Long-Term Bridge Performance Program Strategic Bridge Performance Matrix

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- Identification of high priority bridge performance topics
- Strategic matrices for high priority topics
- Description of Strategic matrix as a "roadmap" to achieve program goals
- Operational Matrix





High-Priority Performance Topics >>

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Based on input from stakeholders and considering current resources of the program, the following key topics are addressed:

CATEGORY	ISSUE
Decks	Untreated Concrete Bridge Decks
Decks	Treated Concrete Bridge Decks
Joints & Bearings	Bridge Deck Joints
Steel Bridges	Coatings for Steel Superstructure Elements
Concrete Bridges	Embedded or Ducted Strands or Tendons







- Identification of high priority bridge performance topics
- Strategic matrices for high priority topics
- Description of Strategic matrix as a "roadmap" to achieve program goals
- Operational Matrix





Strategic Performance Matrix>>

What is the LTBP Strategic Performance Matrix?

It is high level generic framework or roadmap outlining the LTBP research process that can be applied to ANY identified high priority performance topic.

It is **NOT** intended to provide detail on what data to collect nor how to analyze or interpret it. This information is found in a corresponding *Operational Matrix* which is currently under development (but we'll take a sneak peak at it!)





Strategic Bridge-Performance Matrix: Untreated Bridge Decks >>

-				Defining and improving bridge health and performance for more effective safety, mobility, stewardship and asset management through:				
	1,	Objectives	Standardized and enha techniques and criteria	nced inspection			nd operating practices from	
	Questions	"Practical" questions to be answered: Goal: provide owners with data- driven actionable information	How should an untreated concrete deck be inspected?	When should an untreated concrete deck be inspected?	How should an untreated deck be preserved or replaced?	When should an existing deck be preserved or replaced?	How should an untreated concrete deck be designed and constructed?	
	2. Ques	Overarching "Fundamental" questions to be answered Goal: explain observed behavior to support the actions	How do environment How does the design How do structural ch	How does live load influence performance? How do environmental factors influence performance? How does the design of the untreated concrete deck (e.g., cover) influence its performance? How do structural characteristics (e.g., flexibility) of a bridge influence performance? How do preservation activities influence performance?				
	3. Hypotheses	Key causal factors	Precipitation Temperature Proximity to the coast Pollution Age/deterioration	DECK DESIGN Cover Rebar type Concrete mix Proportioning of rebars Use of SIP forms	BRIDGE DESIGN Span length Girder stiffness Girder spacing Angle of skew Bridge profile (bump at the end of the bridge)	LIVE LOAD Frequency Axle weights & spacings Speed	OWNER ACTIONS De-icing Level of preservation Load permitting Construction practices	
	4. Solution	Design of experiment	 Design an appropriate experiment for addressing the practical and fundamental questions above Select a network of bridges (reference and clusters) as the primary population source Conduct paper study (tacit/legacy data collection) If the paper study proves inconclusive, conduct field data collection using the appropriate LTBP data collection protocols Handle all data management through the LTBP Portal Conduct data analysis Develop deterioration models Develop life-cycle cost models Address the question 					
-Teri re Peram	5. Outcomes	Products	Best practices in NDE and SHM techniques for untreated concrete decks	Data-driven, reliability-based inspection intervals & criteria for untreated concrete decks	2 Data-driven life-	cycle cost models for acement practices for	2 Data-driven life-cycle cost models for design and construction practices for untreated bridge decks	

• Strategic Bridge-Performance Matrix: Concrete Bridge Deck Treatments

practices for new											
Standardized and enhanced inspection techniques and criteria probabilistic data-driven tools Protection	[alth and perf	ormance for r	nore effective	safety, mobili	ty, stewardship	
Inspection techniques and criteria probabilistic data-driven tools		нi	Objectives			Enhanced design, construction, preservation and operating practices from					
Products				1							
questions to be answered: Goal: provide owners with data-driven actionable information Overarching Fundamental observed behavior to support the actions EXECUTED 1990 10 Products Questions to be inspected? In			"Practical"	,							
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Products Inspected Inspe			•								
actionable information Overarching Fundamental' questions to be answered Goal: explain observed behavior to support the actions ENVIRONMENT TREATMENT BRIDGE DESIGNS LIVE LOAD OWNER ACTIONS DESIGN Frequency Froximity to the coast Courses Girder spacing spacings Load permitting Proximity to the coast Pollution Thicknesses Girder spacing spacings Load permitting Construction practices and properties experiment for addressing the practical and fundamental questions above 2. Select a network of bridges (reference and clusters) as the primary population source 3. Conduct data analysis a. Develop inter-cycle cost models 7. Address the question intervals & criteria for treated decks and replacement practices for treated decks and construction practices for treated decks and replacement practices for treated decks and construction practices for treated decks and replacement practices for treated decks and repl				inspected?	inspected?					• • •	
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• Strategic Bridge-Performance Matrix: Joints & Bearings

