Bridge Management Systems Workshop

Worksheet Packet

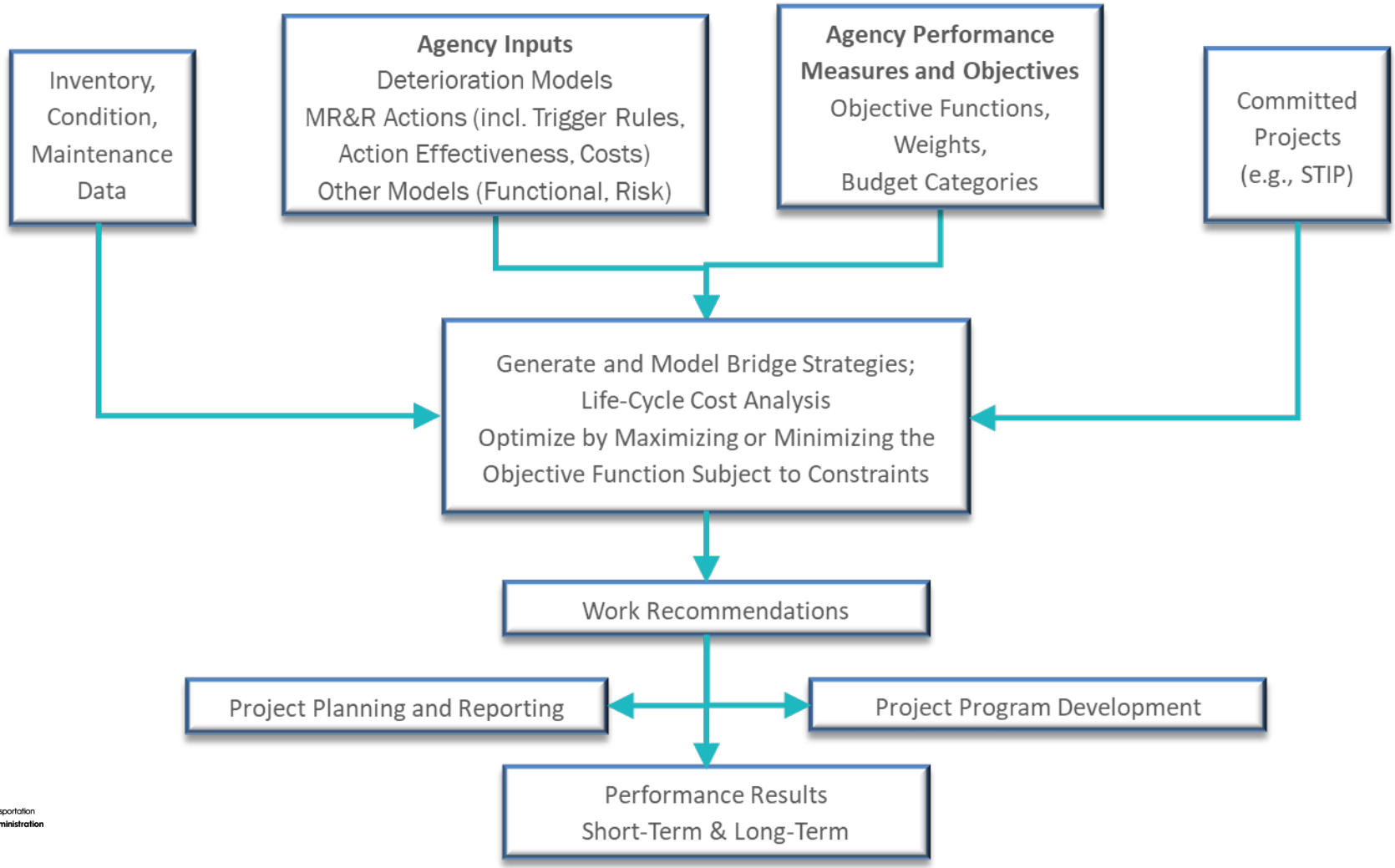
U.S. Department of Transportation
Federal Highway Administration

Agenda

The BMS Workshop is presented over the course of two days. The topics presented on Day 1 provide foundational information regarding BMS software operations. The Day 2 topics expand on this information and provide insight into how BMS software programs can be used for project selection, optimization, and ultimately, a more efficient bridge program.

Day	Module	Title	Estimated Time (minutes)
1	1	Welcome and Workshop Introduction	20
1	2	Purpose and Value of Bridge Management Systems	30
1	3	Key Features and Workflow Steps of a BMS	20
1	4	Inventory and Condition Data; Agency Goals, Objectives and Performance Measures	90
1	5	Deterioration Models	40
1	6	Modeling Actions, Triggers, Costs and Effects	45
1	7	Life-Cycle Agency Costs and Life-Cycle Modeling	40
1	8	Life-Cycle User Costs and Functional Assessment and Improvement Models	15
1	9	Risk Assessment and Mitigation Models	20
1	10	Benefit-Cost Analysis	40
1	11	Optimization and Prioritization	45
1	12	Investment Strategy Simulation and Investigation	20
1	13	Program and Project Planning and Management	25
1	14	Communication and Reporting	15
2	1	BMS Software Implementation Steps	120
2	2	Deterioration Model Development, Use, and Maintenance	120
2	3	Life-Cycle Cost Analysis (LCCA) and Life-Cycle Modeling in a BMS	120
2	4	Benefit-Cost Analysis and Optimization	120
2	5	Using BMS for Investment Strategy Development, Performance Measure Validation/Selection, and Performance Measure Target Setting	120
2	6	Integrating BMS Processes and BMS Software	120
2	7	Host Agency BMS Software Program and Analysis Tools Review	240

