Long-Term Bridge Performance High Priority Bridge Performance Issues

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Long-Term Bridge Performance Program

Research, Development, and Technology
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FOREWORD

This study was conducted as part of the Federal Highway Administration's (FHWA) Long-Term Bridge Performance (LTBP) Program. The LTBP Program is a minimum 20-year research effort, authorized by the U.S. Congress, to collect high- quality bridge data from a representative sample of highway bridges nationwide, that will help the bridge community better understand bridge deterioration and performance. The products from this program will be a collection of data-driven tools, including predictive and forecasting models that will enhance the abilities of bridge owners to optimize their management of bridges.

One of the first needs identified for LTBP Program development was to determine what specific bridge performance issues should be studied under the program. This would lead the way to identifying bridge data needs for the program, designing necessary data infrastructure, selecting bridges for the program, and designing effective experiments. This report documents the process used in the LTBP Program for identifying high priority bridge performance issues. Fifteen State departments of transportation participated in a series of focus group meetings and provided input on high priority bridge performance issues. Input was also solicited from the bridge community at large. The list of issues was periodically refined, evaluated, and described in detail. This report provides the results of that effort: 22 high-priority performance issues and a short list of six 6 issues that will be the initial focus of the LTBP Program. This report will be of interest to bridge program personnel from Federal, State, and local agencies as well as to parties engaged in bridge-related research and the practicing bridge engineering community.

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Research and Development

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16. Abstract

Bridge performance is a multifaceted issue involving performance of materials and protective systems, performance of individual components of the bridge, and performance of the structural system as a whole. The Long-Term Bridge Performance (LTBP) Program was initiated to collect, store, and analyze the data necessary to better understand high priority bridge performance issues. The success of the program depends on first being able to identify the most important performance issues bridge owners face. To identify these issues, input from those bridge owners and other key stakeholders was sought. As part of this outreach, bridge experts in 15 State transportation departments were interviewed and asked to name the performance issues in their bridge inventory that are most common and/or most difficult to solve. The findings of these interviews are included in this report. To supplement these interviews and identify high priority issues related to bridge substructures, a workshop on substructure performance issues was held. The findings from the interviews and the substructure workshop were used to develop a list of 22 high priority performance issues. From this list, a shorter list of six bridge performance issues was recommended as the first group of issues for study under the LTBP Program.

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
^oF	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	^oC
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
^oC	Celsius	1.8C+32	Fahrenheit	^oF
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.
(Revised March 2003)

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LIST OF ACRONYMS AND ABBREVIATIONS

AASHTO	American Association of State Highway and Transportation Officials
ABC	Accelerated Bridge Construction
ABIMS	Alabama Bridge Information Management System
ADOT	Alabama Department of Transportation
ADT	Average Daily Traffic
ASR	alkaline silica reactivity
BAMS	Bridge Analysis & Monitoring
Caltrans	California Department of Transportation
CoRe elements	Commonly Recognized elements
FHWA	Federal Highway Administration
FDOT	Florida Department of Transportation
GASB	Government Accounting Standards Bulletin
GPR	Ground-Penetrating Radar
HI	Health Index
HPC	High Performance Concrete
IADOT	Iowa Department of Transportation
IDOT	Illinois Department of Transportation
KDOT	Kansas Department of Transportation
LTBP	Long-Term Bridge Performance
MDOT	Montana Department of Transportation
Mn/DOT	Minnesota Department of Transportation
MOT	Maintenance of Traffic
MSE	Mechanically Stabilized Earth
NCHRP	National Cooperative Highway Research Program
NBI	National Bridge Inventory
NBIS	National Bridge Inspection Standards
NDE/NDT	Nondestructive Evaluation/Nondestructive Testing
NHS	National Highway System
NJDOT	New Jersey Department of Transportation
NYSDOT	New York State Department of Transportation
ODOT-OH[*]	Ohio Department of Transportation
ODOT-OR[*]	Oregon Department of Transportation
OPI	Operational Performance Indicator
PE	Professional Engineer
PLAT	Project-Level Analysis Tool
QA	Quality Assurance
QC	Quality Control
SHM	Structural Health Monitoring
STIP	State Transportation Improvement Program
TRB	Transportation Research Board
TxDOT	Texas Department of Transportation

[*] The Ohio and Oregon State transportation departments both use the formal abbreviation ODOT. This abbreviation was modified for purposes of this report by appending the standard State abbreviation.

UDOT	Utah Department of Transportation
UT	Ultrasonic Testing
VDOT	Virginia Department of Transportation

CHAPTER 1. INTRODUCTION AND OVERVIEW

The U.S. infrastructure is aging and deteriorating, while public State transportation departments are struggling to keep pace using limited resources. Bridges are critical components of the highway infrastructure; a bridge that is in poor condition or one that has inadequate functional capacities can cause a reduction in the operating capacity of the highway system. The problem is compounded when work is necessary to properly maintain, rehabilitate, or replace an existing structure or a series of structures. Bridge work sites usually involve one or more conditions that result in disruptions to safe, efficient, and economical traffic flow. These include lanes that are narrowed, shifted, or closed; live load restrictions; speed reductions; detours; and work zone related safety hazards. These conditions often result in moderate to severe impacts on local and regional economies and environments, such as loss of productive time because of traffic delays and detours, increased consumption of fuel, and increased engine emissions.

The Federal Highway Administration (FHWA) initiated the Long-Term Bridge Performance (LTBP) Program as authorized in the "Safe, Accountable, Flexible, and Efficient Transportation Equity Act: A Legacy for Users," signed into law in August 2005. The LTBP Program is a 20-year (minimum), multifaceted research effort that is strategic in nature. It is similar to the Long-Term Pavement Performance Program that has been under way for more than 20 years. Critical aspects of bridge performance will be studied to better understand those issues and to improve performance related to those issues. This report describes how the high priority bridge performance issues to be studied under the program were identified and prioritized with the assistance of bridge owners and other key stakeholders in the bridge community.

Bridge performance is a multifaceted issue involving performance of materials and protective systems, performance of individual components of the bridge, and performance of the structural system as a whole. The performance of any single bridge or element of a bridge is dependent on multiple factors, many of which are closely linked. They include the original design parameters and specifications (bridge type, materials, geometries, load capacities); the initial quality of materials and quality of the as-built construction; varying conditions of climate, air quality, and soil properties; and corrosion and other deterioration processes. Other factors influencing performance include traffic volumes, counts and weights of truck loads, truck live load impacts, and damage sustained as a result of scour, seismic events, wind, etc. A final critical factor influencing performance is the type, timing, and effectiveness of preventive maintenance, of minor and major rehabilitation actions, and ultimately of replacement actions applied to the bridge. All of these factors combine to affect the condition and operational capacities of the bridge and its various structural elements at any given point in the life of the bridge. Currently, some important aspects of bridge performance are not well understood, and some of the main factors related to bridge performance are not well documented. Often, attempts at assessment of how bridges are performing are partly based on expert opinion and/or on analyses that are hampered by lack of crucial data and thus are dependent on one or more assumptions or generalizations.

Optimal performance of bridges is of paramount importance to support the fundamental mission of State transportation departments to provide the best service to the traveling public and commercial interests. It is also vital for minimizing the overall (lifecycle) costs of keeping bridges in service. Understanding bridge performance is a key factor in a State transportation department's ability to address current bridge deficiencies (functional as well as structural) and to design and build better performing bridges for the future. Understanding performance is critical to the planning, design, and construction processes that lead to bridges that are easier, faster, and less costly to build and maintain, including the use of new and innovative bridge materials. More information on bridge performance can be found in the FHWA publication *LTBP Bridge Performance Primer* (FHWA-HRT-13-051).(1)

To achieve a better understanding of bridge performance, it is necessary to examine bridge performance as a broad spectrum concept in which multiple issues sometimes compete and often are interrelated. A primary objective of the LTBP Program is to collect data, information, and knowledge on bridges. It is important to collect and prioritize the issues to be studied and the data items according to feasibility and economics, as well as relevance and value to gain a better understanding of bridge performance.

To assist with this challenge, the possible performance issues and the parameters influencing performance were first classified into four broad categories. This is the starting point for beginning to identify the performance issues that are most important to owners. As figure 1 shows, the primary issues in bridge performance are the following:

- Structural condition—durability and serviceability (including fatigue).
- Functionality—user safety and service.
- Costs (State transportation department and users).
- Structural integrity—safety and stability in failure modes.

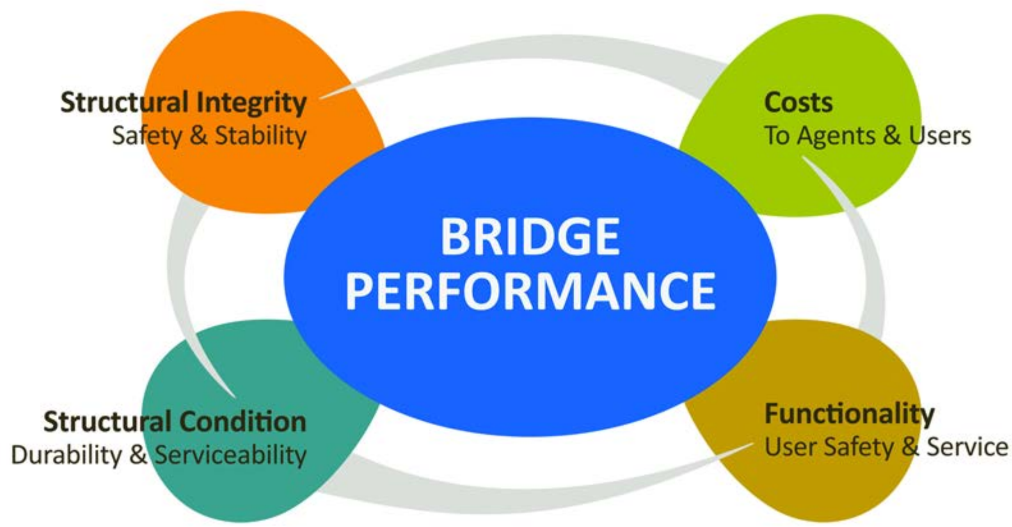

Figure 1. Illustration. Categories of bridge performance issues.

Many of the important parameters that influence these four categories of bridge performance are listed in table 1.

Table 1. Categories of bridge performance and influencing factors.

Category	Influencing Factors
Structural Condition—Durability and Serviceability (including fatigue)	• Structure type. • Structural materials and material specifications. • As-built material qualities and current conditions. • As-built construction qualities and current conditions. • Truck loads and other live loads. • Environment—climate, air quality, marine atmosphere. • Snow and ice removal operations. • Type, timing, and effectiveness of preventive maintenance. • Type, timing, and effectiveness of restorative maintenance, minor and major rehabilitation. • Flooding, hydraulic design, and scour mitigation measures. • Soil characteristics—settlement.
Functionality—User Safety and Service	• Structure geometry—clear deck width, skew, approach roadway alignment. • Skid resistance and ride quality of riding surface vertical clearances—over and under. • Traffic volumes and percentage of trucks. • Posted speed. • Postings and load ratings—restrictions on use.
Costs (user and State transportation department)	Users • Accident costs. • Detour and delay costs. State Transportation Department • Initial construction costs. • Maintenance, repair and rehabilitation costs. • Costs for maintenance of traffic.
Structural Integrity—Safety and Stability in All Failure Modes	• Seismic performance • Hurricane and flood resistance. • Collision and blast impacts. • Fire resistance. • Structural redundancy and load redistribution.

LTBP PROGRAM OVERVIEW

The overall objective of the LTBP Program is to inspect, evaluate, and periodically monitor representative samples of bridges nationwide to collect, document, maintain, and manage high-quality quantitative performance data over an extended period of time. This will require taking advantage of sensing technologies and nondestructive evaluation and testing tools in addition to typical bridge inspection approaches. It will also require close collaboration among stakeholders, State transportation departments, academia, and industry to gather data that are available but not currently gathered into a single database by anyone in the bridge community. The LTBP Program is designed in part to collect critical performance data that is not available elsewhere and merge it with data gathered from available sources.

It is anticipated that the LTBP Program will provide a better understanding of bridge deterioration, focusing on its numerous causes, including loads, environment, and de-icing chemicals. The program will also collect information regarding the effectiveness of current maintenance and improvement strategies. It is envisioned that data on bridges will be stored in the Bridge Portal, a new tool developed for the LTBP Program, and will be used to solve a variety of bridge condition assessment and management problems, to develop new tools, and to advance the state-of-the-knowledge of bridge management, design, maintenance, and preservation.

GENERAL DATA REQUIREMENTS FOR THE LTBP PROGRAM

An early requirement during the development of the program was to establish what specific aspects of bridge performance are most critical to FHWA, State transportation departments, and other public bridge-owning State entities. Following this, these aspects of bridge performance were evaluated to determine whether they could be adequately studied with the available LTBP Program resources. Finally, the issues were ranked in priority order to determine which issues would be addressed first.

The selection of performance issues to study under LTBP is intrinsically linked to the feasibility of collecting the data necessary to study the issues. In addition to owner input on the priority for performance issues, input from the owners on data to collect, and that could feasibly be collected, was critically important. The owners know what types of data are already being collected by their State transportation departments, as well as how it is stored and how accessible it is for transfer to the LTBP Program database. With regard to field inspection data to be collected, the owners must approve and allow all aspects of field testing on their bridges. Another reason for owner input on data needs is that the owners know what types of decision support tools would be most useful in their decisionmaking processes. This also helps define the LTBP data needs.

The issue of data to be collected was an important part of the discussions with owners about the performance issues to be studied and was included in the objectives of the focus group meetings described in chapter 2. It is the subject of the upcoming FHWA report *Identifying Long-Term Bridge Performance Data Needs*.

CHAPTER 2. STAKEHOLDER INPUT—STATE TRANSPORTATION DEPARTMENT FOCUS GROUPS

Early and continual involvement by bridge owners in the development and implementation of the LTBP Program was deemed to be critically important to the success of the program. At an early stage in the development phase, three issues were identified for which input from bridge owners was important to the pursuit of the development phase tasks. First was the need to determine what aspects of bridge performance were most important to the owners and then to determine what gaps existed in their understanding of these aspects of bridge performance. That information is the focus of this report. Second was the need to examine what information and data owners currently had for use in their decisionmaking processes and to identify where there were critical gaps. Third was to understand their decisionmaking process and business practices to help identify what products the LTBP Program could develop that would best assist bridge owners in managing their bridge programs. That information was used internally by FHWA.

The approach selected to collect this information was to hold a series of focus groups across a number of geographically distributed States. The best source of the required information was deemed to be the State transportation departments. Therefore, focus group meetings were designed to allow interviews with a group of bridge inspectors, engineers, and managers from each of the selected States. As a result of the meetings, valuable information was obtained on performance issues of concern, data needs, performance measures that the transportation departments currently use, and what those departments saw as desired outcomes of the program. Detailed records of the meeting discussions are included in appendix B.

FOCUS GROUP OBJECTIVES

A focus group interview process was adopted to assist the team in achieving the following objectives:

1. Develop an understanding of how representative States manage and track bridge performance.

2. Identify the most common concerns and the most costly activities of the representative States in maintaining, repairing, rehabilitating, and replacing bridges.

3. Determine what data the States currently collect and use for their decisionmaking processes and what gaps they see in their currently available data.

4. Identify the aspects of bridge performance on which the States would like the program to focus.

PROCESS

The first step was to develop a practical process to solicit the assistance of State transportation department bridge personnel (experts in bridge design, inspection, maintenance, preservation, and management) in gathering information about the processes they use and the activities they carry out related to bridge performance. To develop a program that is grounded in the real world of bridge engineering, input was needed from experienced bridge practitioners. State transportation department input was obtained to help ensure that the LTBP Program would provide practical data and results that practitioners could use in managing the performance of bridge inventories and to allow State transportation departments to share with the FHWA what they believe is needed.

It was agreed that the focus groups should represent owners of a geographically, economically, and environmentally diverse cross section of State transportation departments because they represent a majority of the custodians of the national bridge inventory. Six regions were designated across the continental United States; table 2 presents the list of State transportation departments ultimately selected from each region.

Table 2. List of focus group States by region.