j					and performance fo	or more effective sa	fety, mobility, stewardship			
	1.	Objectives	standardized and enha	and asset management through: standardized and enhanced inspection techniques and criteria enhanced design, construction, preservation and operating praction probabilistic data-driven tools		nd operating practices from				
	Questions	"Practical" questions to be answered: Goal: provide owners with data- driven actionable information	How should joints and bearings be inspected	When should joints and bearings be inspected?	How should joints & bearings be preserved or replaced?	When should joints and bearings be preserved or replaced?	How should joints and bearings be selected?			
	2. Ques	Overarching "Fundamental" questions to be answered Goal: explain observed behavior to support the actions	How does environme How does the selecti How do structural ch	low does live load influence performance? low does environment influence performance? low does the selection & installation of the joint or bearing influence performance? low do structural characteristics of the bridge (such as skew) influence performance? low do preservation activities influence performance?						
	3. Hypotheses	Key causal factors	Precipitation Temperature Proximity to the coast Pollution Age/deterioration	JOINT OR BEARING SELECTION Type Materials Installation Details	BRIDGE DESIGN Span length Girder stiffness Girder spacing Angle of skew Bridge profile (bump at the end of the bridge)	Frequency Axle weights & spacings Speed	OWNER ACTIONS De-icing Level of preservation Load permitting Construction practices			
	4. Solution	Design of experiment	Select a network Conduct paper study If the paper study	anagement through the lysis foration models ycle cost models	above LTBP data collection protocols					
ng-Ti idge	5. Outcomes	Products	Best practices in NDE and SHM techniques for joints and bearings	Data-driven, reliability-based inspection intervals & criteria for joints and bearings	1 Data-d 2 Data-driven life- preservation and repl joints and	2 Data-driven life-cycle cost models for selection and installation of joints and bearings				

Long-To Bridge Progra

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Strategic Bridge-Performance Matrix: Coatings for Steel Components

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Γ		Objectives			and performance fo	r more effective sa	fety, mobility,			
4	ij.			stewardship and asset management through:						
2			standardized and enha techniques and criteria		enhanced design, construction, preservation and operating practices from probabilistic data-driven tools					
	Questions	"Practical" questions to be answered: Goal: provide owners with data- driven actionable information	How should coatings for steel components be inspected	When should coatings for steel components be inspected?	How should coatings for steel components be preserved or replaced?	When should coatings for steel components be preserved or replaced?	How should new steel components be coated?			
	2. Ques	overarching "Fundamental" questions to be answered Goal: explain observed behavior to support the actions	How does the selecti	ow does environment influence performance? ow does the selection & application of the coating influence performance? ow do preservation activities influence performance?						
	3. Hypotheses			Type Coats Thicknesses Surface prep		OWNER ACTIONS De-icing Level of preservaion Load permitting Construction practices				
	4. Solution	Design of experiment	1. Design an appropriate experiment for addressing the practical and fundamental questions above 2. Select a network of bridges (reference and clusters) as the primary population source 3. Conduct paper study (tacit/legacy data collection) 4. If the paper study proves inconclusive, conduct field data collection using the appropriate LTBP data 5. Handle all data management through the LTBP Portal 6. Conduct data analysis 7. Develop deterioration models 8. Develop life-cycle cost models 9. Address the question							
					1 Data-driven dete	erioration models for co	atings for steel components			
-Te _l	5. Outcomes	Products	Best practices in NDE and SHM techniques for coatings for steel components	Data-driven, reliability-based inspection intervals & criteria for coatings for steel components	2 Data-driven life-o preservation and repla coatings for ste	cement practices for	2 Data-driven life-cycle cost models for selection and application of coatings for steel component practices on new bridges			