BMS Workflow Steps



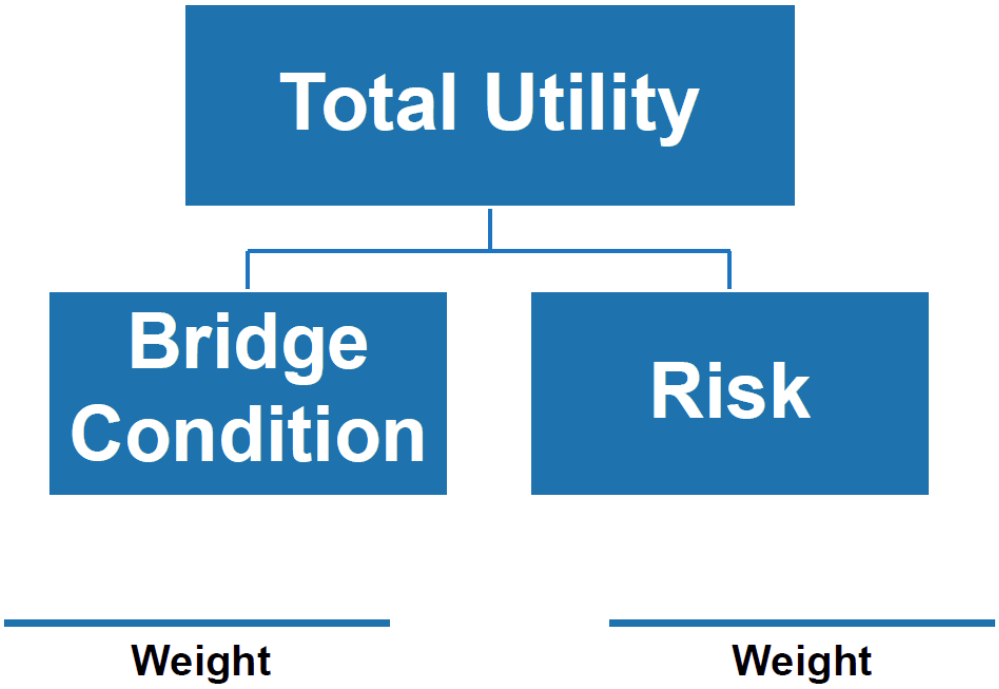
Module	Follows Module Slide #	Worksheet Activity Title
D1M10	20	Assign Relative Weight
D1M10	21	Assign Scaling - Scour Risk
D1M10	22	Showing Amalgamation
D2/3M1	9	Agency Implementation Steps
D2/3M1	10	Agency Implementation Steps - Potential Answers
D2/3M1	39	Setting Up Your Decision Tree - Step 1
D2/3M1	40	Setting Up Your Decision Tree - Step 2
D2/3M1	41	Setting Up Your Decision Tree - Step 3
D2/3M1	42	Setting Up Your Decision Tree - Step 4
D2/3M1	47	Setting Element Benefits Resulting From Actions
D2/3M2	78	Deteriorating Modeling Expert Elicitation
D2/3M2	79	Create a Major Component Deterioration Model
D2/3M2	80	Compare Element Percentage in Condition States When Major Component Becomes Poor
D2/3M2	81	Create an Element Deterioration Model
D2/3M3	17	Calculating Net Present Value (NPV) Worksheet (Three Thin Overlays)
D2/3M3	18	Calculating Net Present Value (NPV) Worksheet (Two Thin Overlays)
D2/3M3	19	Calculating Net Present Value (NPV) Worksheet (Rigid Overlay)
D2/3M3	26	Calculating NPV With User Cost Worksheet (Three Thin Overlays)
D2/3M3	27	Calculating NPV With User Cost Worksheet (Two Thin Overlays)
D2/3M3	28	Calculating NPV With User Cost Worksheet (Rigid Overlay)
D2/3M3	34	Calculating Life Cycle Utility Value Worksheet
D2/3M3	43	Calculating Residual Value Worksheet
D2/3M4	5	Health Index – Weight Factor for Condition States
D2/3M4	6	Health Index – Relative Element Weight
D2/3M4	8	Calculating Health Index Worksheet
D2/3M4	14	Calculating Utility Value Worksheet
D2/3M4	17	Maximize Benefit with Constrained Budget
D2/3M5	14	Select or Create an Objective Function
D2/3M5	15	Maximize or Minimize?
D2/3M5	20	How to Model Scenarios
D2/3M5	24	BMS Work Program Simulation and Optimization Validation
D2/3M5	48	Setting Targets
D2/3M5	55	Using BMS Optimization Results to Set Up Annual Bridge Program
D2/3M6	6	Create Your Agency Bridge Asset Management Team
D2/3M6	7	Create Your BMS Support Team
D2/3M6	10	Agency BMS Business Process, Discussion 1
D2/3M6	11	Agency BMS Business Process, Discussion 2
D2/3M6	12	Agency BMS Business Process, Discussion 3
D2/3M6	13	Agency BMS Business Process, Discussion 4
D2/3M7	6	Host Presentation Feedback Notes

D1M10 – Slide 20: Interactive Group Exercise Worksheet

Assign Relative Weight

Complete each of the questions below.

1. What do you think the relative weight is for the two objectives as compared to each other? Assign a number value for each condition based upon a 100-point scale. Record your answer below:



2. Explain why Bridge Condition and Risk should be weighted this way.

D1M10 – Slide 21: Interactive Group Exercise Worksheet

Assign Scaling – Scour Risk

1. Assign a number value for each scour vulnerability rating based upon a 100-point scale with 100 being best and 0 being worst. Record your values in the table below:

Risk	
Scour Vulnerability Rating	**Scaling Value**
Not Scour Critical (NBI Item 113 = 8)	
Mitigated for Scour (NBI Item 113 = 4, 5, or 7)	
Scour Critical (NBI Item 113 = 3)	

2. Explain your reasoning for scaling the scour vulnerability ratings.

D1M10 – Slide 22: Interactive Group Exercise Worksheet

Showing Amalgamation

1. Write the relative weight you selected for condition and risk for the Slide 20 exercise in the appropriate Relative Weight boxes below.
2. Write the Risk Scaling Values for Not Scour Critical, Mitigated for Scour, and Scour Critical for the Slide 21 exercise in the appropriate Scaling Value boxes below.
3. Using the Utility Value equation shown below, calculate the Utility Value when Bridge Condition (Health Index) equals 75, and Risk Scour Vulnerability Rating is "Scour Critical." Enter the value in the Utility Value box.

$$\textbf{Utility Value} = \frac{\omega_C S_C + \omega_R S_R}{(\omega_C + \omega_R)}$$

ω_C = Relative Weight for Bridge Condition
S_C = Scale Value for Bridge Condition
ω_R = Relative Weight for Risk
S_R = Scale Value for Risk

Condition		Relative Weight
Bridge Condition (Health Index)	**No Scaling Needed**	
Good (Health Index ≥ 90)		
Fair (Health Index < 90 and ≥ 70)		
Poor (Health Index < 70)		

Risk		Relative Weight
Scour Vulnerability Rating	**Scaling Value (0 - 100)**	
Not Scour Critical (NBI Item 113 = 8 or 9)		
Mitigated for Scour (NBI Item 113 = 4, 5 7)		
Scour Critical (NBI Item 113 = 2 or 3)		

Bridge Condition (Health Index)	75	**Utility Value**
Scour Vulnerability Rating	Scour Critical	