Region	States
Northwest	Montana, Oregon, Utah
Southwest	California, Texas
North Central	Iowa, Illinois, Kansas, Minnesota
South Central	Alabama
Northeast	New Jersey, New York, Ohio
Southeast	Virginia, Florida

Figure 2 presents the geographic distribution of State transportation departments identified for focus group participation**.**

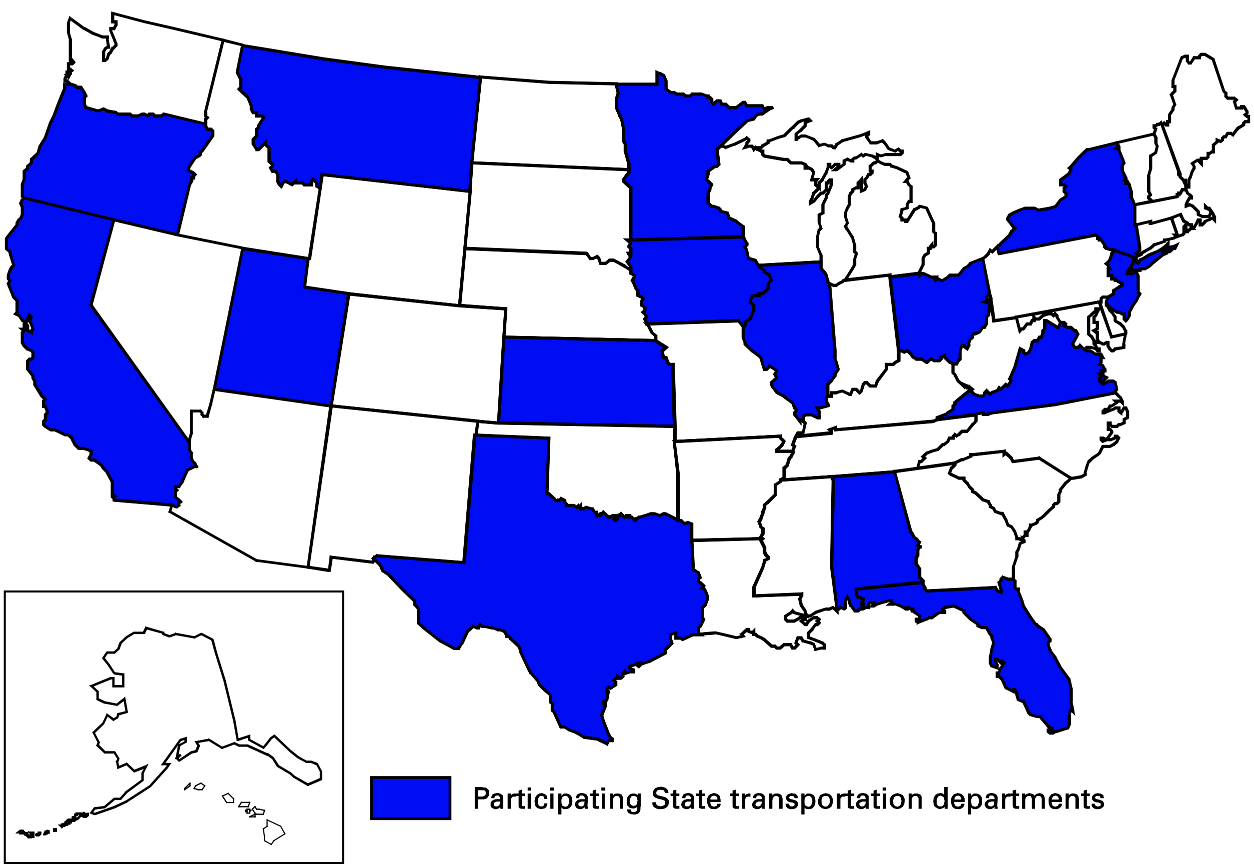

Figure 2. Map. Participating State transportation departments.

In 2008, focus group meetings were conducted in Virginia, California, New Jersey, New York, and Florida. In 2009, focus group meetings were conducted in Minnesota, Utah, Texas, Iowa, Montana, Oregon, Ohio, Alabama, Illinois, and Kansas. State transportation department bridge personnel were asked to come to the meetings ready to discuss the following:

- Organizational structure and processes within the transportation department relative to bridge funding, design, management, inspection, and maintenance programming.
- The 5 to 10 most common forms of deterioration, damage, or functional issues faced in maintaining, repairing, or rehabilitating highway bridges.
- The 5 to 10 most common bridge maintenance, repair, or rehabilitation activities on which the State transportation department expends the most resources, with estimates of man-hours and funds spent on each annually.

The focus groups discussed specific modes of deterioration for bridge decks, superstructures, substructures, and ancillary systems, as well as functional and operational aspects of bridge management. Focus group meetings concentrated on the following:

- State transportation department organizational structure relative to bridge management and bridge maintenance, the roles of the relevant groups or divisions within their department, and how those groups made decisions and shared information.
- Each group discussed State transportation department bridge management systems, including the policies, processes, and procedures for program-level management of the bridge inventory within its organization. This included overviews of the system(s) in place for collecting, housing, and reporting bridge inventory, condition, activities, and expenditures. In general, each group was asked to identify the information and sources transportation departments perceived as most useful for program-level decision support.
- Performance measures used by the State transportation department to gauge the success of the bridge management program and at what levels.
- The most common forms of deterioration and damage on the transportation department's bridges, what information the department used to evaluate condition(s) and what information it used to develop feasible solutions. Generally, the responses were grouped into categories by general structural components of the bridge, including decks, superstructure, substructure, ancillary systems, and also a nonstructural functional category.
- The most common maintenance activities the State transportation department performed and the information they had to base their choice of feasible solutions.
- Innovative policies, or new techniques or tools, that had been implemented and that the State transportation department felt had been successful.
- Outcomes the State transportation department would like to see from the LTBP Program.

Appendix A contains the specific questions asked of the focus groups. Interviews were taped and transcribed and notes were summarized. The information gathered served as a guide in identifying high priority performance issues.

KEY FINDINGS

Appendix B outlines the detailed results from the respective focus group interviews. Representatives of 5 transportation departments indicated that their departments had a centralized organizational structure for managing the bridge inventory, whereas 10 indicated such operations were distributed among operating districts or other decentralized units.

An National Bridge Inventory (NBI) bridge is defined as any structure on a public highway that meets the NBI definition of a bridge: A structure including supports erected over a depression or an obstruction, such as water, highway, or railway, and having a track or passageway for carrying traffic or other moving loads, and having an opening measured along the center of the roadway of more than 20 ft between undercopings of abutments or spring lines of arches, or extreme ends of openings for multiple boxes; it may also include multiple pipes, where the clear distance between openings is less than half of the smaller contiguous opening.(1) At the time the interviews were conducted, representatives of 12 State transportation departments indicated that they collect AASHTOWare Bridge Management® software element-level condition information during their periodic inspections of NBI bridges, and 3 transportation departments did not. The representative of one transportation department indicated that the department was awaiting the release of the new national bridge elements definitions, which were expected to replace the American Association of State Highway and Transportation Officials (AASHTO) Commonly Recognized (CoRe) element definitions.(2) The other three States collect NBI condition ratings but do not collect element-level condition information.(3)

Table 3 provides information regarding the bridge inventories in the focus group States and whether they collect element-level inspection data on their bridges.

Each transportation department was asked to identify bridge performance issues it experienced on decks, superstructures, and substructures. Table 4 indicates which transportation departments experienced certain performance issues related to bridge decks. The Alabama Department of Transportation (ADOT) did not report any performance issues with decks.

Table 5 indicates the transportation departments that experienced certain performance issues related to bridge superstructures. All of the transportation departments that were interviewed reported at least one performance issue with superstructures.

Table 6 indicates the transportation departments that experienced certain performance issues related to bridge substructures. The Oregon Department of Transportation (ODOT-OR) did not identify any specific performance problems related to substructures. (Note that the Ohio and Oregon State transportation departments both use the formal abbreviation ODOT. To avoid confusion, this report uses the abbreviation ODOT-OR for the Oregon agency.)

Table 3. State transportation department bridge inventory and management structure.

Characteristic	AL	CA	FL	IA	IL	KS	MN	MT	NJ	NY	OH	OR	TX	UT	VA
Transportation Department Management Structure	D	C	D	C	D	C	D	C	C	D	D	D	D	D	D
No. of NBI Bridges in the State	16,070	24,807	10,845	24,495	26,056	24,812	13,121	5,120	5,391	16,473	26,573	7,631	51,467	2,947	13,965
No. of Bridges under State Responsibility	5,738	12,180	5,414	4,071	7,740	4,976	3,615	2,488	2,371	7,460	10,345	2,706	33,513	1,773	11,892
No. of Bridges under Local or Other Responsibility	10,332	12,627	5,431	20,424	18,316	19,836	9,506	2,632	3,020	9,013	16,228	4,925	17,954	1,174	1,965
Collect AASHTOWare Bridge Management® Software Data	Pending	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes

C = Centralized
D = Decentralized

Table 4. State transportation department reported issues related to decks.

Issue	Total States	CA	FL	IA	IL	KS	MN	MT	NJ	NY	OH	OR	TX	UT	VA
Spalling	9	✓	✓	✓			✓	✓	✓	✓	✓			✓	
Cracking	8	✓	✓			✓	✓		✓	✓	✓				✓
Delamination	8	✓		✓		✓		✓		✓	✓			✓	✓
Sealing	4	✓	✓				✓					✓			
Overlays	3						✓				✓			✓	
Patches	2						✓								✓
Delamination of polymers overlays	2						✓							✓	
Carbonation of older concrete decks	2							✓					✓		
Fatigue cracking	1														✓
Soffit spalling	1			✓											
Studded tires	1									✓					
Construction related issues, e.g., deck curing procedures	1									✓					
Timber replacement	1														✓
Ingress of chlorides	1				✓										

All blank cells indicate that no issues of this type were reported by the given State transportation department.

Table 5. State transportation department reported issues related to superstructures.

Issue	Total States	AL	CA	FL	IA	IL	KS	MN	MT	NJ	NY	OH	OR	TX	UT	VA
Coating system failures, steel corrosion on steel bridge superstructure members	11	✓	✓	✓		✓	✓		✓		✓	✓	✓		✓	✓
Joint deterioration, leakage	11	✓	✓		✓	✓	✓	✓		✓	✓	✓	✓		✓	
Impact damage; steel and/or concrete beams	9			✓	✓			✓	✓	✓	✓			✓	✓	✓
Deterioration of concrete and steel girder ends under joints	4	✓			✓	✓					✓					
Prestressed concrete beams—difficulty of inspecting condition of strands	2					✓									✓	
Steel fatigue	3	✓	✓				✓									
Drainage off the deck	3									✓		✓			✓	
Cracked girders	2		✓										✓			
Spalling of beams	1			✓												
Excessive rusting of weathering steel	1														✓	
Concrete pop-outs due to freezing	1															✓
Rusting/freezing of box girder hinges	1		✓													
Cracks in elements—impact or construction related	1			✓												
Alkaline Silica Reactivity (ASR)	1													✓		
Added inspection needs for fracture critical bridges	1													✓		
Parapet spalling	1															✓
Deterioration of concrete in box beams	1												✓			
Corrosion at construction joint between rail and deck	1				✓											

All blank cells indicate that no issues of this type were reported by the given State transportation department.

Table 6. State transportation department reported issues related to substructures.

Issue	Total States	AL	CA	FL	IA	IL	KS	MN	MT	NJ	NY	OH	TX	UT	VA
Scour	13	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓
Cracking, spalling, or delaminations of components	9			✓	✓	✓		✓		✓	✓		✓	✓	✓
Corrosion of steel pile bents	4	✓		✓	✓								✓		
Bearing corrosion or malfunction	7			✓	✓		✓	✓	✓	✓			✓		
Approach slab settlement	3											✓	✓	✓	
Corrosion of mild steel reinforcing in components	2			✓							✓				
Leaking joints	2							✓		✓					
Seismic	2		✓			✓									
Leaking joints	2							✓		✓					
ASR	1		✓												
Beam locking on steel bridges	1													✓	
Corrosion of strands in pre-stressed piling	1			✓											
Erosion under approach slabs	1													✓	
Splash zone issues	1													✓	
Timber piles	1										✓				
Settlement	1						✓								
Cathodic protection	1					✓									

Beam locking describes a situation on a simple-span steel girder bridge where one bearing is frozen and all of the expansion must be accommodated by the other bearing; in some cases, clearance between the beam end and the abutment backwall is too small to allow full expansion and so the beam end contacts and sometimes damages the abutment backwall.

All blank cells indicate that no issues of this type were reported by the given State transportation department.

Each State transportation department was asked to identify any issues related to functional performance of their bridges. As table 7 shows, only five State transportation departments identified any specific performance problems related to functional issues.

Table 7. State transportation department reported issues related to functional issues.

Issue	Total States	FL	MT	NJ	NY	TX
Load ratings	3	✓		✓	✓	
Approach versus bridge width	2		✓		✓	
Traffic service	2		✓		✓	
High mast illumination poles	1					✓
Impact damage from barges	1	✓				
Railings and transitions	1					✓
Vertical clearance	1			✓	✓	

All blank cells indicate that no issues of this type were reported by the given transportation department.

Functional issues represent a safety hazard (such as a narrow bridge or a poor alignment between bridge and approach roadway) or affect traffic capacity (such as insufficient lanes).

Performance Measures

Many of the State transportation departments interviewed use performance measures by which to evaluate the effectiveness of their bridge programs. These performance measures generally fall into one of three types. The first type of measure counts the number of bridges or total deck area of bridges that meet a defined standard such as "structurally deficient." Alternatively, the measure may be number of bridges or total deck area of bridges that are rated to be in "good," "fair," or "poor" condition. In this rating system "good" usually means bridges with an NBI condition rating of 9, 8, or 7; "fair" means bridges with an NBI condition rating of 6 or 5; and "poor" means bridges with an NBI condition rating of 4 or below.

A second approach is to count the number of bridges or total deck area of bridges that have a defined minimum value on a defined index such as the Federal Sufficiency Rating. A third approach tracks completion of items that have been identified as needing maintenance or repair.

Several States use multiple measures. Note that these measures do not, by and large, directly measure the performance of individual bridge engineering, maintenance, and management actions or strategies. Some of the program performance measures in use are listed in table 8.

Table 8. Performance measures identified by focus groups.

Type	Measure	No. of Transportation Departments Using
Defined Status or Condition	Load posted bridges	2
	Structurally deficient bridges	5
	Functionally obsolete bridges	3
	Bridges rated good, fair, poor	3
Defined Index	Federal Sufficiency Rating	4
	Health Index for the whole bridge	4
	Custom rating systems for bridges and components	3
Status of Maintenance Needs	Actual versus desired maintenance response time	3
	"Percentage of deficiencies 'flagged' for maintenance items that have been fixed"	1
	No. of critical findings resolved	1

CHAPTER 3. OTHER STAKEHOLDER INPUT

During the development phase of the LTBP Program and even prior to its start, FHWA and the research team sought input on critical aspects of bridge performance from key stakeholders and strived to maintain a continuing dialogue with members of the bridge community. An important element of that dialogue was the discussion of the bridge performance issues that the program could and should study. This dialogue was carried on in workshops and technical conference sessions devoted to long-term bridge performance, in briefings and discussions with bridge-related technical committees (for example, AASHTO and Transportation Research Board (TRB)), and in informal meetings with State transportation department bridge personnel.

FHWA LTBP WORKSHOP

In January 2007, FHWA, the National Science Foundation, and the University of Nevada—Reno cosponsored a workshop in Las Vegas to develop initial strategies and recommendations for implementing the LTBP Program. The workshop was attended by 46 professionals from State transportation departments, FHWA, industry, and academia. The purpose of the workshop was to gather the collective advice of these experts on how to implement the program and, most important, what they would suggest for the priorities for collection of bridge data. The workshop did not produce recommendations on performance issues to study but did generate a comprehensive list of data that could be collected on the properties and conditions of bridge elements and materials. The data needs identified are the subject of the upcoming FHWA report *Identifying Long-Term Bridge Performance Data Needs*. However, the lists of data recommended for collection clearly indicate an emphasis on the condition of the major elements of the bridge as a key issue.

FHWA SUBSTRUCTURES WORKSHOP

Based on the conclusions reached from the first 15 focus group meetings, several of the issues identified were ones in which geotechnical factors were of potential importance. These issues are the following:

- Direct, reliable, timely methods to measure scour.
- Scour countermeasures.
- Structure foundation types.
- Unknown foundation types.
- Bridge bearings (all types).
- Jointless structures (integral, semi-integral, continuous for live load).

Within this range of topics, FHWA research and management personnel were concerned that geotechnical, foundation, and substructure concerns may not have been adequately captured. Therefore, FHWA, as part of the LTBP initiative, hosted a Workshop to Identify Bridge Substructure Performance Issues in Orlando, FL, in March 2010. FHWA personnel, the LTBP Program research team, and approximately 30 invited attendees representing State transportation departments; FHWA headquarters, Federal aid, and Federal lands and research; academia; and consultants met to consider overall bridge performance and identify geotechnical performance metrics that may correspond to good and poor performance. Attendance at the workshop was by invitation from FHWA so that an effective mix of backgrounds and perspectives would be represented. The core of the workshop comprised breakout sessions to discuss three key elements of the program: bridge performance issues (affected by geotechnical factors); data needs and gaps (related to the issues identified); and tools, technology development, and monitoring (related to the data gaps).

Based on the brainstorming of the three groups and from the post-workshop discussions, the following short-term bridge performance priorities emerged (not in ranked order):

- Approach and bridge interface issues.
- Material degradation, corrosion, and deterioration issues.
- Mechanically stabilized earth (MSE) wall material degradation and assessment of wall integrity.
- Hydraulics, scour, and erosion.

From the results of this workshop and other available information, these issues are being considered and refined for inclusion in the LTBP Program list of study topics.(4,5)

STATE LTBP COORDINATORS

FHWA has established an LTBP State Coordinators Group with one key bridge person from each State in the Nation, the Commonwealth of Puerto Rico, and the District of Columbia. The inaugural meeting of the LTBP State coordinators was held September 13–14, 2011, to familiarize the State representatives with the scope and goals of the program, summarize the anticipated role of the coordinators, and solicit their ideas and feedback on the conduct of the program and planning for the broader execution phase of the program. The list of high priority performance issues that was current at the time was presented to the group, and the coordinators endorsed the list.