• Strategic Bridge-Performance Matrix: *Embedded or Ducted Strands or Tendons* >>

		Ohio atiwa	Defining and improving bridge health and performance for more effective safety, mobility, stewardship and asset management through:					
2	1.	Objectives	standardized and enha- techniques and criteria	nced inspection			nd operating practices from	
	Questions	"Practical" questions to be answered: Goal: provide owners with data-driven actionable information	How should embedded or ducted strands or tendons be inspected	When should embedded or ducted strands or tendons be inspected?	How should embedded or ducted strands or tendons be preserved or replaced?	When should embedded or ducted strands or tendons be preserved or replaced?	How should a new embedded or ducted strands or tendons be designed and constructed?	
	2. Ques	overarching "Fundamental" questions to be answered Goal: explain observed behavior to support the actions	How does environment influence performance? How does the design & construction of the strands or tendons influence performance? How do preservation activities influence performance?					
	3. Hypotheses	Key causal factors	ENVIRONMENT Precipitation Temperature Proximity to the coast Pollution Age/deterioration	Type Concre Cover Duct ty		OWNER ACTIO De-icing Level of preser Load permittin Construction p	vation g	
	4. Solution	Design of experiment	 Design an appropriate experiment for addressing the practical and fundamental questions above Select a network of bridges (reference and clusters) as the primary population source Conduct paper study (tacit/legacy data collection) If the paper study proves inconclusive, conduct field data collection using the appropriate LTBP data collection protocols Handle all data management through the LTBP Portal Conduct data analysis Develop deterioration models Develop life-cycle cost models Address the question 					
g-Te	5. Outcomes	Products	Best practices in NDE and SHM techniques for embedded or ducted strands or tendons	Data-driven, reliability-based inspection intervals & criteria for embedded or ducted strands or tendons	2 Data-driven life- preservation and repl	tendons	2 Data-driven life-cycle cost models for design and construction practices for pretensioned bridges	





- Identification of high priority bridge performance topics
- Strategic matrices for high priority topics
- Description of Strategic matrix as a "roadmap" to achieve program goals
- Operational Matrix & its components





Description of Untreated Bridge Deck Matrix

Hypotheses

What causal factors that may govern the performance of Interest

Solution

Design of Experiment
Sampling
Paper Study
Field Data Collection
Data Analysis

Questions to be answered

- "Practical"
- "Fundamental"

4									
	1	Ohiostivos	Defining and improving bridge health and performance for more effective safety, mobility, stewardship and asset management through:						
	-	Objectives	Standardized and enha techniques and criteria	nced inspection	Enhanced design, construction, preservation and operating practices from probabilistic data-driven tools				
	Questions	"Practical" questions to be answered: Goal: provide owners with data- driven actionable information	How should an untreated concrete deck be inspected?	When should an untreated concrete deck be inspected?	How should an untreated deck be preserved or replaced?	When should an existing deck be preserved or replaced?	How should an untreated concrete deck be designed and constructed?		
	2. Ques	Overarching "Fundamental" questions to be answered Goal: explain observed behavior to support the actions	How do environment How does the design How do structural ch	How does live load influence performance? How do environmental factors influence performance? How does the design of the untreated concrete deck (e.g., cover) influence its performance? How do structural characteristics (e.g., flexibility) of a bridge influence performance? How do preservation activities influence performance?					
	3. Hypotheses	Key causal factors	ENVIRONMENT Precipitation Temperature Proximity to the coast Pollution Age/deterioration	Cover Rebar type Concrete mix Proportioning of rebars Use of SIP forms	BRIDGE DESIGN Span length Girder stiffness Girder spacing Angle of skew Bridge profile (bump at the end of the bridge)	LIVE LOAD Frequency Axle weights & spacings Speed	OWNER ACTIONS De-icing Level of preservation Load permitting Construction practices		
	4. Solution	Design of experiment	Design an appropriate experiment for addressing the practical and fundamental questions above Select a network of bridges (reference and clusters) as the primary population source Conduct paper study (tacit/legacy data collection) If the paper study proves inconclusive, conduct field data collection using the appropriate LTBP data collection protocols Handle all data management through the LTBP Portal Conduct data analysis Develop deterioration models Develop life-cycle cost models Address the question						
	5. Outcomes	Products	Best practices in NDE and SHM techniques for untreated concrete decks	Data-driven, reliability-based inspection intervals & criteria for untreated concrete decks	2 Data-driven life- preservation and repl	eterioration models for o cycle cost models for acement practices for ncrete decks	untreated concrete decks 2 Data-driven life-cycle cost models for design and construction practices for untreated bridge decks		