4. Does the Utility value seem reasonable? Explain why.

D2/3M1 - Slide 9: Agency Implementation Steps

1. Describe the steps that need to be taken to implement a BMS.

2. Indicate which steps your agency has done.

3. Indicate any challenges you are having with ongoing steps or steps you have not done yet.

D2/3M1 - Slide 10: Agency Implementation Steps – Potential Answers

1. Set up bridge data base
2. Set up and maintain bridge inventory data
3. Create communication link between inspection system and BMS (If they are not the same)
4. Collect bridge condition data (GCR and element)
5. Create agency defined elements and protective systems
6. Do QA/QC of bridge inspection system and resulting condition data
7. Set up goals, objectives, and performance measures
8. Create deterioration models
9. Set element environments
10. Set element to GCR convertor profile (needed if using GCRs as performance measures)
11. Develop a risk assessment process
12. Populate work candidates or work recommendations and determine how you will use them
13. Organize your bridge network in segments (subdivisions of the network)
14. Develop program and project types.
15. Develop agency rules and practice.
16. Build decision trees or matrices with trigger values that set actions based upon element or component condition and inventory items
17. Write rules for grouping actions into practical projects
18. Write rules for removing or replacing elements when major actions (rehab or replacement) are taken
19. Develop life-cycle cost analysis parameters and policies
20. Generate action benefits.
21. Populate direct and indirect cost for actions
22. Develop user costs
23. Set project and program funding sources
24. Create and track fixed projects
25. Create deferment rules (used with LCCA)
26. Create optimization objective function and multi-objective scaling, weighting, and amalgamation rules (utility tree)
27. Set constraints for the optimization problem

D2/3M1 - Slide 39: Setting Up Your Decision Tree – Step 1

Your Selected Element.

Your Selected Protective System (If Appropriate)

D2/3M1 - Slide 40: Setting Up Your Decision Tree – Step 2

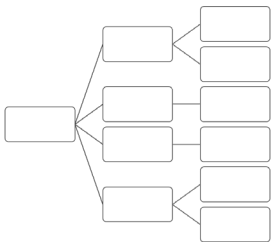
List all actions performed to your group's chosen element and protective system.

D2/3M1 - Slide 41: Setting Up Your Decision Tree – Step 3

Set trigger values for each action for your element and protective system.

D2/3M1 - Slide 42: Setting Up Your Decision Tree – Step 4

Create a decision tree for your groups assigned element.



D2/3M1 - Slide 47: Setting Element Benefits Resulting From Actions

Assign benefits for all actions identified for your group's chosen element.

D2/3M2 - Slide 78: Deterioration Modeling Expert Elicitation

Together as a class, choose (and write down below):

1. A major bridge component

2. Location and environment

3. Factors influencing deterioration

D2/3M2 - Slide 79: Create a Major Component Deterioration Model

Write in the table below what you feel the transition time (time the component lingers in that condition rating) is for each condition rating shown.

GCR	Transition Time
9	
8	
7	
6	
5	
4	
3	

D2/3M2 - Slide 80: Compare Element Percentage in Condition States When Major Component Becomes Poor

Using the bridge element corresponding to the major component rating used in the first exercise, estimate what you feel the percentage of the element will be in CS1, CS2, CS3, and CS4, when the corresponding major component reaches a GCR of 4 (poor).

Condition State	Percentage in Condition State When Major Component Becomes Poor (GCR = 4)
CS1	
CS2	
CS3	
CS4	

D2/3M2 - Slide 81: Create an Element Deterioration Model

Using the bridge element corresponding to the major component rating used in the first exercise, estimate the median years in each condition rating CS1, CS2, and CS3, and write these values in table below.

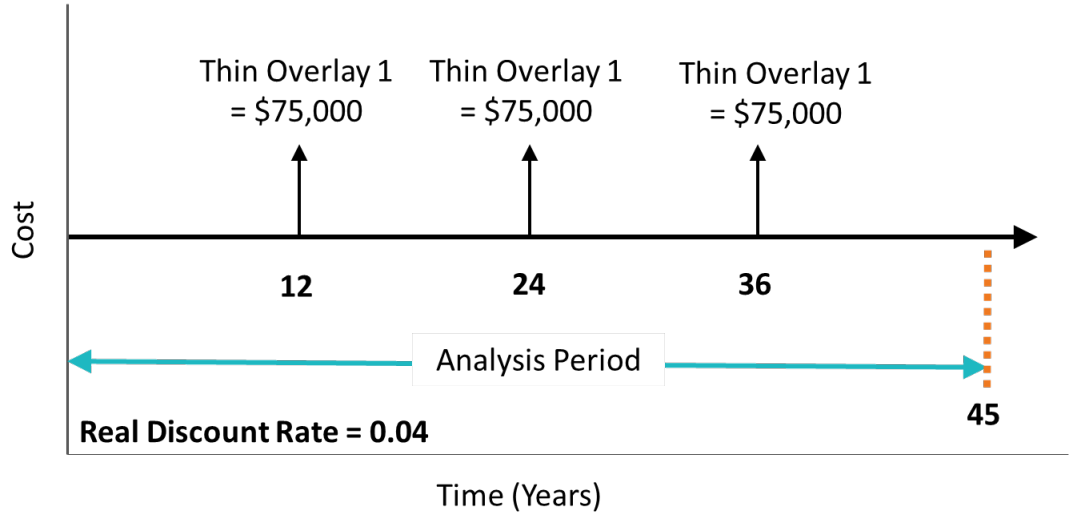
Condition State	Estimated Median Years in Condition State
CS1	
CS2	
CS3	

D2/3M3 - Slide 17: Calculating Net Present Value (NPV) Worksheet (Three Thin Overlays)

Using the Present Value equation below, calculate NPV for the three thin overlays.

$$\text{Present Value} = \text{Future Value} \times \frac{1}{(1+r)^n}$$

where
r = real discount rate
n = number of years in the future when the cost will be incurred.