One additional meeting was held with the Pennsylvania Department of Transportation in January 2012 to familiarize its representatives with the program and general findings of the development phase and solicit their comments. They identified some of the same issues as the focus group States, such as performance of deck joints and verification of the condition of embedded prestressing strands in prestressed concrete. They also identified the wear and tear that trucks used for fracking have caused to bridges along a specific highway in their State, early age cracking of high-performance concrete decks, and the uncertainty of how much that cracking might decrease the life of the deck as important issues to address.

TRB LTBP COMMITTEE

Under contract with the National Academy of Sciences, FHWA has coordinated with TRB to organize and facilitate a TRB LTBP Committee composed of members from government, industry, consultants, and academia to annually provide feedback on the progress of the LTBP Program and provide recommendations on strategies for the Program.

At the first meeting of the TRB LTBP Committee in November 2011, the members reviewed the high priority performance issues being recommended for study and subsequently informed FHWA of their concurrence with the proposed list.[6,7]

CHAPTER 4. SUMMARY OF FINDINGS

COMMON PERFORMANCE ISSUES THAT NEED RESEARCH

The LTBP Program is to be a long-term program to collect comprehensive information on bridge performance issues that will support improvements to bridge management practice and lead to improvements in bridge performance. However, a clear message is being received from many stakeholders that the program must provide early results and clear benefits in the near term. The issues most often identified by the focus groups and other stakeholders were related to preservation of bridges and performance improvements that would show great promise for service life extension, increase in safety, or reduction of user and State transportation department costs relative to maintenance and operation of the structures. Focusing efforts early on these issues can pay swift dividends and pave a clear path toward longer term gains. The performance issues most frequently cited by the State transportation departments during the focus group meetings are described below. It is recommended that these items become the key topics that the LTBP Program addresses.

Decks

In middle and northern latitudes of the United States, degradation of reinforced concrete bridge decks is a widespread problem. Cracking, spalling, and delaminations were common results requiring maintenance and rehabilitation. Indeed, all of the focus groups, with the exception of Florida Department of Transportation (FDOT), noted that repair and rehabilitation of decks accounts for more than half of the maintenance expenditures on their bridges and represent the highest priority issues for performance. Hence, significant benefits can be gained from better characterization of deck performance and prevention of deterioration of decks. Performance concerns cover both bare (untreated) concrete decks and concrete decks treated with sealers and overlays. These State transportation departments are seeking methods to diagnose problems early, accurately, and with minimal traffic impact. Further, these departments expressed a need for the following:

- Better predictions of the time when deck repair or rehabilitation will be needed.
- Better tools to rapidly and accurately quantify the extent and severity of damage to decks without requiring lane closure to support detailed visual surveys or sounding.
- Better information about which treatments perform the best and the optimum time that each should be applied.

Joints

Almost hand-in-hand with decks is the problem with joints; some State transportation departments report very limited service life of most available joint systems and difficulty in monitoring joint conditions. Often, joints have completely failed and remained so for a period of time before they can be resealed or replaced. Joint failures can lead to corrosion-induced deterioration of bearings, abutment bridge seats, pier caps, and the ends of beams, especially in regions with significant de-icing operations. A practice that is becoming more common is to design and build bridges that do not have joints in the deck, thereby eliminating the need for joint maintenance to protect bearings, bridge seats, girder ends, etc.

Jointless Bridges

As noted above, when bridge joints fail and potentially corrosive materials are allowed to contact other elements of the bridge, significant corrosion-induced deterioration of other critical elements of the bridge can result. A good practice that can serve as an alternative to open or sealed joints on a bridge is to design and build a bridge without joints in the deck. Some of these jointless bridges are designed to have a fully integral abutment that allows thermally induced changes in the bridge superstructure to be taken up by movement of the abutment. Other jointless bridges are designed with semi-integral abutments, i.e., with integral superstructure/backwall connections that move according to the thermal demands but are independent of the vertical load support system. This practice eliminates the necessity for maintenance of the joint material or assembly and helps prevent corrosion-induced deterioration of bearings, abutment bridge seats, pier caps, and the ends of beams.

Bearings

Types of bridge bearings range from fixed to those that allow rotation and longitudinal movement, such as simple steel rollers and rockers, to unreinforced and reinforced elastomeric pads, to sophisticated high load multirotational bearings. Some are intended to allow expansion and rotation of the girders under live loading and as the ambient temperature changes. Bearing performance can degrade, as corrosion or other forms of deterioration occur, deleterious materials build up at the bearings, unanticipated movements occur, etc. These conditions may lead to unanticipated stresses in superstructure and substructure components. Long-term studies are needed to investigate and evaluate how different types of bearings perform in the field under various conditions and over an extended time. Changes in structural behavior of the bridge that may be caused by bearings not performing as designed may also be investigated.

Coatings for Steel Superstructure Elements

Protective coatings have served as the primary corrosion protection system for steel bridges for many decades. Coating technology has progressed from the lead-based paint era to the current era of environmentally compliant, high-performance coating materials. However, many of the focus groups identified performance of coatings for steel bridges as an area where further improvements would be beneficial. Some needs expressed included the following:

- More effective methods to assess and predict coating system performance under various field conditions.

- Methods to predict the optimum time for maintenance painting operations so that maintenance is performed before the critical point when the coating system deteriorates beyond repair.

- Strategies for protection of ends of beams where concentrations of chloride-laden moisture result in a more aggressive environment for corrosion.

Identification of the Condition of Embedded Prestressing Strands and Post-tensioning Tendons

Bridges that use prestressed concrete girders to support the bridge deck are more commonly used in today's infrastructure. In the early 1950s, prestressed girder bridges made up roughly 2.5 percent of the total bridge inventory, whereas in 2007, 40 percent of the newly constructed bridges were made with prestressed concrete girders. A critical factor influencing the long-term performance of these types of bridge superstructure systems is the performance of prestressing strands and tendons both in pretensioned (embedded) and post-tensioned (ducted) applications. It is important to verify the condition of prestressing strands to determine whether they are performing well. Visual inspection is the most common approach for inspecting prestressed concrete girders but signs of early corrosion activity and damage to the prestressing are difficult to detect. Long-term field studies are needed to investigate and examine the performance of embedded or ducted prestressing wires and tendons in bridges in various service environments and under various traffic loadings and service conditions. An important element of the studies will be investigating and evaluating methods for early assessment of the condition of pretensioned and post-tensioned strands and tendons in prestressed concrete.

The Bump at the End of the Bridge

A common issue at many bridges occurs when differential settlement at the roadway/bridge interface causes a change in elevation between pavement and bridge. This difference in elevation can be a hazard to driver safety and can cause undue impact loads on the deck and superstructure when heavy truck vehicles cross the bump. Most bridges are designed to have a concrete "approach slab" that is intended to minimize the differential settlement. In many cases, however, the final magnitude of settlement exceeds the capacity of the approach slab, and costly and sometimes repetitive repairs are necessary. Thus many State transportation departments regard the settlement of bridge approach slabs as a substantial maintenance problem.

Scour

Most of the focus groups identified scour as a significant safety concern and ranked it high among substructure performance issues. For example, the California Department of Transportation (Caltrans) takes a proactive approach to scour, including the following:

- A specific program group actively works to identify scour-susceptible structures and takes preemptive action where possible.
- Monitoring is in place in a number of locations, with a variety of instrumentation.

Critical needs identified by several State transportation departments included the following:

- Direct, reliable, timely methods of measuring scour.
- Evaluation of the effectiveness of different scour countermeasures.

DESIRED OUTCOMES OF THE LTBP PROGRAM

Each State transportation department was asked what it would most desire as an outcome or multiple outcomes from the LTBP Program. The numerous suggestions covered many different aspects of bridge engineering. As an illustration of the different desired outcomes, suggestions included the following:

Better forecasting of bridge conditions and need for actions.

- Methods to accurately forecast the remaining life of a bridge.
- Refined deterioration models.
- Determination of the lifecycle of a bridge and what repair needs will be encountered during that life.

Best practices for preserving bridges and bridge components in satisfactory condition.

- Value and relative effectiveness of different protective/preservation actions.
    - How much added life results from sealers and overlays?
    - What is the best material for deck patching?
    - How long will bridges with epoxy-coated rebar last?
- Optimum time and/or condition for preservation actions. Examples include the following:
    - Should sealers be applied to new decks?
    - Protection of beam ends.
    - Sealing of joints.
- Accurate data on costs of preservation actions and benefit- cost ratios.
- Balancing of bridge preservation and environmental stewardship.

An effective risk-based prioritization or ranking process or a better classification system to rank structures in an inventory according to overall risk. Currently, New York State Department of Transportation (NYSDOT) has defined six basic failure modes of vulnerability:

- Hydraulic.
- Overload.
- Steel Details.
- Collision.
- Concrete Details.
- Seismic.

Best practices for inspection and evaluation of bridges.

- Practical, successful and durable health monitoring technologies.
- Practical, real-time processing of structural health monitoring (SHM) data.
- Tests for proper weathering of weathering steel.
- Data for risk-based inspection frequencies.
- Evaluation of prestressed concrete for early identification of strand corrosion.

- More efficient methods of detecting/monitoring the following:
    - Frozen bearings or excessive movement of bearings.
    - Leaking or failed joints.
    - Fatigue crack initiation and growth.
    - Chloride content and corrosion potential/rate.
    - Concrete deck cracking frequency and severity.
    - Accurate quantities of deck delaminations.
    - Deck condition beneath overlays.
    - Corrosion/breaks in beam prestressing strands.
    - Magnitude and frequency of truck loads, axle weights.
    - Direct, real-time effects of scour.

RECOMMENDATIONS ON LTBP PROGRAM PRIORITIES

The identification of the high priority bridge performance issues to be studied under the LTBP Program has been an ongoing process that began at the earliest stages of the program. As early as February 2008, the LTBP research team had identified a list of high priority research topics related to various aspects of bridge performance. The list was compiled and supplemented with some background information and the general scope of possible research study. The team then proceeded to rate each topic on a scale from 0 to 3 with respect to perceived importance and urgency relative. A rating of 0 meant least important or least urgent, and a rating of 3 meant most important or most urgent. The team discussed each topic and arrived at consensus on the perceived importance and relative urgency of the topic. The two ratings were then added to arrive at an overall rating for each topic that could range from 0 to 6. Table 9 shows the ratings assigned by the LTBP team.

The list—without any ratings—was then shared with a select working group of experts in government, academia, and industry who were thoroughly familiar with bridge design, construction, management, and maintenance practices. The list was also shared with an internal steering group of FHWA bridge experts. Each of the members of both groups was asked to individually rate the topics according to urgency and importance. Group members were also invited to submit comments regarding the topics or scope of the program and to suggest additional topics that might have been addressed in the presented list. Table 9 also presents a summary of ratings of each topic by the external stakeholders and by the FHWA internal steering group. In both of these cases, the ratings for each topic were calculated by averaging the ratings of all the members in each group. Again, the two ratings were then added to arrive at an overall rating for each topic that could range from 0 to 6. Appendix C provides a list of the members of the select working group and FHWA internal steering group.

Table 9 is arranged so that the topics are listed in order, from high to low, by the overall rating from the external stakeholders.

Table 9. Ratings and rankings of proposed study topics by stakeholders.

Proposed Study Topic	External Technical Working Group				LTBP Team				FHWA Steering Committee			
	Imp.	Urg.	Total	Rank	Imp.	Urg.	Total	Rank	Imp.	Urg.	Total	Rank
Performance of Untreated Concrete Bridge Decks	2.9	2.8	5.6	1 (Tie)	3	3	6	1 (Tie)	3.0	3.0	6.0	1
Performance of Bridge Deck Treatments	2.8	2.9	5.6	1 (Tie)	3	3	6	1 (Tie)	2.8	2.3	5.2	3
Performance, Maintenance and Repair of Bridge Deck Joints	2.8	2.5	5.3	3	3	3	6	1 (Tie)	2.7	2.0	4.7	4 (Tie)
Performance of Coatings for Steel Superstructure Elements	2.4	2.1	4.5	4 (Tie)	3	2	5	5 (Tie)	2.3	2.0	4.3	6 (Tie)
Performance of Bare/Coated Concrete Super- and Substructures	2.5	2.0	4.5	4 (Tie)	2	1	3	13 (Tie)	2.3	2.0	4.3	6 (Tie)
Performance of Innovative Bridge Designs and Materials	2.3	2.1	4.4	6	1	1	2	17 (Tie)	1.8	1.6	3.4	15
Performance of Embedded Prestressing Wires and Tendons	2.1	2.1	4.3	7	2	3	5	5 (Tie)	2.3	2.0	4.3	6 (Tie)
Performance of Bridge Bearings	2.1	2.0	4.1	8	3	2	5	5 (Tie)	2.7	2.0	4.7	4 (Tie)
Performance of Precast Reinforced Concrete Deck Systems	2.1	1.9	4.0	9 (Tie)	2	1	3	13 (Tie)	2.0	2.0	4.0	13
Performance of Jointless Structures	2.1	1.9	4.0	9 (Tie)	2	1	3	13 (Tie)	1.3	1.0	2.3	19 (Tie)
Performance of Alternative Reinforcing Steels	2.1	1.8	3.9	11	2	2	4	9 (Tie)	2.3	2.0	4.3	6 (Tie)
Direct, Reliable, Timely Methods to Measure Scour	1.8	1.8	3.5	12 (Tie)	3	3	6	1(Tie)	1.8	1.8	3.5	14
Performance of Weathering Steels	1.8	1.8	3.5	12 (Tie)	1	1	2	17 (Tie)	1.7	1.7	3.3	16 (Tie)

Proposed Study Topic	External Technical Working Group				LTBP Team				FHWA Steering Committee			
	Imp.	Urg.	Total	Rank	Imp.	Urg.	Total	Rank	Imp.	Urg.	Total	Rank
Serviceability of Cracked HPC Decks	1.9	1.5	3.4	14	2	2	4	9 (Tie)	3.0	2.7	5.7	2
Performance of Scour Countermeasures	1.7	1.6	3.3	15 (Tie)	2	1	3	13 (Tie)	2.5	1.8	4.3	6 (Tie)
Risk and Reliability Evaluation for Structural Safety Performance	1.7	1.6	3.3	15 (Tie)	3	2	5	5 (Tie)	1.7	1.7	3.3	16 (Tie)
Performance of Prestressed Concrete Girders	1.6	1.6	3.3	15 (Tie)	2	2	4	9 (Tie)	1.7	1.7	3.3	16 (Tie)
Unknown Foundation Types	1.6	1.6	3.1	18	-	-	-	20	2.3	2.0	4.3	6 (Tie)
Performance of Structure Foundation Types	1.5	1.5	3.0	19	1	1	2	17 (Tie)	2.3	2.0	4.3	6 (Tie)
Criteria to Classify Functional Performance	1.1	1.1	2.3	20	2	2	4	9	1.3	1.0	2.3	19

Imp. = Important
Urg. = Urgent
HPC = High performance concrete

The members of the external review group individually offered additional topics for consideration under the program. These are summarized as bullets, in no particular order, below:

- Loss of longitudinal post-tensioning over time in precast decks.
- Performance of connection details in prefabricated bridges.
- Distinguishing damage due to live load versus environmental factors in concrete bridges.
- Effect of overloads on bridge durability.
- Durability of repairs done to prestressed concrete girders.
- Fatigue of concrete bridges.
- Increasing truck weights and frequencies.
- Inspection methods (visual and nondestructive evaluation (NDE)/nondestructive testing (NDT)).
- Security.
- Bridge funding.
- Preventative bridge maintenance.
- Vulnerability.
- Deck shear capacity.

Many of these suggested topics overlap or complement topics within the ranked list, while others may deserve consideration for future implementation within the program. Table 10 presents the comprehensive list of topics after considering all input from stakeholders. This list was derived from a sequence of steps as follows:

1. Develop preliminary list of performance topics.
2. Gather input from internal and external stakeholders.
3. Evaluate the list of potential topics and prepare a brief literature review and background summary for each.
4. Revise this list based on input derived from the focus group meetings and periodic feedback from discussions with other stakeholders as previously described.

Table 10. Long-term bridge performance suggested study topics.

Category	LTBP Bridge Performance Topic
Decks	Performance of Untreated Concrete Bridge Decks
	Performance of Bridge Deck Treatments
	Performance of Precast Reinforced Concrete Deck Systems
	Performance of Alternative Reinforcing Steels
	Influence of Cracking on the Performance of High-Performance Concrete Decks
Joints	Performance of Bridge Deck Joints
	Performance of Jointless Structures
Bearings	Performance of Bridge Bearings
Concrete Bridges	Performance of Bare/Coated Concrete Super- and Substructures
	Performance of Embedded Prestressing Wires and Tendons
	Performance of Prestressed Concrete Girders
	Performance of Impact-Damaged Concrete and Prestressed Concrete Beams
Steel Bridges	Performance of Coatings for Steel Superstructure Elements
	Performance of Weathering Steels
	Performance of Impact-Damaged Steel Beams
New Construction	Performance of Innovative Bridge Designs and Materials
Foundations and Scour	Performance of Scour Countermeasures
	Performance Issues at the Bridge Approach-Abutment Interface
	Performance of Substructure Components
	Performance of MSE Walls
Risk	Risk and Reliability Evaluation for Structural Safety Performance
Functional	Performance of Functionally Obsolete Bridges

MSE = mechanically stabilized earth

After discussions among the research team, FHWA, State coordinators, and the TRB LTBP Committee, it was recognized that all topics could not be addressed immediately, and the number of topics to be addressed would likely be constrained by program resources. Therefore, the research team, in conjunction with the FHWA LTBP staff, developed a short list of top priority topics for immediate consideration. Table 11 presents the six top priority topics recommended for immediate study in the execution phase of the program. This list was refined based on discussions with the TRB LTBP Committee. As time and resources permit, additional topics may be incorporated into the program.