Description of Untreated Bridge Deck Matrix

Hypotheses

What causal factors that may govern the performance of Interest

Solution

Design of Experiment
Sampling
Paper Study
Field Data Collection
Data Analysis

Questions to be answered

- "Practical"
- "Fundamental"

Obje<mark>ctiv</mark>es

	-	Objectives	stewardship and a Standardized and enha	sset management t	Enhanced design, cons	truction, preservation a	fety, mobility, nd operating practices from		
			techniques and criteria		probabilistic data-drive	n tools			
	Questions	"Practical" questions to be answered: Goal: provide owners with data- driven actionable information	How should an untreated concrete deck be inspected?	When should an untreated concrete deck be inspected?	How should an untreated deck be preserved or replaced?	When should an existing deck be preserved or replaced?	How should an untreated concrete deck be designed and constructed?		
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	4. Solution	Design of experiment	1. Design an appropriate experiment for addressing the practical and fundamental questions above 2. Select a network of bridges (reference and clusters) as the primary population source 3. Conduct paper study (tacit/legacy data collection) 4. If the paper study proves inconclusive, conduct field data collection using the appropriate LTBP data collection protocols 5. Handle all data management through the LTBP Portal 6. Conduct data analysis a. Develop deterioration models b. Develop life-cycle cost models 7. Address the question						
-	5. Outcomes	Products	Best practices in NDE and SHM techniques for untreated concrete decks	Data-driven, reliability-based inspection intervals & criteria for untreated concrete decks	2 Data-driven life-	cycle cost models for acement practices for	2 Data-driven life-cycle cost models for design and construction practices for untreated bridge decks		



To define and improve bridge health and performance for more effective safety, mobility, stewardship and asset management through:

- Standardization and enhanced inspection techniques and criteria
- Enhanced design, construction, preservation and operating practices from probabilistic datadriven tools







Description of Untreated Bridge Deck Matrix

Hypotheses

What causal factors that may govern the performance of Interest

Solution

Design of Experiment
Sampling
Paper Study
Field Data Collection
Data Analysis

Questions to be answered

- "Practical"
- "Fundamental"

Defining and improving bridge health and performance for more effective safety, mobility,								
-i	Objectives		sset management t	hrough:	struction, preservation a	fety, mobility, nd operating practices from		
Questions	"Practical" questions to be answered: Goal: provide owners with data- driven actionable information	How should an untreated concrete deck be inspected?	When should an untreated concrete deck be inspected?	How should an untreated deck be preserved or replaced?	When should an existing deck be preserved or replaced?	How should an untreated concrete deck be designed and constructed?		
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5. Outcomes	Products	Best practices in NDE and SHM techniques for untreated concrete decks	Data-driven, reliability-based inspection intervals & criteria for untreated concrete decks	2 Data-driven life- preservation and rep	leterioration models for -cycle cost models for lacement practices for oncrete decks	2 Data-driven life-cycle cost models for design and construction practices for untreated bridge decks		



Untreated Decks – Questions to be answered

Practical (Providing Actionable Information)

- How should an untreated concrete deck be inspected?
- When should an untreated concrete deck be inspected?
- How should an untreated deck be preserved or replaced?
- When should an existing deck be preserved or replaced?
- How should an untreated concrete deck be designed and constructed?

Fundamental (Underpin Forecasting and Asset Management)

- How does live load influence performance?
- How do environmental factors influence performance?
- How does the design of the untreated concrete deck (e.g., cover) influence its performance?
- How do structural characteristics (e.g., flexibility) of a bridge influence performance?
- How do preservation activities influence performance?