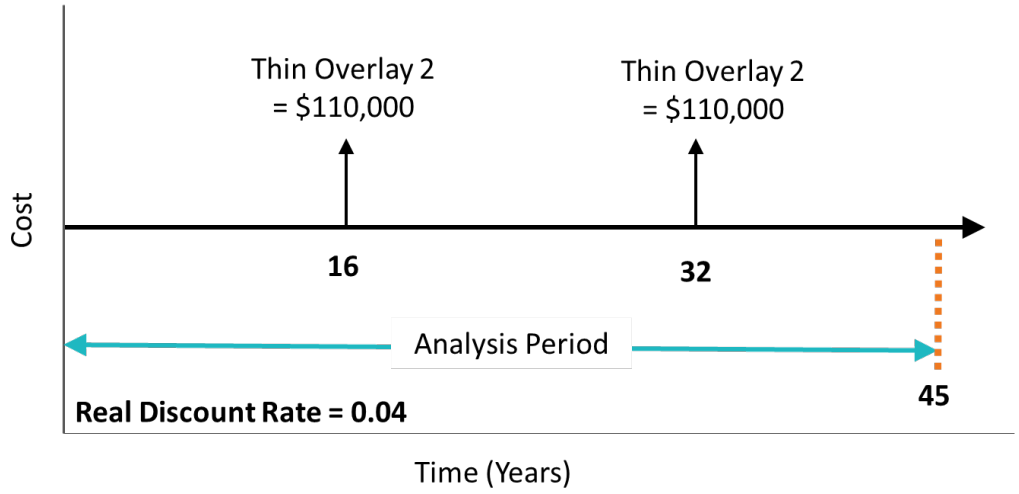


D2/3M3 - Slide 18: Calculating Net Present Value (NPV) Worksheet (Two Thin Overlays)

Using the Present Value equation below, calculate NPV for the two thin overlays.

$$\text{Present Value} = \text{Future Value} \times \frac{1}{(1+r)^n}$$

where
r = real discount rate
n = number of years in the future when the cost will be incurred.

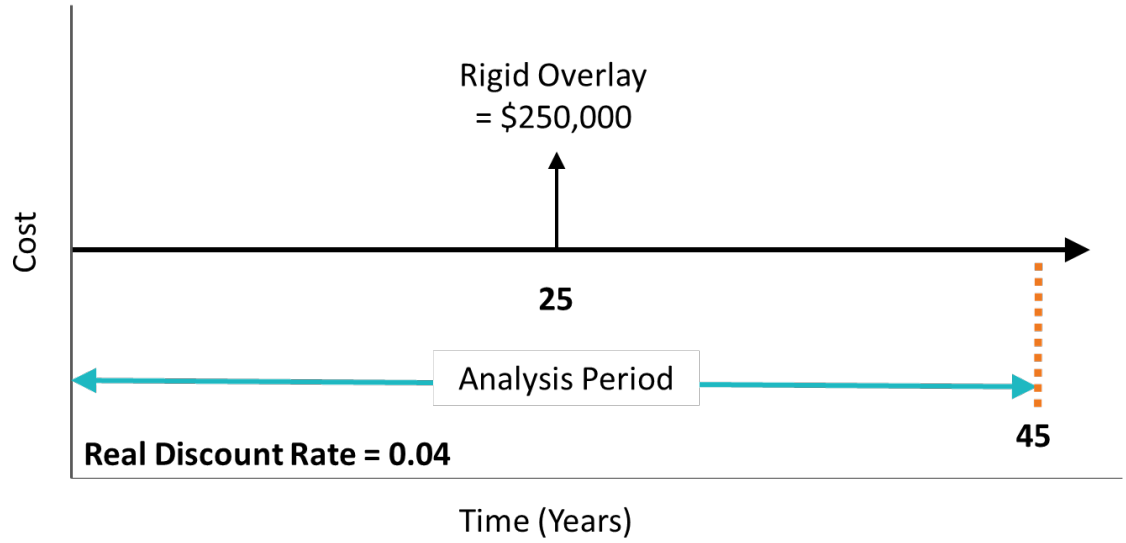


D2/3M3 - Slide 19: Calculating Net Present Value (NPV) Worksheet (Rigid Overlay)

Using the Present Value equation below, calculate NPV for the rigid overlay.

$$\text{Present Value} = \text{Future Value} \times \frac{1}{(1+r)^n}$$

where
r = real discount rate
n = number of years in the future when the cost will be incurred.

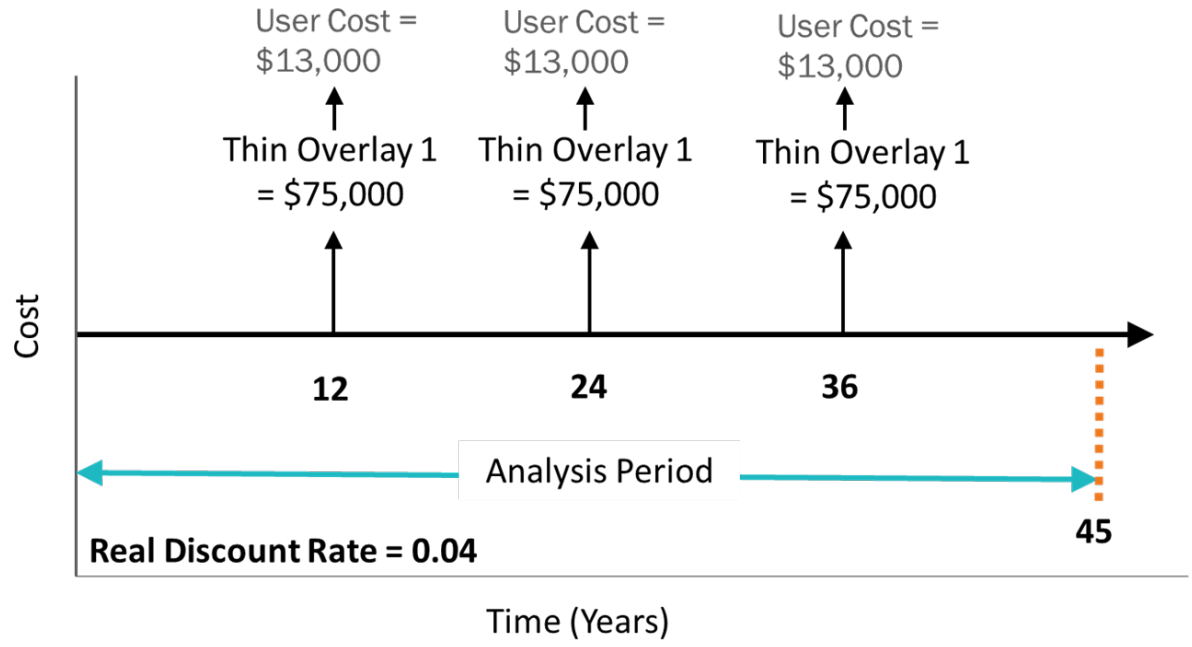


D2/3M3 - Slide 26: Calculating NPV With User Cost Worksheet (Three Thin Overlay)

Using the Present Value equation below, calculate NPV for the three thin overlays with User Cost.

$$\text{Present Value} = \text{Future Value} \times \frac{1}{(1+r)^n}$$

where
r = real discount rate
n = number of years in the future when the cost will be incurred.