Table 11. Initial study topics for LTBP Program.

Category	Issue
Decks	Untreated Concrete Bridge Decks
Decks	Treated Concrete Bridge Decks
Joints	Bridge Deck Joints
Bearings	Bridge Bearings
Steel Bridges	Coatings for Steel Superstructure Elements
Prestressed Concrete Bridges	Detection of Condition of Embedded Pretensioned Strands and Post-Tensioning Tendons

CHAPTER 5. CONCLUSIONS

Bridge performance is a multifaceted issue involving performance of materials and protective systems, performance of individual components of the bridge, and performance of the structural system as a whole. Bridge performance is influenced by many different factors. Some are static or fixed (for example, design type); others are variable (for example, live loadings). The LTBP Program's resources may be inadequate to study every aspect of bridge performance. A basic principle governing the program is that it should serve the needs of bridge owners across the nation as identified by those bridge owners. Thus, considerable effort was undertaken to solicit input from bridge owners as well as from the bridge community at large on what high priority bridge performance issues should be addressed by the LTBP Program. The State transportation departments, bridge technical committees, and other individuals interviewed also provided input on the types of data that should be collected by the program and on the types of decision support tools that the program should deliver.

The result of the focus group meetings and other interviews is a list of 22 high priority bridge performance issues recommended for study under the LTBP Program. The initial priorities for study under the program are the following six issues:

- Untreated concrete bridge decks.
- Treated concrete bridge decks.
- Bridge deck joints.
- Bridge bearings.
- Coatings for steel superstructure elements.
- Detection of condition of embedded pretensioned strands and post-tensioning tendons.

These 6 issues and the majority of the other issues in the list of 22 are all related primarily to the physical condition and the structural integrity of bridges. They represent issues that bridge owners most commonly face in maintaining, repairing, or rehabilitating their bridges and involve the most common maintenance, repair, or rehabilitation activities they need to perform. These performance issues may arise because of certain design and/or construction details or may be the result of or be aggravated by service conditions and loadings.

Each of the high priority performance issues will be examined in detail and the specific data necessary to study the issues will be identified. The results will be published in the upcoming FHWA report *Identifying Long-Term Bridge Performance Bridge Data Needs.*

APPENDIX A—FOCUS GROUP INTERVIEW QUESTIONS

Focus group interviews were conducted with individuals involved in bridge asset management at each participating State transportation department ranging from the system-wide to individual structure levels. Accordingly, a series of structured questions were used to guide the discussion and to elicit details about the perceptions, policies and practices that influence the State transportation department's bridge management program, and perceived needs for improvement.

QUESTIONS FOR LTBP FOCUS GROUP INTERVIEWS

1. Explain your organizational structure, as it pertains to bridge management and maintenance.

2. Please review your inspection processes. Who performs inspections? Qualifications? Quality assurance/quality control (QA/QC)? Localities?

3. What sources of information are most useful to you for program-level decision support?

    a. Does your State have a formal bridge management system? Is it useful?
    b. Do you use it to just archive data or use it to make system-level decisions? And if you use it to what extent?
    c. Does the system track maintenance, repair and rehabilitation actions?
    d. Does your system capture and report cost information?
    e. What additional capabilities do you wish you had?

4. What sources of information are most useful to you for project-level decision support?

    a. In addition to inspection reports (NBIS) what other information do you base these decisions on?
    b. What non-structure specific data sources do you use to support project selection? (traffic data, environmental, truck data, corridor or multi-asset project planning)
    c. Do you perform element-level inspection or to what level of detail do your inspections document condition?
    d. What supplemental testing do you do? Do you use nondestructive methods? Are the NDE results maintained in a central database?
    e. Have you used health monitoring instrumentation as a supplement to your inspection program? If so, how?
    f. What data/information would help you more accurately define the extent of repairs and make your estimate better?
    g. How do you go from inspection report to a contract to get a job done?
        i. Identify problem
        ii. Generate suggested methods of repair
        iii. Generate costs of repairs
        iv. In order to achieve efficiency, cost effectiveness, safety and minimize user impacts, what are some contracting methods you employ?
    h. Are you capturing actual repairs performed versus specified repairs? How? Do you record where the repair was actually performed?

5. What performance measures do you use to gauge the success of your bridge management system?
    a. What is the most useful information you get out of the process?
    b. How do you utilize that information in your decisionmaking process?
    c. What are the weaknesses in the data for your performance measure process?
    d. Do you monitor your bridge maintenance program for performance?
    e. If you use a system-level performance measure, can you separate the impacts of replacement construction versus maintenance on system-level performance?
    f. How do you measure the effectiveness of particular maintenance activities?
        i. What data do you have
        ii. What data do you think you need?

6. We intend to pose questions to elicit the most common forms of deterioration and damage on your bridges, what information you use to evaluate the condition and what information you use to develop a feasible solution. What are the five to ten most common forms of deterioration or damage you face in maintaining, repairing or rehabilitating your bridges?)
    a. What do you consider to be the three most critical to address and why?
    b. What processes do you consider to be the causes of the deterioration or damage?
    c. What inspection and/or test data do you currently use that enables you to estimate the severity and the extent of the deterioration or damage?
    d. What parameters that you do not currently measure would improve your ability to estimate the severity and the extent of the deterioration or damage?
    e. What factors are preventing you from collecting the desired data?

7. We intend to pose questions to elicit the most common maintenance, repair or rehabilitation activities you perform and what information you have to base your choice of feasible solutions on. On what 5 to 10 maintenance, repair, or rehabilitation activities do you expend the most resources (time or money) to address?)
    a. What are the three most critical to address and why?
    b. What inspection and/or test data do you use that enables you to develop a feasible and economical solution?
    c. What parameters that you do not currently measure would improve your ability to develop a feasible and economical solution?
    d. What factors are preventing you from collecting the desired data?

8. What does long-term bridge performance mean to you? What suggestions do you have?

9. Tell us some things you’ve done in your program that you consider successes or clear improvements.

APPENDIX B—FOCUS GROUP SUMMARIES

Summaries of the focus group interviews are presented in this section in the order of occurrence, and a summary of responses and discussion is given for each general area of questioning. Each State transportation department was requested to identify the forms of bridge deterioration that were most common on the bridges in their State and the maintenance and repair activities requiring the most resources. These were classified as being related to decks, superstructure elements or substructure elements. The transportation department was also requested to identify any functional issues that were prevalent on/at its bridges. The typical functional issues identified included the following:

- Insufficient vertical clearance over the roadway that the bridge crosses.
- Inadequate capacity for existing traffic volumes.
- Impact damage.
- Poor performance of deck drains.
- Poor performance of railing and transitions.
- Settlement and shifting of slope paving.
- Damage of approach slab where it is tied in with joints.
- Bridge width not matching road width.
- Utilities under structures—corrosion of straps and hangars.
- Settlement of MSE walls.
- Slope protection—loss of protective materials and sloughing of backfill.

ALABAMA STATE DEPARTMENT OF TRANSPORTATION

The Alabama Department of Transportation (ADOT) focus group meeting was conducted at an ADOT facility in Montgomery on December 2, 2009. Focus group interviewees included the following:

- John Black, Bridge Office, ADOT.
- George Conner, Bridge Office, ADOT.
- Robert King, Division Bridge Engineer, FHWA Alabama Division.
- Tim Colquett, Bridge Office, ADOT.

Organizational Structure

ADOT has a decentralized structure comprising nine divisions, some of which have bridge maintenance crews, along with three statewide bridge maintenance crews; the central office provides oversight and support. Table 12 shows the number of bridges owned by various types of agencies in the State.

Table 12. Number of bridges owned by various types of agencies in Alabama.

Agency Type	Number of Bridges Owned
State transportation department	5,738
Other State agency	38
Local agency	10,098
Federal agency	165
Toll authority	0
Railroad company	24
Private	7
Total	**16,070**

Program-Level Decision Support

ADOT has a bridge maintenance system called Alabama Bridge Information Management System (ABIMS), which has been in place since 1995.(8) ADOT has deferred implementation of AASHTOWare Bridge Management® software until the upcoming changes to AASHTO CoRe elements are in place. The ABIMS module for maintenance needs summary is completed by the inspectors who identify and document the maintenance need, determine necessary quantities of work items, attach the cost from the cost table in a database, and then classify it as emergency, priority, routine, or monitoring. Inspectors and superintendents can mark work completed, but most of the data are in the maintenance management system, which is not integrated with the bridge management system.

The central bridge maintenance office determines bridge replacement needs. In making decisions, the primary tool is an assessment called a deficiency algorithm (developed by the University of Alabama) that ranks structures on how well they meet targets.(9) During the selection process, each division has input on its bridges.

All State inspections are done by ADOT employees with the exception of specialty cases. ADOT has an underwater unit that performs inspections and assists in construction. The emergency bridge inspection team includes a designer.

Project-Level Decision Support

Each division has authority to determine how to spend its budget dollars. The budget is distributed proportionately based on asset needs. Bridge painting is funded separately.

When an inspector finishes the inspection (items BI5—element-level inspection and BI9—maintenance needs), the recommendations are reviewed by someone who can make decisions on prioritization of work (could be bridge operations engineer/manager or division maintenance engineer or his assistant). BI5—element-level inspection and BI9—maintenance needs are examples of inspection reporting items on the ADOT Structure Inventory and Inspection Menu as described in the Alabama ABIMS User Guide.[8]

What ADOT would like to see is the changeover to AASHTOWare Bridge Management® software CoRe element, which will better capture quantity, and the project development modules, which will address many of the issues.

Additional testing includes load-rating analysis, dye penetrant, ultrasonic testing (UT), and magnetic particle testing. ADOT employs ground-penetrating radar (GPR) occasionally.

Performance Measures

- Sufficiency rating—track for better roads annual survey, how many deficient bridges. (These have gone down every year, but Alabama has interstate bridges reaching 50 years old, so problems are anticipated.).

- Deficiency algorithm—a deficiency algorithm of 100 is bad. It looks at target level of service, geometrics, vertical clearance, load carrying capacity, and condition.[8]

- Government Accounting Standards Bulletin (GASB) 34 index—aggregated number, i.e., a weighted average based on deck area on the deck (20 percent), super (40 percent), sub (40 percent), and culvert (100 percent) condition ratings—NBI ratings).[10]

The GASB 34 index refers to an Asset Sustainability Index and its related ratios that are used in reporting transportation asset management needs and issues. The Asset Sustainability Index and its related ratios are considered in GASB 34 as evolutionary next steps to further enhance the reporting of transportation asset management needs and issues. For bridges, the sum of the weighted ratings for deck, superstructure, and substructure equates to 100; for culverts, the index value is based 100 percent on the culvert condition rating.

Common Forms of Deterioration

Substructure:

- Scour.
- Section loss of substructure elements (primarily steel but some timber).

Superstructure:

- Section loss and fatigue issues in steel members.
- Deterioration of concrete girder ends as joints are filled with debris.
- Joint deterioration.

Deck**:** (none cited).

Functionality: (none cited).

Maintenance and Repair Activities Requiring the Most Resources

Substructure**:** 50 percent of budget.

Superstructure**:** 50 percent of budget.

Deck**:** (none cited).

Functionality**:** (none cited).

Desired Outcomes From LTBP Program

- Anything on the design side that pays off over the life of the bridge.

- Benefits of general experience and guidance and ability to consider options not being used now.

CALIFORNIA DEPARTMENT OF TRANSPORTATION

The California Department of Transportation (Caltrans) focus group was conducted on September 17, 2008, at the Caltrans headquarters in Sacramento, CA. Caltrans interviewees included the following:

- Denix Anbiah, Central Office Division of Local Assistance, Caltrans.
- Nick Burmas, Central Office Materials and Infrastructure, Caltrans.
- Anthony Gugino, Central Office Bridge Engineering, Caltrans.
- Pat Hipley, Central Office Earthquake Engineering (Strong Motion Instrumentation Program), Caltrans.
- Michael Johnson, Central Office Maintenance, Caltrans.
- Michael Keeve, Central Office Earthquake Engineering, Caltrans.
- Greg Kolle, Structural Engineer, FHWA California Division.
- Wes Lum, Central Office Division of Research, Caltrans.
- Steve Mitchell, Central Office Earthquake Engineering (Toll Bridge Post-EQ Analysis), Caltrans.
- Barton Newton, Central Office Maintenance, Caltrans.
- Steve Ng, Central Office Division of Engineering Services, Structures Hydraulics and Hydrology, Caltrans.
- Cliff Roblee, Central Office Division of Research, Caltrans.
- Li-Hong Sheng, Central Office Earthquake Engineering, Caltrans.
- Charly Sikorsky, Central Office Earthquake Engineering, Caltrans.
- Phil Stolarski, Caltrans Transportation Laboratory, Caltrans. [2]
- Pete Whitfield, Central Office Maintenance, Caltrans.
- Ray Wolfe, Central Office Bridge Design, Caltrans.

Organizational Structure

Caltrans has a centralized structure, divided into two Regions with bridge staff primarily located in either the Sacramento Headquarters office or in southern California (Los Angeles). Table 13 shows the number of bridges owned by various types of agencies in the State.

Table 13. Number of bridges owned by various types of agencies in California.

Agency Type	Number of Bridges Owned
State transportation department	12,180
Other State agency	167
Local agency	11,881
Federal agency	563
Toll authority	5
Railroad company	9
Private	6
Total	**24,811**

[2] The Caltrans Transportation Laboratory is the central research facility of Caltrans.

Program-Level Decision Support

Caltrans has a formal bridge management system built on AASHTOWare Bridge Management® software and augmented with additional data including the following:

- Hydraulics.
- Steel fatigue.
- Steel fracture.
- Other issues on steel bridges.
- Work recommendations that cover crew work and major maintenance contracts and rehabilitative work.

Caltrans maintains a complete archive of plans and inspection reports, to which it is adding photos, information on emergency response for large-scale and significant seismic and flood events, and information on encroachments (for which it is electronically collecting data on utilities such as high pressure water, gas, and anything flammable that can fill up the box and potentially cause an explosion). The State does track maintenance, repair, and rehabilitation actions and cost information, which is kept in a work management system, although it does not include the cost of maintenance of traffic.

Project-Level Decision Support

At Caltrans, bridge needs are identified through the following:

- Inspection.

- Risk-based prioritization or ranking process for maintenance, repair, and rehabilitation actions.

- Analysis (hydraulic analysis for scour or seismic analysis).

- Changing standards (for example, barrier rails or crash testing standards) that are introducing whole new classes of work not previously done.

- Goods movement needs (generate strengthening and/or bridge raising needs).

These needs are kept in a centralized location and are filed under each bridge.

The State performs both NBI safety and element-level inspection (AASHTOWare Bridge Management® software). Additional testing, i.e., sounding, may be performed by the material engineering testing group. Its greatest difficulties are access to the decks because of traffic and the need for lift equipment to get to areas of the bridge.

Reliance is placed on inspector recommendations when determining needed repairs. (All inspectors have Professional Engineer (PE) licenses and are encouraged to determine the reason for problems and deterioration.) The Division of Engineering Services provides districts with recommendations of how to spend resources, but districts determine actual actions with the exception of very low sufficiency rating or critical issues such as scour. They track 55 maintenance actions.

Performance Measures

Caltrans stated that it needs performance metrics that will tell why a bridge fails. It would like to see different performance measures that could be linked to ones previously or currently used, such as structurally deficient.

Common Forms of Deterioration

Substructure**:** Scour, ASR, seismic.

Superstructure**:** Steel fatigue, corrosion of steel girders and resulting protective coating systems for steel girders, box girder hinges, cracking.

Deck**:** Cracking, delaminations, spalling.

Functionality**:** Lack of capacity for traffic.

Maintenance and Repair Activities Requiring the Most Resources

Substructure**:** None explicitly identified.

Superstructure**:** Bridge painting, structural steel painting.

Deck**:** Joint seals, deck seals.

Functionality**:** Lack of capacity for traffic.

State Transportation Department Successes

Caltrans has supplemented AASHTOWare Bridge Management® software with the following other significant sources of information:

- The database captures information about hydraulics, steel fatigue, and fracture.
- The system tracks issues on work recommendations that cover crew work and major maintenance contracts and rehabilitative work.
- Associated with the database is a complete archive of plans and inspection reports, with photos, and supporting data for emergency response for large-scale seismic and flood events where a significant response is required.
- There is a module for encroachments (wherein Caltrans electronically tracks the presence of utilities in the structure right-of-way—high pressure water, gas, anything flammable.

Desired Outcomes From LTBP Program

Caltrans wants data that will help determine the lifecycle of a bridge and what repair needs will be encountered during that life. However, Caltrans is more concerned with the “why” (source of problem) than the “what” of deterioration—something emphasized with its inspectors.

FLORIDA DEPARTMENT OF TRANSPORTATION

The Florida Department of Transportation (FDOT) focus group meeting was conducted at the FDOT maintenance yard in Jacksonville, FL, on November 13, 2008. Focus group interviewees included the following:

- Keith Campbell, FDOT District 2, Jacksonville.
- John Clark, FDOT Central Office, Tallahassee.
- Richard Kerr, FDOT Central Office, Tallahassee.
- Will Watts, FDOT District 2, Jacksonville.

