highways, which results in travel time increases, trip reliability decreases and economic impacts.	75%	3	2.25
Pavements	Principals Pavements continue to exist at 10% "poor condition" by 2019 in the District, which results in public trust and confidence issues and impacts to the public's QOL.	75%	3	2.25
Trip Predictability	Trip predictability from incidents throughout IRC in the District is reduced, and results in further frustration and outside of the norm travel times. This also results in impacts to quality of life, safety, and impacts on the economy.	62%	2	1.24
Bridge	A number of additional District bridges need to be addressed over a ten-year period that is not covered by Chapter 152, which results in percent of poor bridge increasing significantly from current levels.	40%	3	1.2

Source: Mn/DOT Office of Policy, Analysis, Research and Innovation, February 2011.

System (TIS) at Mn/DOT. This example illustrates the relationship between data systems and risk management.

TIS is a complex mainframe system that was developed 30 years ago and is used to maintain roadway, traffic volume, and crash data. There were issues and differences of opinion between the business units and the IT office regarding the best approach for replacing TIS. This included discussions of the limitations of the current TIS mainframe.

TIS could not

- Integrate with new information systems such as the Bridge Management System;
- Provide a user-friendly interface for access to TIS data;
- Support a full range of query, analysis, and reporting functions;
- Keep track of history information for the roadway system;
- Provide multiple referencing systems for locating roadway changes and characteristics;
- Interface with newer GIS mapping applications; and
- Allow for easy addition of new roadway features like ramps and bikeways.

Mn/DOT used a risk assessment process to determine the risks associated with the development and implementation of three alternatives for replacing the system.

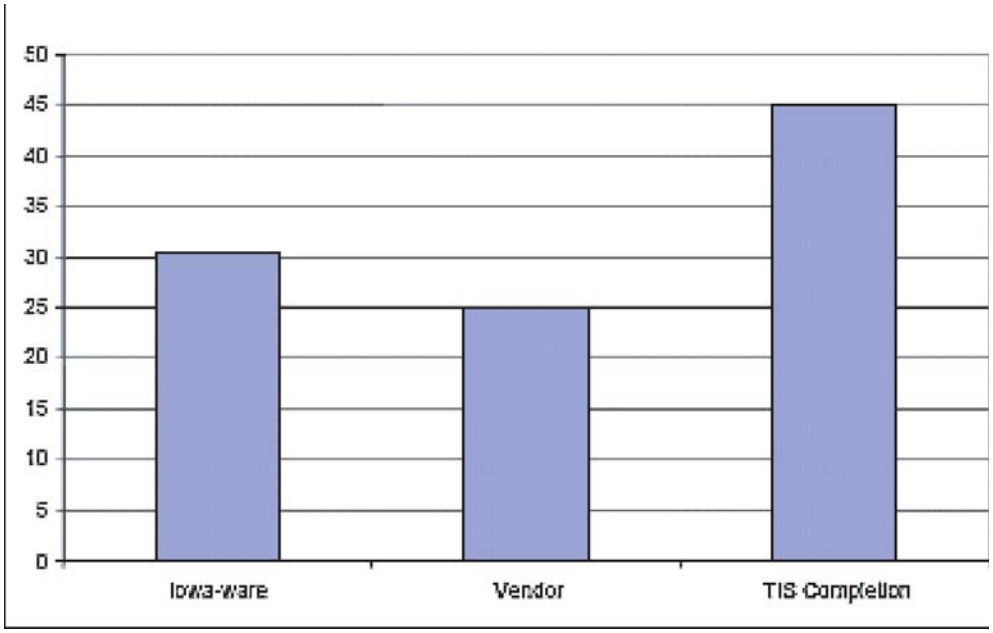
These alternatives were identified as follows:

- Iowa-ware,
- TIS completion, and
- Vendor alternative.

Mn/DOT evaluated the risks associated with each of these alternatives and identified strategies to minimize those risks. The risk management process was coordinated by Mn/DOT's Office of Policy Analysis, Research, and Innovation.

Risks were grouped similarly to the IT issues presented in this primer, into groups of high-, medium-, and low-level risks. Figure 2.3.3 illustrates the risk scores of each alternative, based on the risk analysis process.

In addition to evaluating the risk scores, other risk factors including costs and delivery of products in a timely manner also were closely compared.



Source: *TIS Risk Assessment Final Report*, November 17, 2009.

Figure 2.3.3. Mn/DOT TIS risk score.