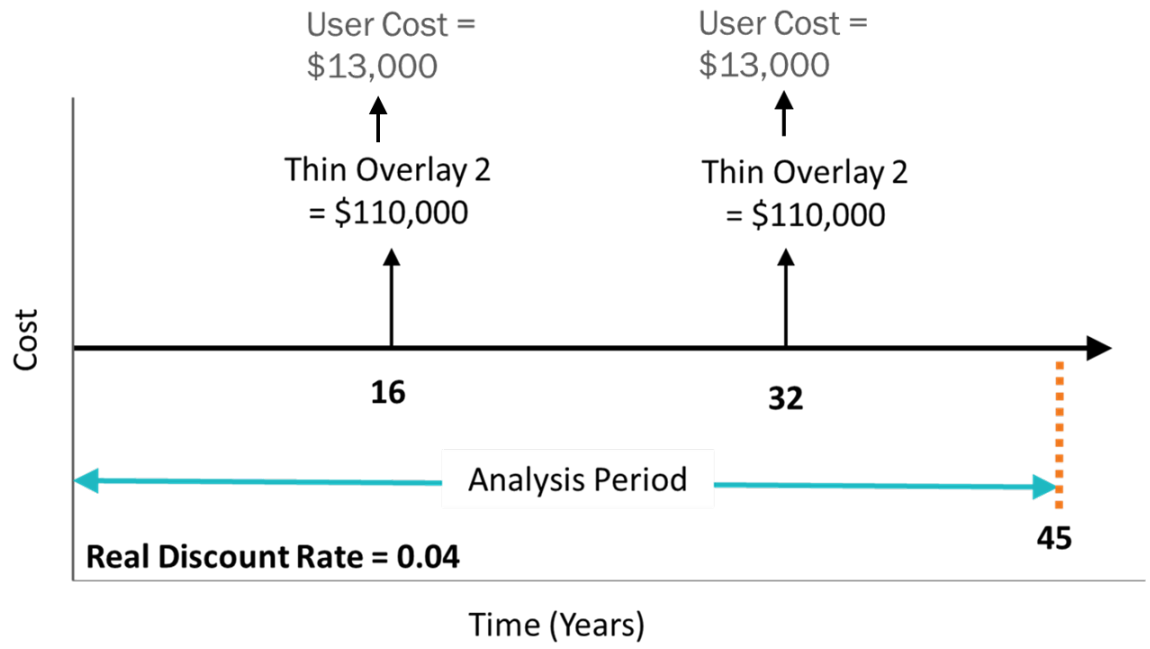


D2/3M3 - Slide 27: Calculating NPV With User Cost Worksheet (Two Thin Overlays)

Using the Present Value equation below, calculate NPV for the two thin overlays with User Cost.

$$\text{Present Value} = \text{Future Value} \times \frac{1}{(1+r)^n}$$

where
r = real discount rate
n = number of years in the future when the cost will be incurred.

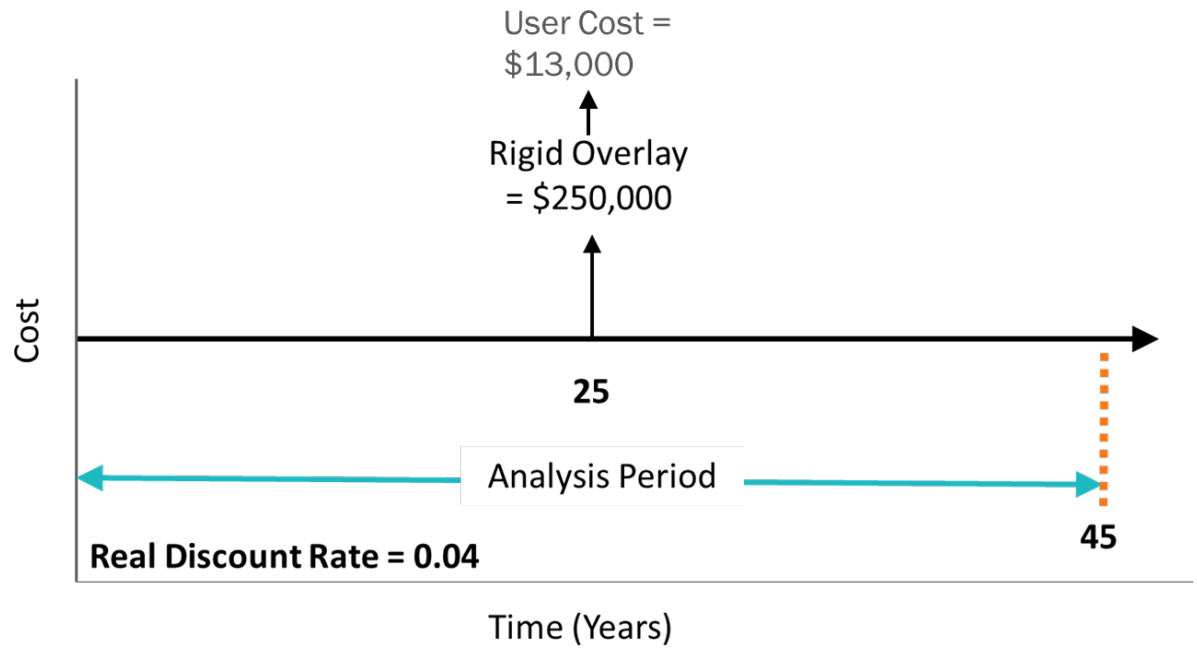


D2/3M3 - Slide 28: Calculating NPV With User Cost Worksheet (Rigid Overlay)

Using the Present Value equation below, calculate NPV for the rigid overlay with User Cost.

$$\text{Present Value} = \text{Future Value} \times \frac{1}{(1+r)^n}$$

where
r = real discount rate
n = number of years in the future when the cost will be incurred



D2/3M3 - Slide 34: Calculating Life Cycle Utility Value Worksheet

$$LCC_{Utility} = \left(1 - \frac{LCC}{2 \times Replacement\ Cost}\right) \times 100$$

where: LCC = NPV = Net Present Value

1. Compute the LCC Utility Value for Thin Overlay 1 with NPV = $94,379 and Replacement Cost = $1,300,000 in the space below.

2. Compute the LCC Utility Value for Thin Overlay 2 with NPV = $90,086 and Replacement Cost = $1,300,000 in the space below.

3. Compute the LCC Utility Value for Thin Overlay 1 with NPV = $93,779 and Replacement Cost = $1,300,000 in the space below.

D2/3M3 - Slide 43: Calculating Residual Value Worksheet

$$\left(\frac{\text{Remaining Service Life}}{\text{Service Life}}\right) \times \text{Replacement Cost}$$

1. Compute the Residual Value for Alternate A with Remaining Service Life of 60 years, Service Life of 75 years, and Replacement cost of $2,800,000 in the space below.