Organizational Structure

FDOT has a decentralized structure comprising seven geographical districts, plus the Florida Turnpike, with bridge maintenance staff for each (Districts 1 and 7 share an office). The central office provides planning and support, establishes policy, and conducts QA. Table 14 shows the number of bridges owned by various types of agencies in the State.

Table 14. Number of bridges owned by various types of agencies in Florida.

Agency Type	Number of Bridges Owned
State transportation department	5,414
Other State agency	157
Local agency	5,078
Federal agency	140
Toll authority	1,137
Railroad company	0
Private	56
Total	**11,982**

Program-Level Decision Support

State-owned bridges are primarily inspected by in-house personnel, although larger structure inspections may be outsourced. Local governments generally have their structures inspected by consultants.

FDOT uses a customized version of the AASHTOWare Bridge Management® software for its bridge management system. FDOT has customized AASHTOWare Bridge Management® software probably more extensively than any other State. Some of the modifications include the following:

- Administration.

- Element-level bridge data collected according to the element definitions and condition State definitions.

- Collection of additional data.

- Customized handling of bridge inspection reports.

- Financial data.

- Miscellaneous bridge data.

- Load rating data.

- Truck data—truck traffic counts as well as vehicle classifications and/or weight-in-motion data if available.

- Scour information.

- Track warranties.

- Utility to plot channel cross section over time to monitor scour to see whether there is a change in the channel.

- Inspection-related information that allows FDOT to add more than one inspector, as well as the supervisor and the PE who review the report for each inspection.

- Customized reports that include the following:

    - Standard inventory reports: for example, lists of moveable, structurally deficient, posted, or closed bridges.
    - Management reports: a bridge replacement ranking report to influence local government prioritization of replacement projects, compliance reports to track whether inspections are completed on time and according to standard (used to report to FHWA), inspection schedule, load rating report, and critical deficiencies.
    - Work order reports: Recommended work reviewed and prioritized by a Feasible Action Review Committee composed of engineering department, maintenance, and inspections group representatives.

- Security for bridge data: restricts access according to district, bridge owner, local government, or bridge group; often used for contracts; can restrict data to a specific bridge, or various combinations.

- Multimedia support: allows users to add images, videos, and drawings, which can be selectively included in inspection reports when printed out.
  Example: Planning Division makes video logs of State highways. It now has a system to access video through AASHTOWare Bridge Management® software by entering the bridge number, calling up that section of the bridge, and "driving" down the road.

FDOT has integrated AASHTOWare Bridge Management® software with the following other systems:

- Roadway Characteristics Inventory: allows download of traffic data (automatic update to AASHTOWare Bridge Management® software once a year)—State system.

- Load Rating information extracted to support routing of overweight trucks (permitting reports in the bridge management section in the FDOT Central Office).

- Daily extract to the Financial Management System.

FDOT has been integrating more between maintenance and financial management—it previously had to physically make a file and send, but now the systems are increasingly tied together electronically. The maintenance office, the planning office, the work program office and the district bridge inspection offices all have ad hoc reporting capability. Report access is read-only. For security reasons, FDOT developed a front-end for AASHTOWare Bridge Management® software to code the password so users cannot use that system directly to run reports; thus, ad hoc reporting is accomplished through an Oracle database queried by Microsoft® Access, FoxPro, or Infomaker® software.

When asked whether FDOT tracks costs of specific types of maintenance or repair activities, representatives indicated FDOT's asset maintenance process tracks in-house man-hours and equipment, but because contractors are not required to give actual costs, it is not possible to record actual contracted repair costs.

Project-Level Decision Support

AASHTOWare Bridge Management® software database is used to support a custom project-level analysis tool (PLAT). One example is a desktop PC Microsoft® Excel program that can pull up a specific bridge and allow users to look at it to project future deterioration. This program is currently in the development stage. The intent is to help districts in planning for maintenance and preservation projects at the bridge level.

FDOT's collection of AASHTOWare Bridge Management® software data started in November 1998. FDOT has been using the PLAT for only the last 3 to 4 years because it required a lot of outside data, including user costs, State transportation department costs, and other data AASHTOWare Bridge Management® software normally did not collect.

Despite their use of AASHTOWare Bridge Management® software, the engineers at FDOT feel they often operate in reactive mode, wherein most work is based on needs identified at the time of inspections or as a result of unpredicted incidents. Because the overall inventory is in good condition, they generally build a 2- to 3-year program that includes the most important priorities and then revise it each year based on inspection reports.

In addition to structural considerations, bridge engineers also consider traffic levels, maintenance of traffic (MOT), environmental factors (for example, bats' nesting season), and public events (for example, tourist season, major sporting events) that can affect when it is best to do bridge work. They tend to do more maintenance and repair work when the winter tourists leave (i.e., when traffic counts go down) and try to finish before tourist season starts.

With regard to routine inspection procedures, they rely primarily on visual inspection; they do not perform chain drags because decks are not often a maintenance issue in Florida—primarily they have problems with substructure deterioration in marine environments. For inspections, additional testing often includes UT for pin-and-hangar assemblies, magnetic particle, and dye penetrant. FDOT has a special contract for NDT.

Performance Measures

FDOT identifies priorities from field inspections or response to incidents, according to the following scale:

- Priority 1—emergency (address within no more than 60 days; usually field crews are working to address the problem before the work order is issued).
- Priority 2—urgent (within 180 days).
- Priority 3—routine (within 1 year).
- Priority 4—informational work order (no deadline), i.e., small repairs that may be grouped for efficiency or convenience. This category is used for identifying general work program issues and for tracking purposes.

Performance measures are part of an annual quality assessment review—each year the Central Office makes an oversight visit to every district. It assesses compliance or noncompliance with regard to whether or not there has been any delinquency in addressing Priority 1 or 2 work orders. The Central Office may have findings on priorities review as well. The performance criterion for Priority 1 and 2 work orders is that 95 percent of the work orders must be completed on time. (Most districts are generally running at 100 percent.)

As a statewide performance measure, FDOT has established a goal that 90 percent of State bridges will meet State standards of being in good or excellent condition (using NBIS 1–9 condition ratings, where excellent is 8–9, good is 6–7, fair is 5, and poor is 4 or below). Currently, 93 percent of statewide bridges are in the good or excellent categories.

Common Forms of Deterioration

***Substructure*:** The most common forms of substructure deterioration are the following:

- Prestressed concrete piling with corrosion of prestressing strands.
- Steel piling—concrete jackets are installed during construction for the purpose of corrosion protection and to protect the painting system where the steel piles interface with the concrete bent and the concrete jacket.
- Cathodic issues with corrosion on reinforced concrete piles.
- Exposed reinforcing steel, cracked piles, and cracked pipe piles due to construction.
- Cracking of concrete substructure exposing steel.

***Superstructure*:** The most common forms of superstructure deterioration are the following:

- Deterioration of bearings—primarily from leakage of joints and corrosion.
- Impact loading.
- Deterioration between bearing and masonry joint.
- Deteriorated joints.
- Spalls in concrete beams (the reinforcement was too shallow and the State patches to protect reinforcing).
- Cracks due to impact and construction problems (these will be sealed).

***Deck*:** The most common forms of deck deterioration are the following:

- Cracks due to poor curing (these will be sealed).
- Spalls (these will be repaired).

***Functionality*:** The most common are the following:

- Impact damage from barges—these can be expensive and significant.
- Impact damage from over-height trucks.
- Damage from heavy loads.
- Issues arising from design.

Maintenance and Repair Activities Requiring the Most Resources

Substructure:

- Cathodic protection—most money is spent here.
- Mechanical and electrical rehabilitation of moveable bridges—done on a 10-year cycle.
- Shoring up bents—crutch bent (a crutch bent is an extra bent added to the bridge to shore up the superstructure, but FDOT does not use them very often; when they do, it is very expensive).

Superstructure:

- Beams and bearings.
- Painting.
    - Prior to 10 years ago, spot painting was the favored practice.
    - During the last 10 years, the practice has been full removal to surface preparation level SP-10 then spot paint to extend life—for example, spot painting on a bridge that received a full paint job 6 years earlier.

Deck**:** (none cited).

Functionality: (none cited).

State Transportation Department Successes

The elimination of deck joints on bridges up to 120 ft.

Desired Outcomes From LTBP Program

- Joints that will not leak.
- Help with substructures in marine environments (FDOT's greatest concern).
- Moveable bridges are also a concern to FDOT).
- More data on painting existing bridges: Is service life better when they have to sandblast and repaint? Need some proof. Is workmanship more critical than the paint system materials?

ILLINOIS STATE DEPARTMENT OF TRANSPORTATION

The Illinois Department of Transportation (IDOT) focus group meeting was conducted at the IDOT facility in Springfield, IL, on December 9, 2009. Focus group interviewees included the following:

- Bill Kramer, Geotechnical Engineer, IDOT.
- Dan Brydl, Division Bridge Engineer, FHWA Illinois Division.
- Ralph Anderson, State Bridge Engineer, IDOT.
- Todd Ahrens, Bridge Planning Engineer, IDOT.
- Carl Puzey, Structural Services, IDOT.

Organizational Structure

The central office for IDOT provides technical expertise and manages the big investment bridges but IDOT is otherwise decentralized; the nine districts (transitioning to five regions) handle maintenance and inspection. Most districts still have bridge maintenance crews, and IDOT does have regional bridge engineers. Table 15 shows the number of bridges owned by various types of agencies in the State.

Table 15. Number of bridges owned by various types of agencies in Illinois.

Agency Type	Number of Bridges Owned
State transportation department	7,740
Other State agency	44
Local agency	18,125
Federal agency	43
Toll authority	458
Railroad company	71
Private	33
Total	**26,514**

Program-Level Decision Support

IDOT has a system for bridge management that was developed specifically for it. Most projects are scheduled in conjunction with roadway projects, and roadway projects are first determined on the basis of pavement needs, with bridge needs then added into the project. IDOT does use AASHTOWare Bridge Management® software but not to generate projects. IDOT uses a system, Bridge Analysis & Monitoring System (BAMS), developed in-house, to plan and program bridge projects. BAMS separates bridges into 16 tables based on the type of bridge deficiency and the severity of the deficiency. For example, bridges that are structurally deficient with an NBI deck rating of 0–3 are placed in table 2. The other 15 tables are related to different deficiencies (structural or functional) or the same deficiency with a higher or lower NBI condition rating. For example, bridges that have a deck with an NBI deck rating of 5 are placed in table 10. The lower number tables are for bridges with the most urgent needs. So, bridges that fall into tables 1 through 4 are considered urgent, those that fall into tables 5 through 10 are considered short-term needs, and those that fall into tables 11 through 16 are considered long-term needs.

Maintenance activities are recorded in the maintenance management system, which is currently being rewritten.

District IDOT personnel perform modified AASHTO CoRe element-level inspections for State bridges, while special inspections, such as underwater or fracture critical, are outsourced. Inspections for about half of the major bridges managed by the Central Office are outsourced. (So, every other cycle, a bridge is inspected by a consultant.) Additional testing includes: dye penetrant, magnetic particle testing, UT, and GPR.

The preventive maintenance program for major bridges is a line item in the programming process, so it is funded separately from the rest of the system.

Project-Level Decision Support

The Central Office does make recommendations, but the districts make decisions on their bridge maintenance. If repairs are within a contract maintenance project, the local district bridge maintenance engineer for IDOT reviews the reports and makes the plan. If repairs are more significant, a bridge condition report is prepared to identify project scope and cost. In addition to structural deficiencies, IDOT also considers roadway needs and load capacity.

Performance Measures

- Goal of having 93 percent of bridges at acceptable rating.
- Informally, how does IDOT stand when compared with its neighboring States?

Common Forms of Deterioration

Substructure:

- Surface spalling on concrete substructure elements.
- Seismic damage.
- Occasional scour.

Superstructure:

- Expansion joint damage.
- Beam end deterioration for precast I-beams.
- Corrosion and/or peeling paint on steel members.

Deck:

- Ingress of chlorides.
- Leaking joints.

Functionality: Deterioration of approach slabs.

Maintenance and Repair Activities Requiring the Most Resources

***Substructure*:** (none cited).

***Superstructure*:** (none cited).

***Deck*:** Most of the money is spent here, with MOT being the biggest cost factor.

***Functionality*:** (none cited).

Desired Outcomes From LTBP Program

- Get the same type of data on bridges with span length less than 20 ft as IDOT gets for bridges with span lengths greater than 20 ft.
- Support for defining maintenance needs and management.
- How to encourage preventive maintenance so IDOT can avoid bridge rehabilitations and replacements (IDOT has an issue that pavements drive work, and the pavement lasts longer than bridge decks)—what is good practice?
- Best practices for sealers, overlays, and coatings.
- How to deal with concrete structures that need to be sealed in joint areas.
- Better inspection techniques for prestressed concrete members and verification of the condition state of strands and tendons in prestressed concrete members.
- What to do with deteriorated concrete or steel beam ends.
- Innovative materials such as fiber reinforced polymer superstructures—how does one inspect it in-service—what does one look for to take action?
- Use of alternative reinforcing steels—what are the performance results? How are they performing?

IOWA DEPARTMENT OF TRANSPORTATION

The Iowa Department of Transportation (IADOT) focus group meeting was conducted at the IADOT bridge office in Ames, IA, on April 17, 2009. Focus group interviewees included the following:

- Jan Wiley, Bridge Management Engineer, IADOT.
- Sandra Larson, Research and Technology Bureau Director, IADOT.
- Bruce Brakke, Bridge Maintenance Engineer, IADOT.
- Ahmad Abu-Hawash, Chief Structural Engineer, IADOT.
- Scott Neubauer, Bridge Rating Engineer, IADOT.
- Norm McDonald, Bridge Office Director, IADOT.
- Mark Dunn, Operations Research Director, IADOT.
- Max Grogg, Technical Programs Team Leader, FHWA Iowa Division.
- Tom Owen, Co-op Student, FHWA Iowa Division.

Organizational Structure

IADOT has two units, bridge design and bridge maintenance and inspection. Bridge inspection is centralized. There are six districts, and each has a district bridge repair specialist. Table 16 shows the number of bridges owned by various types of agencies in the State.

Table 16. Number of bridges owned by various types of agencies in Iowa.

Agency Type	Number of Bridges Owned
State transportation department	4,071
Other State agency	22
Local agency	20,366
Federal agency	33
Toll authority	1
Railroad company	1
Private	2
Total	**24,496**

Program-Level Decision Support

IADOT uses AASHTOWare Bridge Management® software-based element-level inspection but does not use AASHTOWare Bridge Management® software for network budgeting and programming. IADOT performs dual inspection using AASHTO CoRe elements and has collected element-level inspection data since 1994. It uses the Bridge Electronic Records Management System to track maintenance recommendations and when these recommendations have been performed.

Project-Level Decision Support

IADOT uses a Microsoft Access® database (named BRIDGE CAN) to accumulate and prioritize maintenance and preservation work on bridges for development of a 5-year program before putting out to contract. There must be agreement between the districts and the central office before a bridge is put into the program.

Performance Measures

IADOT tracks the percentage of structures with Structure Inventory and Appraisal/NBI condition ratings and sufficiency ratings that meet the previous year's values. The annual target is 95 percent. Bridges for which the sufficiency rating falls simply because of increased traffic are not deemed to have missed the previous year's value. IADOT is currently reviewing its performance measures.

Common Forms of Deterioration

Substructure:

- Corrosion of reinforced concrete piers.
- Settlement and exposure of steel abutment piles.
- Scour.

Superstructure:

- Chloride ingress.
- Deterioration of glands in expansion joints (maintaining and replacing glands).
- Corrosion of prestressed beam ends.
- Damage due to traffic impact.

Deck:

- Corrosion of deck reinforcement.
- Delaminations of deck concrete.
- Soffit spalling.

Functionality: Corrosion at construction joint between rail and deck.

Maintenance and Repair Activities Requiring the Most Resources

The majority of bridge maintenance expenditures were noted to be on deck repair and maintenance. IADOT has concerns about future needs related to deterioration of prestressed concrete beams.

Desired Outcomes From LTBP Program

- Better tools to track the effectiveness of repair strategies.

- More accurate mapping of deterioration and delaminations of bridge decks and overlays, providing an accurate picture of the delaminations so that an overlay can be placed in time and delay a full deck replacement.

- A test to determine whether weathering steel is weathering/performing properly.

- An understanding of the frequency and benefits of bridge washing.

- An understanding of how to resolve aggregate problems in reinforced concrete.
- An understanding of the effectiveness of electro-chemical chloride removal.

KANSAS STATE DEPARTMENT OF TRANSPORTATION

The Kansas Department of Transportation (KDOT) focus group meeting was conducted at the KDOT facility in Topeka, KS, on December 10, 2009. Focus group interviewees included the following:

- Kenneth Hurst, State Bridge Engineer, KDOT.
- John Patrick Jones, Bridge Manuals, Modeling and Policy, KDOT.
- Calvin Reed, Bridge Maintenance Plans, KDOT.
- Don Whisler, Bridge Management Engineer, KDOT.
- Loren Risch, Bridge Design Engineer, KDOT.
- Randy Leonard, Local Project Engineer, KDOT.
- Brad Rognlie, Bridge Engineer (Design/Scour), KDOT.
- Jim Brennan, Geotechnical Engineer, KDOT.
- Mike Orth, Bridge Engineer (Scour), KDOT.
- Steve Toillion, Division Bridge Engineer, FHWA Kansas Division.