Description of Untreated Bridge Deck Matrix

Example: Untreated Bridge Decks

Hypotheses

What are the causal factors that may govern the performance of Interest

Solution

Design of Experiment
Sampling
Paper Study
Field Data Collection
Data Analysis

Questions to be answered

- "Practical"
- "Fundamental"

		Defining and improving bridge health and performance for more effective safety, mobility, stewardship and asset management through:					
ij.	Objectives	Standardized and enhanced inspection techniques and criteria		Enhanced design, construction, preservation and operating practices from probabilistic data-driven tools			
Questions	"Practical" questions to be answered: Goal: provide owners with data- driven actionable information	How should an untreated concrete deck be inspected?	When should an untreated concrete deck be inspected?	How should an untreated deck be preserved or replaced?	When should an existing deck be preserved or replaced?	How should an untreated concrete deck be designed and constructed?	
2. Ques	Overarching "Fundamental" questions to be answered Goal: explain observed behavior to support the actions	How do environment How does the design How do structural ch		erformance? crete deck (e.g., cove xibility) of a bridge in			
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Untreated Decks - Hypotheses

The observed deterioration of bridge decks is caused by the individual and combined influences of...

- Environment Precipitation, Temperature, Proximity to the coast, Pollution, Age/deterioration
- Deck Design Cover, Rebar type, Concrete mix, Proportioning of rebars, Use of SIP forms
- Bridge Design Span length, Girder stiffness, Girder spacing, Angle of skew, Bridge/approach profile
- Live Load Frequency, Axle weights & spacings, Speed
- Owner Actions De-icing, Level of preservation, Load permitting, Construction practices



These factors are the hypothesized "Inputs" to the process of bridge deck performance



Description of Untreated Bridge Deck Matrix

Example: Untreated Bridge Decks

Hypotheses

What causal factors that may govern the performance of Interest

Solution
Design of Experiment
Sampling
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Field Data Collection
Data Analysis

Questions to be answered

- "Practical"
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S							
1,	Objectives		sset management t		truction, preservation a	fety, mobility, nd operating practices from	
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3. Hypotheses	Key causal factors	ENVIRONMENT Precipitation Temperature Proximity to the coast Pollution Age/deterioration	Cover Rebar type Concrete mix Proportioning of rebars Use of SIP forms	BRIDGE DESIGN Span length Girder stiffness Girder spacing Angle of skew Bridge profile (bump at the end of the bridge)	LIVE LOAD Frequency Axle weights & spacings Speed	OWNER ACTIONS De-icing Level of preservation Load permitting Construction practices	
4. Solution	Design of experiment	2. Select a network 3. Conduct paper stu 4. If the paper study protocols 5. Handle all data m 6. Conduct data ana a. Develop detei b. Develop life-co	Design an appropriate experiment for addressing the practical and fundamental questions above Select a network of bridges (reference and clusters) as the primary population source Conduct paper study (tacit/legacy data collection) If the paper study proves inconclusive, conduct field data collection using the appropriate LTBP data collection				
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Untreated Decks - Solution

- 1. Design an appropriate experiment for addressing the practical and fundamental questions
- 2. Select a network of bridges (reference and clusters) as the primary population source
- 3. Conduct paper study (tacit/legacy data collection)
- 4. If the paper study proves inconclusive, conduct field data collection using the appropriate LTBP data collection protocols
- 5. Handle all data management through the LTBP Portal
- 6. Conduct data analysis
 - a) Develop deterioration models
 - b) Develop life-cycle cost models
- 7. Address the question

Specific details provided within an

"Operational Matrix"



Description of Untreated Bridge Deck Matrix

Strategic Matrix

Hypotheses

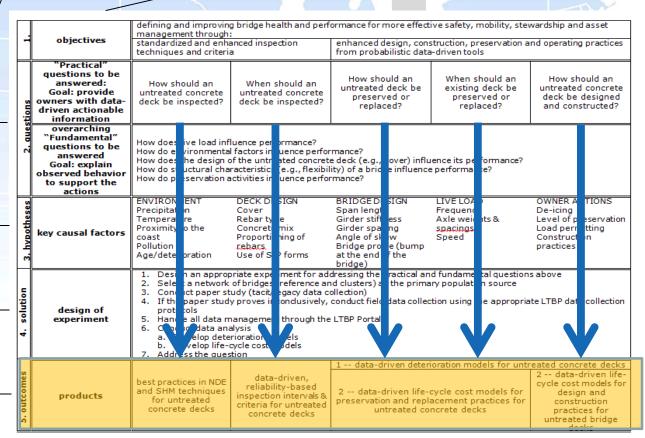
What causal factors that may govern the performance of Interest

Solution

Design of Experiment
Sampling
Paper Study
Field Data Collection
Data Analysis

Questions to be answered

- "Practical"
- "Fundamental"





Untreated Decks - Outcomes

Question: How should an untreated concrete deck be inspected?