2. Compute the Residual Value for Alternate B with Remaining Service Life of 30 years, Service Life of 75 years, and Replacement cost of $2,800,000 in the space below.

D2/3M4 - Slide 5: Health Index – Weight Factor for Condition States

Choose Weight Factors for Condition State 2 (CS2) and Condition State 3 (CS3) that will be used in the following example calculations.

CS2 _____

CS3 _____

D2/3M4 - Slide 6: Health Index – Relative Element Weight

Record what you would use for relative element weights for the elements shown in the table.
Note, relative element weights are simply compared to the unit weights of other elements. They can be on any reasonable scale the user chooses.

ωe = Relative Unit Weight

Element Number	Element Name	ω_e
12	Concrete Deck	
107	Steel Girder/Beam	
215	Concrete Abutment	
300	Strip Seal Expansion Joint	
205	Reinforced Concrete Columns	

1. Record your reasoning for selecting the relative element weights.

D2/3M4 - Slide 8: Calculating Health Index Worksheet

Compute each element Health Index and the overall bridge Health Index using the group agreed upon values for the Weight Factors for CS2 and CS3 and the relative element weights in the table below.

$$HI = Bridge\ Health\ Index = \frac{\sum_e q_e \omega_e HI_e}{\Sigma_e q_e \omega_e}, where\ \ HI_e = \frac{CS_1 + WF_{cs2} CS_2 + WF_{cs3} CS_3}{Total\ Element\ Quantity}$$

HI_e = Element's Health Index
q_e = Element's Total Quantity
ω_e = Relative Unit Weight
$cs_{(Condition\ State\ \#)}$ = Quantity Element in Condition State
$WF_{(Condition\ State\ \#)}$ = Weight Factor for Condition State

Bridge Health Index

WF_1	WF_2	WF_3

Element Number	Element Name	Total Quantity	Units	CS1	CS2	CS3	CS4	ω_e	HI_e	$q_e \omega_e HI_e$	$q_e \omega_e$
12	Concrete Deck	300	SFT	0		300					
107	Steel Girder/Beam	100	LFT	61	34	5					
215	Concrete Abutment	24	LFT	24							
300	Strip Seal Expansion Joint	24	LFT	0			24				
205	Reinforced Concrete Columns	4	Each	4							
									Total		

D2/3M4 - Slide 14: Calculating Utility Value Worksheet

1. Compute Utility Value after a Preservation action in the space below given the following:
   a. The equation provided below
   b. Bridge condition after the action is fair with a Health Index equal to 80
   c. The bridge is mitigated for scour so the Risk Utility equal to 70
   d. Preservation Action is chosen having a Life-Cycle Cost Utility equal to 90
   e. The relative weight for each objective as shown

$$\text{Utility Value} = \frac{\omega_C s_C + \omega_R s_R + \omega_{LC} s_{LC}}{(\omega_C + \omega_R + \omega_{LC})}$$

ω_C = Relative Weight for Bridge Condition
S_C = Scale Value for Bridge Condition
ω_R = Relative Weight for Risk
S_R = Scale Value for Risk
ω_{LC} = Relative Weight for Life-Cycle
S_{LC} = Scale Value for Life-Cycle

Utility Value =	

Condition		**Relative Weight**
Bridge Condition (Health Index)	No Scaling Needed	40
Good (Health Index ≥ 90)		
Fair (Health Index < 90 and ≥ 70)		
Poor (Health Index < 70)		

Risk		**Relative Weight**
Scour Vulnerability Rating	Scaling Value (0 - 100)	30
Not Scour Critical (NBI Item 113 = 8 or 9)	100	
Mitigated for Scour (NBI Item 113 = 4, 5 7)	70	
Scour Critical (NBI Item 113 = 2 or 3)	30	

Life-Cycle Cost		**Relative Weight**
Fix Type	Scaling Value (0 - 100)	30
Do Nothing	75	
Preservation	90	
Rehabilitation	80	
Replacement	70	

D2/3M4 - Slide 18: Maximize Benefit with Constrained Budget

1. Select actions.
    a. Only one action per bridge number is allowed.
    b. The annual budget of $2,000,000 cannot be exceeded.
2. Add up total benefits and cost from the list of "Available Actions" shown in the table below.
3. Try different combinations of actions to maximize benefit

Note that benefits are weighted by bridge size.

Annual Budget
$2,000,000

Bridge Number	Action Name	Action Cost	Action Benefit	Benefit-Cost Ratio	Picked Strategy
1001	PR1	$100,000	68	6.80	
1001	PR2	$200,000	71.5	3.58	
1001	PR3	$1,400,000	79.5	0.57	
1002	PR1	$150,000	50	3.33	
1002	PR2	$180,000	51	2.83	
1002	PR3	$1,200,000	65	0.54	
1003	PR1	$6,000	87.5	145.83	
1003	PR2	$10,000	88	88.00	
1003	PR3	$30,000	88.5	29.50	
1004	PR1	$140,000	75	5.36	
1004	PR2	$500,000	79.5	1.59	
1004	PR3	$1,800,000	84.5	0.47	
1005	PR1	$20,000	91	45.50	
1005	PR2	$50,000	94	18.80	
1005	PR3	$80,000	94.5	11.81	
	Total				

D2/3M5 - Slide 14: Select or Create an Objective Function

1. Discuss and choose the objective function that your BMS will optimize. It must be more detailed than just saying the Total Utility. If you have multiple objectives, you need to describe these objectives and give a formula to combine the different objectives into a single objective function.

2. Which inputs would need to be modeled over time, and which would be static?

D2/3M5 - Slide 15: Maximize or Minimize?

1. Describe your approach for using the optimizer solver to develop your investment strategy.
    a. Are you going to maximize benefit or minimize costs? Describe your process.
    b. Describe your bridge management investment plan. (Note: example investment plans may include subprograms and budgets.)

2. Describe the different scenarios you would run.
    a. Explain how you would use the results.

D2/3M5 - Slide 20: How to Model Scenarios

1. Describe your experience with using BMS to set up and run scenarios.
    a. Which tools do you find most helpful for creating or editing a work plan or program?

2. If you have not used BMS features, what kinds of features would you like to see?
    a. What would help you assemble your bridge program?

D2/3M5 - Slide 24: BMS Work Program Simulation and Optimization Validation

1. Describe your experience with performing BMS model simulation and optimization and reasonableness testing.

2. If you have no experience with BMS model validation, what would you want to verify before using BMS models?

D2/3M5 - Slide 48: Setting Targets

1. Describe your bridge program targets.

2. Describe how you will use the BMS optimization to set your targets.

3. Discuss differences between short-term targets and long-term sustainable targets.

D2/3M5 - Slide 56: Using BMS Optimization Results to Set Up Annual Bridge Program

1. With your investment strategy set and targets established, how will you use your BMS optimizer to help set your annual bridge program?