Organizational Structure

KDOT has six districts, two of which have bridge maintenance crews although the heavy maintenance crews in each district do bridge work. The central office handles design and contract maintenance while districts are responsible for in-house maintenance and bridge inspection. Table 17 shows the number of bridges owned by various types of agencies in the State.

Table 17. Number of bridges owned by various types of agencies in Kansas.

Agency Type	Number of Bridges Owned
State transportation department	4,976
Other State agency	41
Local agency	19,673
Federal agency	115
Toll authority	364
Railroad company	3
Private	4
Total	**25,176**

Program-Level Decision Support

KDOT personnel perform routine element-level inspections using AASHTOWare Bridge Management® software, based on AASHTO CoRe elements and supplemented with other custom elements. Localities only provide NBI data. Additional tests that may be performed as conditions indicate include the following:

- Ultrasound for crack detection.
- Magnetic particle testing for crack detection in steel members.
- Dye penetrant for crack detection in steel members.

- GPR for post-tensioned duct inspection and scour detection.
- Bathometric surveys for riverbed profiles.

The State transportation department contracts out inspections on eight bridges in Kansas City and the turnpike bridges, as well as fracture-critical, pin-and-hangar structures, and underwater inspections.

Bridge replacement recommendations are prioritized by applying the following:

- A formula that uses economic impact, condition, roadway widths, and traffic volumes as input.

- AASHTOWare Bridge Management® software and Health Index (HI).(11)

- Application of sound engineering judgment.

KDOT is now tracking a performance measure called the HI, which is part of the AASHTOWare Bridge Management® system. The HI of any particular structure is calculated by dividing the sum of the current value of all the structure's components by the sum of the failure values (replacement or repair) of all components. An HI of 100 percent indicates that all of the components of the structure are in the best possible condition state. An HI of 0 percent indicates that all of the components are in the worst possible condition state.

The State transportation department is also creating a spreadsheet-based bridge management system to supplement AASHTOWare Bridge Management® software. The HI is used to prioritize work, but KDOT has found AASHTOWare Bridge Management® software to be effective for forecasting no more than 3 years ahead. Detailed cost information is lacking on the maintenance side because work is contracted out or combined with road repairs. Bridge funding and prioritization decisions are influenced by which corridor is involved, traffic data, truck data, other programmed roadway work (associated work), and economic impact.

Project-Level Decision Support

Decisions are based on inspection reports. Bridge work is also tacked onto road work. Priority authorizations from the legislature also guide decisions.

Performance Measures

- The major bridge performance measure is the HI—KDOT seeks an average HI in the high 80s to meet Federal guidelines. (Internally, KDOT targets to have no more than 5 percent of structures rated with HI below 80 and shoots for 90s on average.)

- On-budget, on-time is the primary measure for the major projects, as required by legislators.

Common Forms of Deterioration

Substructure:

- Pier cap deterioration.
- Cracking and spalling.
- Concrete riprap deterioration.
- Scour.
- Settlement of substructure elements.
- Inadequate isolation of integral abutments and MSE walls.

Superstructure:

- Deterioration of joints.
- Out-of-plane bending and fatigue of steel members.
- Rocker bearing corrosion.
- Frozen sliding-plate bearings.
- Anchor bolt corrosion of bearings.

Deck:

- Deterioration of joints.
- Ingress of chlorides.
- Deterioration of concrete deck owing to the influence of poor quality aggregates.
- Damage to deck owing to freeze-thaw cycles.

Appurtenances:

- Corrosion of shear ties that connect cathedral rails (at 1-ft intervals) to concrete box bridges.

- Noise walls hanging on rails.

- Damage from signing structures attached to bridges.

- Clogged bridge drains or deteriorated drain hardware.

Maintenance and Repair Activities Requiring the Most Resources

Substructure**:** (none cited).

Superstructure**:**

- Joints are major problem (expansion joints).
- Painting and lead-abatement for steel structures.

Deck**:** Polymer overlays.

***Functionality*:** (none cited).

Desired Outcomes From LTBP Program

- Better forecasting tools.
- Better inspection cycles that make sense—risk associated with structure type should be attached to inventory.
- Guidance on sound and reasonable environmental policy—how to logically balance bridge preservation and environmental stewardship. Currently environmental reviews take inordinately long to complete, and regulations are a major constraint.

MINNESOTA DEPARTMENT OF TRANSPORTATION

The Minnesota Department of Transportation (Mn/DOT) focus group meeting was conducted at the Mn/DOT Bridge Office in St. Paul, MN, on February 19, 2009. Focus group interviewees included the following:

- Dan Dorgan, State Bridge Engineer, Mn/DOT.
- Gary Peterson, State Bridge Construction & Maintenance Engineer, Mn/DOT.
- Duane Green, Metro Maintenance Operations Engineer, Structures, Mn/DOT.
- Dustin Thomas, Bridge Designer, Mn/DOT.
- Jim Pierce, Bridge Management Engineer, Mn/DOT.
- Chris Cromwell, Assistant Bridge Engineer, FHWA Minnesota Division.

Organizational Structure

Mn/DOT has a decentralized structure comprising eight geographical districts with the seven-county Metro district around the Twin Cities accounting for nearly half the bridge network. There are bridge maintenance staffs for each district. The central office establishes bridge policy, houses the bridge management systems, provides construction planning and support, processes load rating and permitting, conducts training and QA of district and county inspection programs, and does specialty (fracture critical) inspections. Mn/DOT directly manages bridges on the county and local systems. Table 18 shows the number of bridges owned by various types of agencies in the State.

Table 18. Number of bridges owned by various types of agencies in Minnesota.

Agency Type	Number of Bridges Owned
State transportation department	3,615
Other State agency	61
Local agency	9,330
Federal agency	78
Toll authority	0
Railroad company	19
Private	18
Total	**13,121**

Program-Level Decision Support

Mn/DOT conducts most inspections with State forces on State bridges, employing some consultants on occasion to help with fracture-critical structures or as QA/QC support. A significant number of inspections were outsourced temporarily following the I-35W bridge collapse in 2007 because the Governor called for re-inspection of all bridges in the State in a very short time window. Many counties with small staffs or few bridges hire consultants for inspections. Inspector qualifications follow NBIS guidelines and required proficiency tests.

Mn/DOT uses AASHTOWare Bridge Management® software with modifications that allow the documentation of more details about particular elements. The department has added some custom elements, such as smart flags for deck cracking, strip seal and/or joint seals, and some additional deck types, to document conditions that are not adequately represented in the basic AASHTO CoRe elements.

Mn/DOT does not directly use AASHTOWare Bridge Management® software for decisionmaking but does employ the system for limited forecasting. Mn/DOT has found AASHTOWare Bridge Management® software useful for maintenance planning, using element-level data to identify needs. Data are pulled from AASHTOWare Bridge Management® software and provided along with other information, such as past maintenance records, to districts to set up maintenance work plans. Maintenance is tracked through time sheets and a spreadsheet developed in-house. Mn/DOT use estimated costs from prior years to determine costs for preventive maintenance items. However, for recent years, much of the information is no longer captured in one central location so there is a gap. Money is allocated to districts based on a formula that is heavily driven by average daily traffic (ADT) and vehicle miles traveled, while a portion of money is managed centrally for major bridge work. Districts use a spreadsheet tool to record and prioritize maintenance actions with data drawn from bridge inspections. Districts take suggested work plans developed by central office personnel to assist in making decisions on specific activities.

For considerations of replacement or new construction, primarily NBI inventory and condition data, and ADT are used as planning inputs. Mn/DOT did establish a "Major Bridge Program" for very large bridges that would otherwise consume a disproportionate share of resources within the districts. Also, at the time of the interview in 2009, MnDOT had a bridge preservation program that was funded separately from the regular bridge maintenance program.

Project-Level Decision Support

Most bridge preservation projects are scheduled in conjunction with roadway projects, and roadway projects are first determined on the basis of pavement needs with bridges needs then added into the project. Work is prioritized (high, medium, and low) on inspection reports. Nondestructive testing (GPR and infrared thermography) is contracted out as needed although experience with NDT has been minimal.

Performance Measures

Mn/DOT primarily tracks bridge performance based on general condition ratings, by trying to limit the number of bridges in fair or poor condition (NBI condition rating of 5 or less) to less than 16 percent. The primary measure used is the number of bridges in poor condition (NBI condition rating of 4 or less) with a goal of 2 percent. There is a goal of 16 percent for bridges in fair condition (NBI condition rating of 5 or less on deck condition rating, superstructure condition rating, or substructure condition rating). The number of good bridges (NBI rating of 7 and above) is tracked for informational purposes.

Mn/DOT has tracked goals on bridge performance for 10 years and used that to drive investment in bridge replacements and improvements.

All maintenance is recorded in spreadsheets so that Mn/DOT can track and report annually the percentage of work performed. Four years ago, it started tracking preventive maintenance measures.

Common Forms of Deterioration

Substructure

- Concrete spalls primarily under joints or pier column faces where salt spray gets on them.
- Leaking under girders.
- Scour.

Superstructure

- Leaking joints.
- Bearings.
- Damage from traffic impacts.

Deck

- Cracking.
- Corrosion of decks with black bars (top or bottom) due to de-icing chemicals.
- Spalls along edges of bridge joints.

Functionality

- Spalls on the traffic side of bridge railings.
- Settlement and shifting of slope paving.
- Damage of approach slab where it is tied in with joints.

Maintenance and Repair Activities Requiring the Most Resources

Substructure**:** (none cited).

Superstructure**:** 10 percent of budget spent here.

Deck**:** 90 percent of budget spent here (including deck patching, deck joints, railings, driving surface and approach slabs).

Functionality**:** (none cited).

State Transportation Department Successes

Mn/DOT has district bridge maintenance crews that have been valuable particularly in preventative maintenance work.

Desired Outcomes From LTBP Program

Mn/DOT wants well-established cost-benefit relationships for the various maintenance actions that it employs on bridges. In particular, Mn/DOT would like better prediction of paint life.

MONTANA STATE DEPARTMENT OF TRANSPORTATION

The Montana Department of Transportation (MDOT) focus group meeting was conducted at the MDOT facility in Helena, MT, on October 19, 2009. Focus group interviewees included the following

- Paul Jensen, Bridge Management Engineer, MDOT.
- Kent Barnes, State Bridge Engineer, MDOT.
- Mike Murphy, Bridge Maintenance Office, MDOT.
- Bob Burkhart, Division Bridge Engineer, FHWA Montana Division.
- Amanda Jackson, Bridge Engineer, MDOT.

Organizational Structure

MDOT has a centralized structure with five districts and a central office. Design is done within the central office while districts are responsible for inspection. Maintenance is under the central office personnel who are assigned maintenance crews in each district to assist with the work. Table 19 shows the number of bridges owned by various types of agencies in the State.

Table 19. Number of bridges owned by various types of agencies in Montana.

Agency Type	Number of Bridges Owned
State transportation department	2,488
Other State agency	0
Local agency	1,930
Federal agency	702
Toll authority	0
Railroad company	0
Private	0
Total	**5,120**

Program-Level Decision Support

MDOT uses AASHTOWare Bridge Management® software along with post-processing to manage goals and objectives. Network-level indices (structurally deficient or functionally obsolete, HI, Sufficiency Rating, and eligibility status) are used to help in prioritization. Indices are also used to help prioritize off-system bridges. Maintenance data are entered into the maintenance management system but cost and work performed are not captured with recommendations/work request on specific structures.

MDOT has a capital program for rehabilitation and replacement. The preventive maintenance program is mill and fill (peel off riding system and fix joints and bearings) or healer/sealer to fill voids in cracks.

Additional functionality in AASHTOWare Bridge Management® software desired includes the following:

- Cost.
- Deterioration models.

- Four condition states for AASHTO CoRe elements.
- Separation of structural versus functional element levels.
- End of functional service level rather than saying failure.
- Fewer elements.

MDOT employees conduct routine biennial bridge inspections, while underwater and hangar and pin inspections are outsourced. Additional testing includes GPR and chloride testing.

Project-Level Decision Support

Maintenance decisions are made based on NBIS and the vulnerabilities index from the National Cooperative Highway Research Program (NCHRP) Report 590—Multi-Objective Optimization for Bridge Management Systems, along with bridge inspection report recommendations.(12) The five major vulnerabilities are seismic, scour, ADT, overloads, and condition. Actions are prioritized high, medium, and low, but they do not have timeframes associated with them. Maintenance work is performed by MDOT road crews and captured in a system designed for road maintenance, so captured information is incomplete for bridges.

Performance Measures

- Number of structurally deficient bridges.
- Number of functionally obsolete bridges.
- Sufficiency rating and eligibility status.
- Modified HI.
- Off-system index to prioritize bridge work that adds in other factors (age, size, priority) and plan to have this system for State bridges.

Common Forms of Deterioration

Substructure:

- Settlement of substructure.
- Scour.
- Deterioration of timber piling.

Superstructure:

- Damage from over-height vehicles.
- Deterioration of paint on steel girders.
- Displaced or lost bearings.
- Debris in bearings.

Deck:

- Damage from studded tires.
- Ingress of chlorides.

- Improper construction techniques, such as poor curing of deck concrete resulting in bridge deterioration.

Functionality:

- Lack of traffic capacity.
- Deterioration of approaches.

Maintenance and Repair Activities Requiring the Most Resources

Substructure: (none cited).

Superstructure: (none cited).

Deck: Majority of resources expended on the deck.

Functionality: (none cited).

Desired Outcomes From LTBP Program

- Check the NBI Translator to see whether Sufficiency Rating is calculated accurately—if not, what should it be?

- New computation of Sufficiency Rating based on element-level inspection.

- What is the value of preventative maintenance over reactive maintenance?

- A construction practice to relieve cracking and stress on the deck without building a joint.

- What is the relationship between traffic and bridge service life and the resulting impact on design and the functionally obsolete rating?

- Bridge design with maintenance in mind—need to give MDOT solutions for anticipated maintenance (such as what Europe has done, for example, an access in the pier wall to fix a joint from the other side or a set of stairs to get down the side of bridge).

- Waterproofing systems to use during construction process.

NEW JERSEY DEPARTMENT OF TRANSPORTATION

The New Jersey Department of Transportation (NJDOT) focus group meeting was held at the Rutgers University Center for Advanced Infrastructure and Transportation on September 24, 2008. Focus group interviewees included the following:

- Helene Bowman Cook, FHWA New Jersey Division.
- Richard Dunne, Central Office Bridge, NJDOT.
- Amad Ghorbani, Central Office Maintenance, NJDOT.
- Greg Renman, Central Office Inspections, NJDOT.

Organizational Structure

NJDOT has a centralized structure. Although there are three geographic regions in the transportation department, bridge staff are located in two central office groups: design and inspection resides under Capital Project Management, and bridge maintenance resides under Operations and Maintenance.

NJDOT owns about 2,500 bridges for which it has design, construction, inspection, and maintenance responsibility. Table 20 shows the number of bridges owned by various types of agencies in the State.

Table 20. Number of bridges owned by various types of agencies in New Jersey.

Agency Type	Number of Bridges Owned
State transportation department	2,371
Other State agency	214
Local agency	2,637
Federal agency	30
Toll authority	1,163
Railroad company	2
Private	17
Total	**6,434**

Program-Level Decision Support

NJDOT uses AASHTOWare Bridge Management® software for its bridge management system to archive data. At the time of the interview in 2008, NJDOT had not had sufficient funds to customize the software.

Decisions regarding maintenance activities are based on inspections and identification of priority repairs: emergency (within 3 days), priority 1 (within 1 month), and priority 2 (within 3 months). A log in the maintenance office is kept to track actual activities; this log is separate from the bridge management system. Cost data are kept within the contracts and are not part of the system. NJDOT shares information with the New Jersey Turnpike Authority because it faces several of the same issues, such as truck traffic volume.

Project-Level Decision Support

NJDOT performs AASHTOWare Bridge Management® software CoRe element and NBI inspections. It uses a capital investment strategy to help prioritize activities. The State looks at bridges and prioritizes them based on condition, which is determined by the sufficiency rating. NJDOT does not capture actual repairs performed versus those recommended from inspections.

Performance Measures

NJDOT inspects all bridges in the State, with the exception of those owned by toll authorities and one county. The department monitors inspection records for all structures to ensure compliance with the inspection cycles. NJDOT has a performance measure to reduce scour critical bridges by 20 structures per year. It focuses on decks because that is where its customers are focused. It tracks the priority log to ensure action is taken within the designated time period (emergency within 3 days, priority 1 within 30 days, and priority 2 within 90 days).

Common Forms of Deterioration

***Substructure*:** Spalling, pier cap deterioration, rusted and/or frozen bearings, scour.

***Superstructure*:** Bearing misalignment or failure, joint deterioration, impact damage deterioration of paint systems, cracking of steel beams, rust and corrosion of steel superstructure members.

***Deck*:** Spalling, cracking.

***Functionality*:** Lack of capacity for traffic volumes, impact damage, poor performance of deck drains.

Maintenance and Repair Activities Requiring the Most Resources

***Substructure*:** Approximately 20 percent of funds.

***Superstructure*:** Approximately 20 percent of funds.

***Deck*:** 60 percent of funds.

***Functionality*:** Impact damage, lack of capacity for traffic volumes.

Desired Outcomes From LTBP Program

- NJDOT wants the ability to do deterioration modeling in support of making the “when” decision for repair or rehabilitation.
- If one seals and overlays a bridge deck, how much life does one get?
- Which is better—a bare or covered bridge?
- What is the value of preventative maintenance?