Outcome: Best practices in NDE and SHM techniques for untreated concrete decks

Question: When should an untreated concrete deck be inspected?

Outcome: Data-driven, reliability-based inspection intervals & criteria for untreated concrete

decks

Question: How should an untreated deck be preserved or replaced?

When should an existing deck be preserved or replaced?

How should an untreated concrete deck be designed and constructed?

Outcome: Data-driven deterioration models for untreated concrete decks

- a) data-driven life-cycle cost models for preservation and replacement practices for untreated concrete decks
- b) data-driven life-cycle cost models for design and construction practices for untreated bridge decks







Presentation Outline

- Identification of high priority bridge performance topics
- Strategic matrices for high priority topics
- Description of Strategic matrix as a "roadmap" to achieve program goals
- **Operational Matrix**





Research Operational Matrix>>

Two Components of Operational Matrix

(There is a layer of Matrix for Each High Priority Performance Issue)

Data Collection

- Pre-Field Visit
- Field Visit

Data Analysis

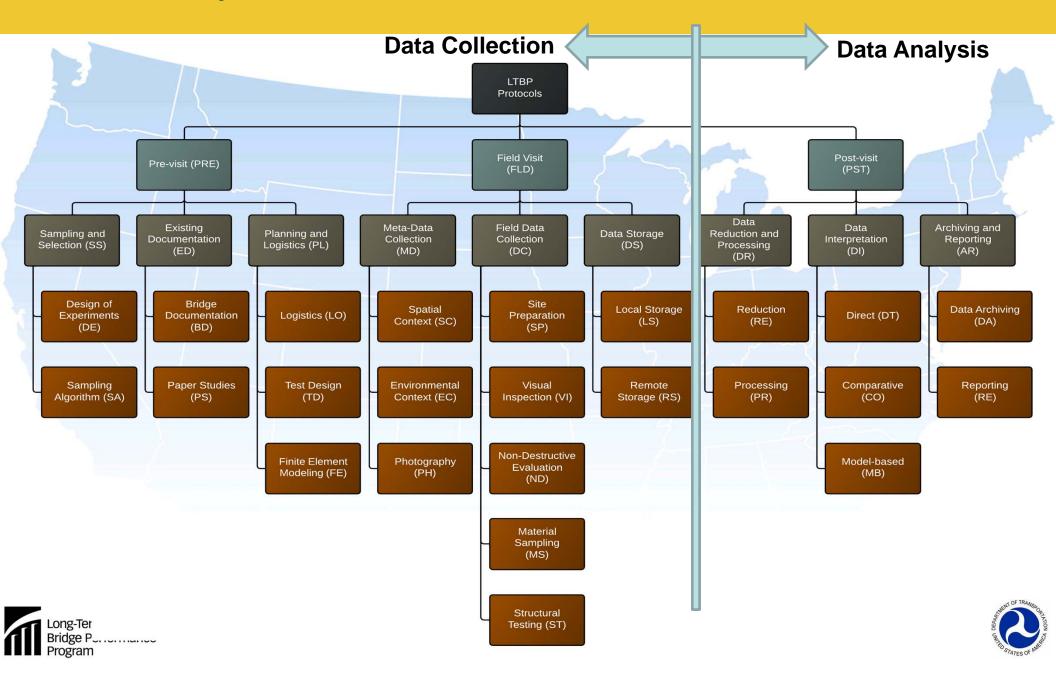
- Data Reduction, processing, visualization
- Data Interpretation

An example of what this looks like in concept





Research Operational Matrix>>



Long-Term Bridge Performance Program Strategic Bridge Performance Matrix

TRB 93rd Annual Meeting
LTBP Program Workshop – Program Briefing
Washington, DC – Thursday January 16, 2014

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