D2/3M6 - Slide 6: Create Your Agency Bridge Asset Management Team

1. Describe your bridge asset management team.

2. What are the responsibilities of the team?

3. How can the team be enhanced?

D2/3M6 - Slide 7: Create Your BMS Support Team

1. Describe your BMS support team.

2. What are the responsibilities of the team?

3. How can the team be enhanced?

D2/3M6 - Slide 10: Agency BMS Business Process, Discussion 1

1. Describe your business processes that currently **support your** BMS.

D2/3M6 - Slide 11: Agency BMS Business Process, Discussion 2

1. Describe your business processes that are currently **supported by** your BMS.

D2/3M6 - Slide 12: Agency BMS Business Process, Discussion 3

1. Describe any challenges you are having with your business processes that either are supporting your BMS, or business processes that are supported by your BMS.

D2/3M6 - Slide 13: Agency BMS Business Process, Discussion 4

1. Describe enhancements you would like to make to your agency bridge business process using your BMS.

2. How can your business processes be improved using a BMS?

D2/3M7 - Slide 6: Host Presentation Feedback Notes

Use this space to take notes regarding feedback on the host presentation or demonstration.

Improvement Ideas:

Action Items:

FHWA Bridge Management Systems Workshop
Glossary of Terms

Action Effects (Benefit)
Action effects or benefits are the improvement in the condition data, inventory data, or other data or indicator resulting from an action.

Actions (or Treatments)
Any activity done to a bridge, component or element to improve or preserve the bridge.

Agency Defined Element (ADE)
Custom bridge elements defined by an agency in accordance with the element framework prescribed in the AASHTO Manual for Bridge Element Inspection. May be subsets of the AASHTO defined elements, or entirely independent representing features that are not included in the AASHTO Manual.

Amalgamation
The process of combining multiple criteria into a single criterion (single measure) utility function. The decision maker's preference toward the different criteria are reflected by relative weighting the criteria before combining.

Asset Management
23 CFR 515.5 - Asset management is a strategic and systematic process of operating, maintaining, and improving physical assets with a focus on engineering and economic analysis based upon quality information to identify a structured sequence of maintenance, preservation, repair, rehabilitation, and replacement actions that will achieve and sustain a desired state of good repair (SOGR) over the lifecycle of the assets at minimum practicable cost.

Benefit Cost Analysis
A systematic approach for selecting optimal projects or implementation alternatives by determining the monetary costs and benefits for each project or alternative.

Benefit Cost Ratio (BCR)
An indicator used in benefit-cost analysis used to compare the cost-effectiveness of projects or implementation alternatives by dividing the benefits by the costs. May also be used within an optimization procedure as an approach to find a set of projects that yield the greatest benefit for that procedure.

Bridge-Level Analysis
Analysis of an individual bridge conducted to estimate present and future performance and needs and evaluate the benefits and costs of alternative projects or life-cycle strategies. May be more detailed than the bridge-level analysis performed during network-level analysis as it may include refined performance data and needs, action types, and costs, as well as manual identification of preferred work which may not occur during the automated procedures of a network-level analysis. Sometimes referred to as project-level analysis.

Bridge Management Element (BME)
Elements such as deck joints, wearing surfaces, protective coating systems, concrete reinforcing steel protection systems and approach slabs, as defined by the AASHTO Manual for Bridge Element Inspection, that are typically managed by agencies utilizing a BMS.

Bridge Management System (BMS)
A comprehensive system for storing and updating bridge data, forecasting deterioration, evaluating alternative actions and strategies, identifying short and long-term needs, and determining the strategies, projects, programs, and implementation schedules that will achieve and sustain a desired state of good repair (SOGR) over the lifecycle of the assets at minimum practicable cost. For the Federal description refer to FHWA's 23 CFR 515.17 Minimum Standards for Developing and Operating Bridge and Pavement Management Systems.

Business Processes with an Agency
Those regular activities and tasks that, once completed, will accomplish an organizational goal.

Component (Major)
As defined by the FHWA Recording and Coding Guide for the National Bridge Inventory (NBI), bridge major components include the deck, superstructure, substructure, or culvert.

Consequence
A measure of the effects of a structure being out of service. This translates into a measure of the importance to the community or "criticality" of the structure.

Constraint
Limitations set in an optimization procedure. Examples include limiting annual program budget or setting a minimum allowable bridge condition.

Cost (Direct)
In a BMS, direct agency costs are those that can be attributed directly to specific components and elements in their unit of measure.

Cost (Indirect)
In a BMS, indirect agency costs are those that cannot be attributed directly to specific components and elements. Examples include mobilization, traffic control, engineering (design and construction), and road work (road work can also be input as a direct cost).

Elicitation
Collecting and synthesizing the opinions of experts, often when data is lacking or does not yield credible results.

Extended Benefit
When the method of showing benefit is area under the performance curve, extended benefit is the additional area under the performance curve after the end of the analysis period until the performance curve reaches a terminal serviceability.

Functional Assessment
A functional assessment model measures how well the bridge meets the needs of society. Often relates to bridge geometric attributes (width, clearances, alignment, etc.), load capacity, or frequency of service disruption due to flooding or other events.

Functional Improvement Action
Action that enhances the ability of the bridge to meet the needs of society.

Functional Improvement Model
Methods that quantify the effects or benefits of making functional improvements to a bridge.

Future Value (or Future Cost)
Future value is the cost incurred for an action at some time in the future.

General Condition Rating (GCR)
Condition ratings on a 0 to 9 scale for the major components (deck, superstructure, substructure, or culvert) of a highway bridge structure and culverts in accordance with the FHWA Recording Guide for the National Bridge Inventory.

Goals
Broad primary outcomes towards which effort and actions are directed.

Health Index
An element health index (sometimes referred to as an element condition index) is a measure of an element's condition compared to its perfect condition on a 0 to 100 scale. A bridge health index is a measure of a bridge's condition compared to its perfect condition by amalgamation of all elements comprising the bridge. An inventory health index is the amalgamation of all elements comprising the inventory. There are multiple ways a health index can be measured as discussed in FHWA-HRT-15-081, May 2016; A reference for Synthesis of National and International Methodologies Used for Bridge Health Indices.

Incremental Benefit Cost Ratio (IBCR)
A measure used to quantify the economic effectiveness of a project when compared to the next less costly alternative. It is computed by dividing the increase in benefit of the more expensive project by the increase in cost incurred when selecting that alternative. May also be used within an optimization procedure as an approach to finding a set of projects that yield the greatest benefit for that procedure.