- What is the best material for deck patching?
- How can one tell if a deck joint is working?
- New Jersey representatives said that one reason NJDOT went to overlays was because it feels there is impact loading when trucks hit potholes or approaches, and that impact load is not measured. They want to know what the effect is on the rest of the deck when a truck impact load is incurred. This may also apply to uneven approaches or joints. They do not have specific data on this but think it contributes to deterioration of decks, so their policy is to put overlays in place to reduce the impact.

NEW YORK STATE DEPARTMENT OF TRANSPORTATION

The New York State Department of Transportation (NYSDOT) focus group meeting was conducted at Parsons Brinkerhoff offices in Penn Plaza, New York, NY, on October 6, 2008. Focus group interviewees included the following:

- Sreenivas Alampalli, Bridge Office, NYSDOT.
- George Christian, Bridge Office, NYSDOT.
- Earl Dubin, FHWA New York Division.
- Harold Fink, Region 11 (New York City), NYSDOT.
- Ron Kudla, Region 10 (Long Island), NYSDOT.

Organizational Structure

NYSDOT has a decentralized structure comprising 11 regions with bridge maintenance staff in each; the central office provides oversight and support. Table 21 shows the number of bridges owned by various types of agencies in the State.

Table 21. Number of bridges owned by various types of agencies in New York.

Agency Type	Number of Bridges Owned
State transportation department	7,460
Other State agency	212
Local agency	8,646
Federal agency	115
Toll authority	364
Railroad company	3
Private	4
Total	**17,420**

Program-Level Decision Support

NYSDOT does not currently use a formal bridge management system, but it does have extensive bridge management tools that were developed in-house and that are used to do various levels of bridge management analysis—forecasting, needs, and inventory—and these tools interface to various degrees. NYSDOT does not use AASHTOWare Bridge Management® software on a production basis, although NYSDOT owns a license and has a small group investigating future options. The program development unit at headquarters, along with the planning division, assesses programs and needs (for example, recently completed a 20-year needs assessment) and have developed a tool that extracts data from the inventory and the program support systems. NYSDOT has a tool that predicts deterioration rates of bridge elements and a cost estimating tool.

NYSDOT personnel and consultant inspectors perform element-level (using customized elements, not CoRe elements) and NBI inspections and collect more data than required by NBI. They use a span-by-span method of rating the elements of the bridge. They have approximately 20 years of maintenance data, although the level of quality of maintenance varies for data older than 5 years. There is a maintenance management system that tracks work and resources. The bridge foreman enters data and the system also serves as a time and attendance system. The accuracy of hours spent on an action is limited, because, for example, an emergency call has a minimum 4-hour charge per worker even if actual work only took 1 hour. Thus, the system shows maintenance activity that was done even if time estimates are sometimes inflated. Currently, the inspection and maintenance systems do not interface.

Decisions regarding maintenance activities are related to regional goals, but goals vary across the State. NYSDOT has good core data and deterioration modeling that is used. Cost estimates are good for replacement but not as accurate for rehabilitation and repair. NYSDOT can forecast costs inventory-wide and forecast element-level deterioration.

Project-Level Decision Support

The maintenance engineer makes the decision(s) on individual projects, giving equal weight to bridge inventory data, recommendations of bridge crews, and the engineer's experience and knowledge. Maintenance engineers track needed work and trends separately. They use the database of bridge conditions and emergency response history in their decisionmaking. NYSDOT has its own definition of "deficient," which is different from the Federal definition. NYSDOT reports inspection data to the FHWA in the 0 to 9 format required by the NBIS. NYDOT also defines deficient bridges using the Federal criteria according NBIS. When prioritizing, they look at Federal sufficiency ratings, NYSDOT condition ratings, geometric dimensions, and eligibility for Federal funds. The Regional offices have all the condition lists, and the main office provides them with a priority list that takes into consideration all of the following:

- Bridge condition.
- ADT data.
- Traffic problems.
- Vertical clearance.
- Highway system—the National Highway System (NHS) has priority because truck traffic causes them to suffer more damage.

Testing to supplement the routine inspections may include indepth load rating analysis, magnetic particle testing, ultrasonic testing, thermographic camera when further testing is needed, UT, and dye penetrant. NYSDOT clarified that "visual" inspection actually employs sight, sound, and touch. If an inspector rates something 4 or less, that inspector must document this with written notes, photo, and test data and add that to the inspection report. NYSDOT employs GPR on many bridges now.

Performance Measures

NYSDOT uses its own custom bridge condition rating system to determine whether a bridge should be classified as deficient. The NYSDOT condition rating scale ranges from 1 to 7, with 7 meaning in new condition, no deterioration, and 1 meaning the element is in a totally deteriorated or failed condition. A rating of 3 means an element has serious deterioration or is not functioning as designed. The several different elements on the bridge are each rated between 1 and 7, and different weights are assigned to the different element ratings. Bridges with a calculated rating of less than 5.000 are deficient. NYSDOT recognizes that using a performance measure that quantifies just the number of bridges produces skewed results when considering long span (high deck area) bridges (such as the Brooklyn Bridge). Thus, NYSDOT tabulates performance data both for number of bridges and for deck area of bridges. NYSDOT looks at critical components—it does not want certain critical elements to be less than 3 and has tools that will list these elements.

NYSDOT looks at posted bridges—load-posted and permit-posted bridges on the network (and where these bridges are located on network). It tracks flagged work needs and resolution of the flagged needs—the number of overdue flagged work needs has increased in the last couple of years, and NYSDOT is not keeping up as well as it did previously. This may be the result of economics, age of bridges, increase in traffic, or increase in heavy loads. The number of flags indicates how well NYSDOT is maintaining its structures for each region. The goal is to minimize flagged work needs, but NYSDOT tries to correct all the problems on a bridge rather than just fixing the flagged item, i.e., if the structure has another condition looming while workmen are fixing a flagged item, they should try to spend more time to correct all the pending problems. NYSDOT feels this might prevent a flagged item down the road; however, resources become an issue.

NYSDOT has had a robust preventive and corrective maintenance program for the last 10 years and has seen positive changes in deterioration rates.

Common Forms of Deterioration

***Substructure*:** Spalling, rusting and exposed rebar, delaminations, scour, corrosion, deterioration of steel piles.

***Superstructure*:** Girder end deterioration, impact damage, paint chalking, peeling, leaking joints.

***Deck*:** Spalling, pot holes, cracking.

***Functionality*:** Bridge width not matching road width, vertical clearance.

***Structural capacity*:** Load rating.

Maintenance and Repair Activities Requiring the Most Resources

***Substructure*:** 50 percent of budget expended, including scour.

***Superstructure*:** (none cited).

***Deck*:** (none cited).

***Functionality*:** (none cited).

Desired Outcomes From LTBP Program

- What is the most reliable way to predict the life of a bridge?
- Does one need to look at fracture critical bridges every 2 years?
- How long will the bridges with epoxy-coated rebar last?
- When will a bridge start to punch through? Are there reliable tools to help predict this condition?
- Is sealing a deck worth it? How much more life does one get? Should it be done on new decks?
- Will New York have problems with its 1960s prestressed beams? NYSDOT has observed some deterioration.
- Evaluation of prestressed concrete to identify any corrosion in the strand early.

OHIO STATE DEPARTMENT OF TRANSPORTATION

The Ohio Department of Transportation (ODOT, presented as ODOT-OH for the purposes of this report) focus group meeting was conducted at the ODOT-OH facility in Columbus, OH, on December 1, 2009. Focus group interviewees included the following:

- Michael Loeffler, Bridge Operations, ODOT-OH.
- Matt Shamis, Division Bridge Engineer, FHWA Ohio Division.
- Jeff Crace, Review Engineer, ODOT-OH.
- Jawdat Siddiqi, Review Engineer, ODOT-OH.
- Mike Brokaw, Bridge Inspection, ODOT-OH.

Organizational Structure

ODOT-OH has a decentralized structure with 12 districts. The central office manages contracts, while districts handle design, maintenance, and inspection. ODOT-OH does have district bridge maintenance crews although the dollars are limited, and ODOT-OH contracts out much of the maintenance work. Table 22 shows the number of bridges owned by various types of agencies in the State.

Table 22. Number of bridges owned by various types of agencies in Ohio.

Agency Type	Number of Bridges Owned
State transportation department	10,345
Other State agency	11
Local agency	16,140
Federal agency	11
Toll authority	472
Railroad company	32
Private	34
Total	**27,045**

Program-Level Decision Support

ODOT-OH does not use AASHTOWare Bridge Management® software. It has its own bridge management/inspection system—each bridge has a unique structural number and shows 5 years of ratings—so ODOT-OH has a history of needs that includes recommended actions with status (new, recurring, completed). Decisions are based on bridge condition, or the operational performance indicator (OPI), as listed in the bridge management system.[3] The inspection is emailed to the bridge engineer for review, and it automatically populates the bridge maintenance system. ODOT-OH employees perform element-level (not per span) inspections on all bridges in the State and comply with NBIS. Underwater bridge inspections are outsourced. Localities and

[3] The organizational performance index monitors the monthly performance of all 12 districts in several key areas of construction management, contract administration, equipment and facilities, finance, information technology, plan delivery, quality and human resources, system conditions, traffic safety, and highway maintenance. These scores are used to monitor several programs and to standardize services across districts. OPI exception reports and action plans are discussed during monthly executive management meetings. Many of these performance measures are used to annually evaluate management and staff.

turnpikes conduct their own bridge inspections. Additional testing included in some State bridge inspections is limited GPR, UT, and magnetic particle testing. ODOT-OH does use SHM (long-term instrumentation) on some major structures.

Repair information is kept in a Web portal. ODOT-OH does have archived cost information. It needs better document handling (for example, photos are all in separate folders and drives) and is planning a geotechnical document database and has scanned old bridge plans, aperture cards, etc. ODOT-OH has multiple systems that currently are not linked.

Project-Level Decision Support

Districts make decisions—some bridge repair work is done in-house, but a lot of bridge repair work is contracted out to the private sector. At the time of the interview in 2009, if the cost of repair on a bridge was more than $50,000, then the repair was contracted out. Central office planning provides oversight. Decisions are based on inspection reports, safety, and congestion.

Performance Measures

No performance measures were captured.

Common Forms of Deterioration

Substructure: Scour.

Superstructure:

- Deterioration of joints.
- Peeling paint.
- Deterioration of prestressed concrete adjacent box beams.

Deck:

- Cracking.
- Ingress of chlorides.

Functionality:

- Deterioration of approach slab.
- Poor drainage.

Maintenance and Repair Activities Requiring the Most Resources

***Substructure*:** (none cited).

***Superstructure*:** Painting.

***Deck*:** Overlays—the majority of the funds are spent on decks.

***Functionality*:** (none cited).

Desired Outcomes From LTBP Program

- Detailed guidance on locating, measuring, and describing deterioration such as cracked areas on a deck; the problem with high-performance concrete (HPC) cracks—how much does that affect deterioration (accelerate corrosion) and needs to be noted in condition rating?
- How does one differentiate between the cracks with different types of concrete such as HPC?
- How is design playing into the performance of various elements?
- More methods of nondestructive testing.
- Sealing and coatings of concrete surfaces—is there an economically good return; is it effective?
- A target value for permeability of concrete to prevent water from getting through and having corrosion.
- Joints that do not leak.
- Reduction in deck cracking.
- Degradation rates.
- Quantifying costs for preventative maintenance to help determine how they compete against each other (for example, bridge treatments that would be cost effective).
- Lifecycle cost recommendations.

OREGON STATE DEPARTMENT OF TRANSPORTATION

The Oregon Department of Transportation (ODOT, presented as ODOT-OR for the purposes of this report) focus group meeting was conducted at the ODOT-OR facility in Salem, OR, on October 20, 2009. Focus group interviewees included the following:

- Bruce Johnson, State Bridge Engineer, ODOT-OR.
- Gary Bowling, Bridge Operations Engineer, ODOT-OR.
- Bert Hartman, Bridge Preventive Maintenance Engineer, ODOT-OR.
- Richard King, Major Bridge Management Engineer, ODOT-OR.
- Mike Gehring, District 2A Bridge Maintenance Engineer, ODOT-OR.
- Ronald Kroop, District Manager, ODOT-OR.
- Jeff Norman, District 4 Bridge Manager, ODOT-OR.
- Tim Rogers, Division Bridge Engineer, FHWA Oregon Division.
- Ray Bottenberg, Corrosion Engineer, ODOT-OR.
- Steve Lovejoy, Senior Bridge Engineer, ODOT-OR.
- Bruce Novakovich, Senior Bridge Engineer, ODOT-OR.
- Dawn Mach, Bridge Financial Analyst, ODOT-OR.

Organizational Structure

ODOT-OR is decentralized, with five regions that are primarily responsible for delivering projects. Within the 5 regions is a total of 15 districts that are responsible for maintaining infrastructure and providing oversight of the region for the capital program. Headquarters has a technical services group (bridges included) that is responsible for inspection and that manages standards and funding for the State Transportation Improvement Program (STIP) and the major maintenance program. Eleven bridge maintenance crews are shared across the districts. Table 23 shows the number of bridges owned by various types of agencies in the State.

Table 23. Number of bridges owned by various types of agencies in Oregon.

Agency Type	Number of Bridges Owned
State transportation department	2,706
Other State agency	54
Local agency	4,074
Federal agency	790
Toll authority	2
Railroad company	5
Private	7
Total	**7,638**

Program-Level Decision Support

ODOT-OR uses AASHTOWare Bridge Management® software to store inventory, inspectors' data and reports, and condition ratings. It also uses the software for external processing of NBI data. ODOT-OR collects additional data in 13 categories to supplement the NBI data (for example, widening). Additional information is used in developing the capital program and stored external to AASHTOWare Bridge Management® software. ODOT-OR has a strategy to focus on structurally deficient bridges or bridges with an NBI rating of 5 on NHS and on State freight routes. At the time of the interview in 2009, ODOT-OR had set aside $7-8 million for major maintenance to target critical deficiencies it could not develop into STIP or could not be done by maintenance forces by supplementing their budget on specific projects . This program is managed statewide. Maintenance activity is captured in the maintenance management system. ODOT-OR is working on coming up with project costs—it is considered a major need for the information technology and bridge groups to develop a system to tie maintenance costs to individual tasks within AASHTOWare Bridge Management® software and to bridges and elements.

Headquarters manages the capital program and identifies needs, working with regions for prioritization and programming in the STIP. About one-third of the capital program is spent on preserving high-cost structures and moveable bridges, one-third is spent on strengthening and freight movement, and one-third is spent on safety or Federal requirements. ODOT-OR would also like to have a program focused on retrofit of bridges with known seismic vulnerabilities.

AASHTOWare Bridge Management® software element-level inspections are performed by State employees and include an underwater crew as well as management of the consultant program for inspecting major bridges and local bridges. ODOT-OR has a rigorous QA/QC program that requires inspector ratings to be within plus or minus 1 of the QA rating. The QA rating is the NBI condition rating assigned by experienced ODOT-OR inspectors to deck, superstructure, or substructure. During training of new inspectors, the trainees must inspect the bridge components and independently arrive at a rating that is plus or minus 1 of the QA rating.

Additional testing includes magnetic particle testing, timber boring, UT, and, rarely, impact echo. ODOT-OR has SHM (long-term instrumentation) on about a dozen bridges, including strain gauges, corrosion surveys, cathodic protection, and load testing.

Project-Level Decision Support

In addition to NBIS, ODOT-OR looks at the following:

- Restricted bridge list.
- Load rating information.
- Scour information from hydraulics.
- Maintenance recommendations from inspection reports.
- Remarks from bridge inspectors—sometimes all the data are not in the sufficiency rating—particularly data on decks.

If maintenance crews are spending a lot of recurring time on a bridge, it may not show in the data, but ODOT-OR would get that data through the feedback loop when sending out the bridge priority list. From the field, ODOT-OR is trying to link projects with road crews/field coordination.

Performance Measures

The only items ODOT-OR routinely reports on are structurally deficient and functionally obsolete; the goal is to have 75 percent of structures rated good or better. ODOT-OR is moving from performance measures to return on investment at the commission level.

Common Forms of Deterioration

Substructure:

- Shear cracking of cross beams between pier columns.
- Shear cracking of pier caps.
- Scour.
- Timber pile deterioration.
- Cracking in abutment walls.
- Spalling in columns.
- Settlement.
- Poor drainage.

Superstructure:

- Bridge joints deterioration.
- Pack rust on steel members.
- Peeling paint on steel members.
- Deterioration of steel bearings.
- Distortion induced fatigue on steel beams and in steel floor systems.
- Shearing on steel structures (excessive loads and age of bridges).
- Shear cracks on concrete bridges.
- Spalling concrete on coastal structures.

Deck:

- Cracking.
- Rutting in asphalt overlays.
- Damage from use of studded tires.
- Ingress of chlorides.

Functionality: Functional obsolescence.

Maintenance and Repair Activities Requiring the Most Resources

***Substructure*:** (none cited).

***Superstructure*:** Most of capital program maintenance funds are spent on paint, cathodic protection, and repairing cracked girders.

***Deck*:** Sealing decks, repairing joints, and replacing timber elements.

***Functionality*:** (none cited).

Desired Outcomes From LTBP Program

- Ideally having results, findings, and conclusions from LTBP Program that ODOT-OR could apply in 20 years that address types of bridges that have to be kept in service for some undetermined number of years—it is looking for a proactive rather than a reactive approach.