The results of this risk assessment indicate that the TIS completion option has the highest level of risk. Mn/DOT determined that a closer comparison of the vendor and Iowa-ware solutions was needed. After further analysis, including comparative costs analysis, the vendor solution was determined to present less of a risk regarding development, implementation, and maintenance, than the Iowa-ware option. The decision was ultimately made to proceed with a Request for Proposals to implement a vendor solution. This example illustrates how a risk assessment process can be used to evaluate competing investments for all programs, including data programs.[11]

[11] *TIS Risk Assessment Final Report,* November 17, 2009, Mn/DOT Office of Policy, Analysis, Research, and Innovation.

APPENDIX A

Acronyms, Abbreviations, and Initialisms

AADT — Annual Average Daily Traffic
ADOT&PF — Alaska Department of Transportation and Public Facilities
ADT — Average Daily Traffic
ATIP — Annual Transportation Improvement Program
ATP — Area Transportation Partnership
AVL — Automatic Vehicle Location
BI — Business Intelligence
Caltrans — California Department of Transportation
CAPTA — Costing Asset Protection: An All Hazards Guide for Transportation Agencies
CCTV — Closed Circuit Television
CDOT — Colorado Department of Transportation
CEVP — Cost Estimate and Validation Process
COI — Community of Interest
COPACES — Computerized Pavement Condition Evaluation System
CRA — Cost Risk Assessment
C-TIP — Cross-Town Improvement Project
DRG — Dynamic Route Guidance
EIR — Environmental Impact Report
FARS — Fatality Analysis Reporting System
FTE — Full-Time Equivalent
FTP — File Transfer Protocol
GDOT — Georgia Department of Transportation
GIS — Geographic Information System
GPS — Global Positioning System
HAS — Highway Analysis System
HPMS — Highway Performance Monitoring System
IMEX — Intermodal Move Exchange
IT — Information Technology
ITS — Intelligent Transportation System
KM — Knowledge Management
KPI — Key Performance Indicators
Mn/DOT — Minnesota Department of Transportation
MPO — Metropolitan Planning Organization
MTC — Metropolitan Transportation Commission
NBI — National Bridge Inventory
OPM — Office of Organizational Performance Management
PACES — Pavement Condition Evaluation System

PBRA — Performance-Based Resource Allocation
PC — Personal Computer
Pga — Peak Ground Acceleration
QA/QC — Quality Assurance/Quality Control
QOL — Quality of Life
ROI — Return on Investment
RTTM — Real-Time Traffic Monitoring
SFR — Statewide Freight Resiliency
TAU — Traffic Analysis Unit
TIS — Transportation Information System
T-MDID — Truck-Mounted Driver Interface Device
TxDOT — Texas Department of Transportation
UPACS — User Profile and Access Control System
VDOT — Virginia Department of Transportation
WDU — Wireless Drayage Updating
WSDOT — Washington State Department of Transportation
XML — Extensible Markup Language

Abbreviations and acronyms used without definitions in TRB publications:

AAAE	American Association of Airport Executives
AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
ACI–NA	Airports Council International–North America
ACRP	Airport Cooperative Research Program
ADA	Americans with Disabilities Act
APTA	American Public Transportation Association
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
ATA	Air Transport Association
ATA	American Trucking Associations
CTAA	Community Transportation Association of America
CTBSSP	Commercial Truck and Bus Safety Synthesis Program
DHS	Department of Homeland Security
DOE	Department of Energy
EPA	Environmental Protection Agency
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
HMCRP	Hazardous Materials Cooperative Research Program
IEEE	Institute of Electrical and Electronics Engineers
ISTEA	Intermodal Surface Transportation Efficiency Act of 1991
ITE	Institute of Transportation Engineers
NASA	National Aeronautics and Space Administration
NASAO	National Association of State Aviation Officials
NCFRP	National Cooperative Freight Research Program
NCHRP	National Cooperative Highway Research Program
NHTSA	National Highway Traffic Safety Administration
NTSB	National Transportation Safety Board
PHMSA	Pipeline and Hazardous Materials Safety Administration
RITA	Research and Innovative Technology Administration
SAE	Society of Automotive Engineers
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (2005)
TCRP	Transit Cooperative Research Program
TEA-21	Transportation Equity Act for the 21st Century (1998)
TRB	Transportation Research Board
TSA	Transportation Security Administration
U.S.DOT	United States Department of Transportation