- SHM—ODOT-OR needs an interface between data on the bridge and the computer, and the ability/mechanism to process the data and make them useful (ways to communicate between the bridge and the computer such as radio frequency, cellular telephone, and/or hard-wired lines; ODOT-OR wants it to be more cost effective).

- Wireless sensors that are independent and powered by batteries, solar, or other source to reduce the expense of an SHM system.

- Forward-looking and reliable maintenance program, including what treatments are useful and when they might be applied.

- At the program level—what is the optimum level of maintenance funding to maintain bridges at the optimum level and extend service life? (For a given bridge inventory with specific structure types and environment, what is needed to maintain optimum performance?)

TEXAS DEPARTMENT OF TRANSPORTATION

The Texas Department of Transportation (TxDOT) focus group meeting was conducted at the TxDOT facility in Austin, TX, on April 29, 2009. Focus group interviewees included the following:

- David Hohmann, Director, TxDOT Bridge Division.
- Tom Yarbrough, Bridge Management Engineer, TxDOT Bridge Division.
- Keith Ramsey, Director of Field Operations Section, TxDOT Bridge Division.
- Brian Merrill, Manager, Bridge Construction and Maintenance, TxDOT Bridge Division.
- Alan Kowalik, Inspection Supervisor, TxDOT Bridge Division.
- Hector Garcia, Assistant Bridge Engineer, FHWA Texas Division.

Organizational Structure

TxDOT has a decentralized structure. There is a central Bridge Division, and each district has a Bridge Engineer. The central Bridge Division provides support for construction and design. It oversees design, field operations, administration, special inspections, and project development. Districts perform inspection and bridge management. There are 25 districts. Maintenance is run from the maintenance division at headquarters. Table 24 shows the number of bridges owned by various types of agencies in the State.

Table 24. Number of bridges owned by various types of agencies in Texas.

Agency Type	Number of Bridges Owned
State transportation department	33,513
Other State agency	34
Local agency	17,663
Federal agency	227
Toll authority	793
Railroad company	3
Private	10
Total	**52,243**

Program-Level Decision Support

There is a dedicated bridge preventive maintenance fund. TxDOT has enhanced AASHTOWare Bridge Management® software for data entry that has decreased entry errors. It would like to enhance the software for use as a planning tool but needs to develop a deterioration model to use for running scenarios. Data records only go back to 2000. TxDOT has developed its own inspection module, currently being piloted by one district because TxDOT wants to collect more information than AASHTOWare Bridge Management® software requires. The maintenance division tracks cost according to broad work categories, but cost is not tied to specific bridges. TxDOT is building a new maintenance system.

Project-Level Decision Support

Maintenance recommendations are made at the district level (ranked list based on condition ratings) and passed to area offices where the recommendations are implemented. There is little corridor planning although TxDOT is promoting it.

Performance Measures

The fundamental performance measure used by TxDOT for bridges is the percentage of bridges that are rated good or better. The State transportation department set a goal of having 80 percent of structures rated good or better by 2011.

Common Forms of Deterioration

Substructure:

- Corrosion of reinforcing elements of concrete substructure.
- Corrosion of steel piling in salt water.
- Scour.

Superstructure:

- Corrosion of reinforcing steel in reinforced concrete girders.
- Damage due to traffic impact.
- Deterioration of steel bearings on older bridges.
- Added inspection requirements for fracture critical bridges as well as risk of failure and repair work.
- ASR issues with prestressed concrete members.

Deck: High levels of carbonation of materials used from 1950s through the 1970s.

Functionality:

- Insufficient compaction behind abutments.
- Performance of railing and transitions.
- Deterioration of high mast illumination poles.

Maintenance and Repair Activities Requiring the Most Resources

Substructure**:** 50 percent of budget.

Superstructure**:** (none cited).

Deck**:** 50 percent of budget.

***Functionality*:** (none cited).

State Transportation Department Successes

TxDOT has revised its inspection processes, now based on rotating assignments within a pool of inspection consultants. This centralized process has improved compliance, QA, and consistency.

TxDOT designed a Web-enabled interface to AASHTOWare Bridge Management® software, called Pontis, which is used by inspection consultants to submit inspection results and by TxDOT personnel to review and analyze the bridge management information.

Desired Outcomes From LTBP Program

- Better documentation to emphasize the importance of preventive bridge maintenance.
- Asset management tools to assist in dividing and prioritizing maintenance funds among disparate asset types.
- Development of a guide that explains the importance of bridge maintenance, particularly for audiences such as policymakers and managers who are not trained or practiced in bridge engineering or maintenance.
- Integrated systems to manage bridges.
- Greater integration of information tools and systems, emphasizing the use and integration of relational database structures.
- Research and documentation to support risk-based scheduling of inspections, rather than prescriptive 2-year increments, which are perceived as wasteful when applied to newer structures in excellent condition.

UTAH DEPARTMENT OF TRANSPORTATION

The Utah Department of Transportation (UDOT) focus group meeting was conducted at the UDOT Central Office in Salt Lake City, UT, on March 5, 2009. Focus group interviewees included the following:

- Stan Burns, Director of Engineering Services, UDOT.
- Fred Doehring, Deputy Bridge Engineer, UDOT.
- Mike Ellis, Structural Maintenance Coordinator, UDOT.
- Jim McMinimee, Director of Project Development UDOT.
- Chris Potter, Deputy Bridge Operations Engineer, UDOT.
- Jason Richins, Senior Design Engineer, UDOT.
- Russ Robertson Bridge Engineer, FHWA Utah Division.

Organizational Structure

UDOT has a decentralized project management organization, so project managers and roadway design staff are located in four regions. Supervisors help manage bridge maintenance projects in their regions of the State. The central design unit oversees consultant design, inspections, and technical specialties. Table 25 shows the number of bridges owned by various types of agencies in the State.

Table 25. Number of bridges owned by various types of agencies in Utah.

Agency Type	Number of Bridges Owned
State transportation department	1,773
Other State agency	0
Local agency	1,029
Federal agency	145
Toll authority	0
Railroad company	0
Private	0
Total	**2,947**

Program-Level Decision Support

UDOT uses a modified version of AASHTOWare Bridge Management® software in an Oracle database (a customized module for UDOT data was added). UDOT has bridge files dating back to the 1920s and is scanning archived bridge plans to create electronic files. It does not use AASHTOWare Bridge Management® software for projecting or planning. UDOT has requested linking databases (materials, construction bid with cost, project management, and AASHTOWare Bridge Management® software) across the State transportation department. Currently, pre-1999 records are hard copy only. UDOT uses a spreadsheet developed in-house to plan for every bridge project. The spreadsheet tracks every bridge in the STIP and indicates whether the bridge is approved for concept and development phase and whether a project is approved for funding. Using this spreadsheet, along with a similar one for projects on pavement sections, the main office and the regional offices work together to schedule bridge projects and, when possible, link them to roadway projects to minimize the disruption of traffic.

Project-Level Decision Support

Information was requested from district engineers on where they perceived needs on bridges. (At the time of the interview in 2009, 50 percent of the budget funds were allocated to preservation and 50 percent to maintenance.) Inspection data feeds into STIP. Public perception and safety feed into decisionmaking.

Performance Measures

UDOT has established a goal to eliminate bridges rated structurally deficient (currently 2.5 percent of the inventory is rated structurally deficient).

Common Forms of Deterioration

Substructure:

- Deterioration of concrete in the splash zone.
- Cracking of backwalls.
- Spalls of substructure concrete close to beams.
- Erosion under abutments and approach slabs.
- Beam locking on steel bridges—bearing at one ends freezes and all expansion occurs at opposite end; can impact and crack concrete backwall.

Superstructure:

- Water leaking from deck joints over beams and bearings.
- Damage of beams from traffic impact.
- Deterioration due to drainage problems on deck.
- Joint deterioration in simple spans.
- Rusting of weathering steel.
- Peeling of paint on steel girders.
- Delaminations.

Deck:

- Potholes.
- Deterioration of deck joints.
- Settlement of approach slabs.
- Cracking.
- Delamination of polymer overlays.

Functionality:

- Interaction of pavement and approach slab—vertical displacement.
- Parapet spalls.
- Utilities under structures; corrosion of hangars.
- Settlement of MSE walls.
- Slope protection—loss of protective materials and sloughing of fill material.

Maintenance and Repair Activities Requiring the Most Resources

Substructure**:** 25 percent of budget.

Superstructure**:** 25 percent of budget.

Deck**:** 50 percent of budget.

Functionality**:** (none cited).

State Transportation Department Successes

UDOT is a leader in using Accelerated Bridge Construction (ABC) to minimize the impact of bridge construction on the public. UDOT is dedicated to its initiative to replace conventional construction techniques with ABC, wherein the State transportation department is able to build new structures while minimizing the impact to the public and increasing worker safety. Utah representatives admit that this is in an early stage—durability of the structures is still unknown. The program has evolved over the last 10 years, starting with partial-depth precast decks, progressing to full-depth precast decks, and then migrating to construction of bridges onsite or offsite and moving them into position using sliding or self-propelled modular transports. Many details evolved during this time; for example, (prefabricated) decks migrated from welded tie to post-tensioning. Changes in connection details on bent caps (constructability issue) are another example. UDOT set the policy that, as of fiscal year 2010, it will use ABC exclusively on new construction. Examples of structures with details that may affect long-term durability and maintenance include the following:

- Pre-assembled bridges that did not seat cleanly when moved into place, thus requiring shims.

- Some fully precast bridges containing considerable post-tensioning in the abutments.

- Corrugated steel girders, constructed on a reversing s-curve, with two-dimensional panels on girders attached using welds and grouted pockets and with a polymer overlay.

Use of geofoam instead of lightweight fill has been implemented to counter the effects of prolonged settlement of lake bed silt and other materials.

Contrary to prior practice, UDOT now designs the exterior girders of bridges to carry full lane loads in anticipation of future expansions needed to address capacity issues.

Desired Outcomes From LTBP Program

Despite expressing confidence in the benefits of the ABC process, UDOT does want to know what implications for long-term bridge life may exist for using precast decks and other elements and what that means for preservation and maintenance efforts in 10 to 15 years.

Utah representatives expressed a desire for a uniform resource to identify and document best practices in bridge preservation. They would also like a resource that identifies design details that help ensure durable structures. For example, UDOT has experimented with moving expansion joints off of structures to approaches and feels this has been a successful practice. Do other States have similar or contrasting experience? There should be a clearinghouse for such information.

Regarding health monitoring concepts, UDOT would like to know what instrumentation is most successful, durable, and applicable to assessing condition and structural performance.

VIRGINIA DEPARTMENT OF TRANSPORTATION

The Virginia Department of Transportation (VDOT) focus group interview was held at the Virginia Center for Transportation Innovation and Research in Charlottesville, VA, on August 13, 2008. VDOT interviewees included the following:

- Anwar Ahmad, Assistant State Structure & Bridge Engineer for Maintenance, VDOT Central Office.
- Garry Lovins, Structure and Bridge Engineer, VDOT Bristol District.
- David Pearce, Structure and Bridge Engineer, VDOT Culpeper District.
- Nicholas Roper, Structure and Bridge Engineer, VDOT Northern Virginia District.
- Keith Weakley, Structure and Bridge Engineer, VDOT Staunton District.

Organizational Structure

VDOT is decentralized, made up of nine engineering districts with bridge offices in each and a central office division that provides planning, design, and bridge management support.

Table 26 shows the number of bridges owned by various types of agencies in the State.

Table 26. Number of bridges owned by various types of agencies in Virginia.

Agency Type	Number of Bridges Owned
State transportation department	11,892
Other State agency	9
Local agency	1,934
Federal agency	340
Toll authority	74
Railroad company	50
Private	10
Total	**17,420**

Program-Level Decision Support

VDOT has a formal bridge management system composed of the AASHTOWare Bridge Management® software and the Highway Traffic Record Information System. However, in practice, these are primarily used to archive data and are more for information management than bridge management. The State is using AASHTOWare Bridge Management® software to perform network-level analysis, to determine statewide needs, and as a guide in allocating funding to the districts. VDOT currently tracks maintenance, repair, and rehabilitation actions through manual inspection reports although efforts to streamline retrieval of information are under way. At the time of the interview in 2008, cost information was tracked separately by each district.

VDOT would like to have these additional capabilities:

- Accurate cost data.

- Risk-based prioritization or ranking process.

- Accurate and current (real-time) unit costs.

- Ability to accurately and currently forecast the life of the bridge.

- Historical data on structurally deficient bridges so VDOT can do trending/plotting of deterioration trends, including the non-NBI data and at the individual bridge level.

- Refined deterioration models.

Project-Level Decision Support

In making decisions, VDOT relies on element-level inspection data along with NDE and other test data, traffic data, flood risk, environmental needs, local transportation needs, information provided by the trucking industry and other interest groups, public involvement, the known and acceptable options available to them, and funding availability.

VDOT performs both NBI safety and element-level inspections, and uses AASHTOWare Bridge Management® software. In addition, it performs the following supplemental testing:

- UT of structural steel.
- Underwater inspection.
- Ultrasound on pins and links.
- NDE methods as needed.
    - Magnetic particles.
    - Dye penetrant.
    - X-ray.
    - Ultrasound.
- Visual inspection.

Results are kept in individual inspection records.

In determining repairs, the State considers the prioritization of needs and funding allocations, condition ratings, and appraisal ratings. To more accurately define the extent of repairs and improve cost estimating, the following nonstructural data would be useful:

- Accurate load data.

- Information that helps define the scope of work, such as type and extent of damage.

- Updated data on quantities of work items needed at the time bidding documents are prepared.

VDOT does not capture actual repairs performed versus specified repairs.

Performance Measures

For performance measures, VDOT tracks the following:

- Condition of structures over time.
- NBI condition ratings.
- Number of posted and functionally obsolete structures.
- Maintenance backlog.
- Federal sufficiency rating.
- HI.

VDOT is now tracking HI, which is part of the AASHTOWare Bridge Management® system.[(10)] The HI of any particular structure is calculated by dividing the sum of the current value of all structure's components by the sum of the failure value (replacement or repair) of all components. An HI of 100 percent indicates that all of the components of the structure are in the best possible condition state. An HI of 0 percent indicates that all of the components are in the worst possible condition state.

The State uses a dashboard that shows the number of structures and their condition (functionally deficient, structurally deficient, and OK).

Common Forms of Deterioration

***Substructure*:** Scour, cracking, spalling, and delamination.

***Superstructure*:** Corrosion, age and deterioration with time of the existing paint system, parapet repair; bearing pedestals deterioration, and concrete pop-outs due to freezing.

***Deck*:** Spalling, fatigue cracks, weathering as well as decay, splitting and insect damage in timber decks.

***Functionality*:** No specific forms noted.

Maintenance and Repair Activities Requiring the Most Resources

***Substructure*:** Shotcrete/pneumatic concrete repair of concrete spalls, scour countermeasures, and blocking and jacking/installation of temporary supports.

***Superstructure*:** Complete painting, repair/replace due to impact damage, complete superstructure replacement.

***Deck*:** Patching, thin overlay, rigid overlay, full or partial deck replacement.

***Functionality*:** No specific forms noted.

Desired Outcomes From LTBP Program

- Use of and access to accurate cost data.
- Prioritization or ranking process for maintenance, repair, and rehabilitation actions.
- Use of and access to accurate, current (real-time) unit costs.
- Methods to accurately and currently forecast the remaining life of a bridge.
- Use of and access to historical data on structurally deficient structures so VDOT can plot deterioration trends, including non-NBI structures and trends at the individual bridge level.
- Refined deterioration models.

APPENDIX C—INITIAL RATING AND RANKING OF BRIDGE PERFORMANCE ISSUES

As discussed in chapter 4 and shown in Table 9, an initial list of high priority bridge performance issues was created. Two groups, one of external stakeholders and one of FHWA bridge experts, were asked to rate the issues for importance as well as for urgency. Table 27 and table 28 list these two groups.

Table 27. External stakeholders.

Board Member	Affiliation	Contact Information
Dr. Sreenivas Alampali, (Chair)	NYSDOT	salampalli@dot.state.ny.us
Richard (Dick) Dunne, PE	NJDOT	richard.dunne@dot.state.nj.us
Mary Lou Ralls, PE	Ralls Newman, LLC	ralls-newman@sbcglobal.net
Bojidar Yanev, PhD, PE	New York City Department of Transportation	byanev@dot.nyc.gov
Barton Newton, PE	Caltrans	barton_newton@dot.ca.gov
Dr. Herbert Wiggenhauser	BAM/Germany	herbert.wiggenhauser@bam.de
Marja-Kaarina Söderqvist	Finnra/Finland	marja-kaarina.soderqvist@tiehallinto.fi
Malcolm T. Kerley	VDOT	mal.kerley@vdot.Virginia.gov
Bruce Johnson	ODOT-OR	bruce.v.johnson@odot.state.or.us
Professor Dan M. Frangopol	Lehigh University	dan.frangopol@lehigh.edu

Table 28. FHWA bridge experts.

Name	Office	Contact Information
Hamid Ghasemi	Infrastructure R&D	hamid.ghasemi@dot.gov
Tom Everett	Bridge	thomas.everett@dot.gov
John Penrod	Infrastructure R&D	john.penrod@dot.gov
Larry O'Donnell	Infrastructure R&D	larry.o'donnell@dot.gov
Paul Virmani	Infrastructure R&D	paul.virmani@dot.gov

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