Investment Strategy
The systematic allocation of funds among programs, work categories, and projects in order to best satisfy one or more objectives. For the Federal definition of investment strategy relative to Asset Management Plans refer to 23 CFR 515.5.

Life-Cycle
A sequence of actions, outcomes, events, and consequences that characterize a bridge's design, construction, management and use through its service life.

Life-Cycle Agency Cost
All costs that an agency incurs to maintain, repair, rehabilitate, and reconstruct portions of the bridge during its life-cycle often converted to a Present Value.

Life-Cycle Activity Profile
The representation of a sequence of activities/actions, costs, and year of activities, occurring over a time horizon. Is normally specific to a particular bridge. Sometimes referred to as a bridge life-cycle strategy or life-cycle model.

Life-Cycle Analysis Period (LCAP)
The entire period over which costs of a strategy are evaluated.

Life-Cycle Cost Analysis (LCCA)
A mathematical procedure for evaluating the economic efficiency of a management strategy or preservation model.

Likelihood
The probability of service disruption measured from the probability of occurrence of a specific natural or man-made event combined with the vulnerability of the structure to that event. Typically combined with consequence to evaluate risk.

Markov Chain Transition Probability
The probability of a portion of a system moving from one state to another state in a single time step. Transition probabilities are used in a deterioration modeling method that estimates deterioration of an element, bridge or network of bridges over time.

Model
A set of ideas and numbers that describe the past, present, or future state of something (Merriam-Webster)

National Bridge Inventory (NBI)
A uniform set of bridge condition and inventory data maintained by the Federal Highway Administration that defines the nation's highway bridges.

National Bridge Element (NBE)
Elements that comprise the primary load carrying members of a bridge as defined by the AASHTO Manual for Bridge Element Inspection.

Network Segmentation (Bridge Families)
A method of dividing up an agency's bridges for network analysis.

Network-Level Analysis
Analysis of an inventory or sub-inventory of bridges conducted to estimate present and future performance and needs, and simulate a work program subject to constraints, to determine inventory or sub-inventory outcomes, including from alternative management strategies. Often automates and uses bridge-level analysis including performance and needs assessment, and evaluation of benefits and costs of alternative projects or life-cycle strategies, although computational constraints often allow for lesser detail than a comprehensive bridge-level analysis.

Objectives
Steps an organization takes to achieve its goals that are measurable and specific.

Objective Function
The formulation of objectives into an expression or value which is maximized or minimized during an optimization analysis.

Optimization
A methodology of identifying actions that maximize or minimize an objective function given certain constraints. An example optimization statement reads as follows: Maximize total benefit calculated by summing average performance index for the analysis period across all bridges in the network, subject to a specific budget in each year, by choosing from a set of strategies for each bridge with different sequences of actions and timing of those actions.

Performance Measure
A quantifiable metric that describes the condition and/or adequacy of a bridge or network of bridges that can be used to determine progress toward specific, defined objectives. For the Federal definition refer to 23 CFR 490.101 National Performance Management Measures.

Planning Horizon
The period during which a work program is simulated by a BMS. Different than the planning period which is the timeframe covered by a plan (ex. Statewide Transportation Improvement Program, Long Range Transportation Plan, Transportation Asset Management Plan).

Present Value
The value of a cost incurred at some future time expressed as the equivalent amount if that cost were incurred now. Computed as a function of the discount rate and time period between now and the anticipated time when the cost will be incurred.

Preservation Action
Action taken to bridge major components or elements to improve minor defects and preserve the overall structure in good or fair condition.

Prioritization
A methodology of ranking actions, projects or strategies. Outside more advanced bridge management systems, a prioritization formula is often used to rank bridges for replacement or other actions.

Protective System
Child elements that protect a parent element thereby slowing deterioration and extending life. Examples of these include wearing surface, steel protective coatings, corrosion resistant reinforcing steel, and concrete protective coating.

Reconstruction (or Replacement) Action
An action to reconstruct or replace an existing bridge with a new facility in the same general traffic corridor.

Rehabilitation Action
A major work action required to restore the structural integrity of a bridge, as well as work necessary to correct major safety defects.

Residual Value
The value of the bridge's remaining life at the end of the Life-Cycle Analysis Period (LCAP).

Risk
AASHTO's Manual for Bridge Evaluation defines risk as the potential for unplanned adverse events to impact one or more transportation facilities in a way that causes unacceptable transportation system performance according to any or all of the Agency's performance objectives. For the Federal definition of risk relative to Asset Management Plans refer to 23 CFR 515.5.

Risk Assessment
The systematic evaluation of potential unplanned adverse events, considering the likelihood of the events and the consequences of their occurrence. It is used to prioritize the mitigation of these potential events and minimize their adverse impacts.

Risk Mitigation Action
Actions that improve one or more inventory items that increase the resilience of the bridge making it less susceptible to damage during extreme events.

Risk Utility
Measure of the ability of a bridge to resist hazards.

Scenario
The set of parameters representative of an investment strategy used to perform a scenario analysis. The parameters may include among other things the funding level, objective function, analysis period, economic factors, and constraints. Multiple "what if" scenarios are often conducted to evaluate the outcomes of alternative investment strategies.

Scenario Analysis
An advanced Bridge Management System function that uses condition data, agency inputs such as deterioration models, trigger rules, action costs and effectiveness, objective functions, optimization and constraints to generate work recommendations, develop programs, and predict short- and long-term performance of the bridge network.

Social Cost
The sum of long-term costs borne by the agency, users, non-users, and the environment, which are affected by a proposed decision.

Strategy
A plan of action or policy designed to achieve a major or overall aim.

Targets
The performance level the program is attempting to achieve. These are typically defined as specific values of performance metrics for the bridge network.

Time in Condition Rating (TICR)
A method used for analyzing condition data to estimate deterioration rates. It measures the time a component remains in a specific condition rating.

Trigger
Action triggers are instructions to your BMS to consider an action on a bridge, major component, or element. Actions are often "triggered" when a condition index such as a general condition rating (major component), condition-state (element), or inventory item attribute exceeds a threshold value.

User Costs
Costs borne by bridge users, such as increased fuel consumption and vehicle operating costs occurring from functional deficiencies or construction work zones that cause truck rerouting or vehicle delay.

Utility Function
A mathematical expression, that combines variables representing the user specified objectives and weights, which is used to calculate the utility value of project alternatives.

Utility Scaling
Translates the decision maker's preferences for each performance criterion to a common scale, often 0-100, to allow for amalgamation of different objectives within a utility function. For example, major component general condition ratings 0 to 9 scale would need converted to a 0-100 scale and each general condition value mapped to a value between 0-100 dependent on the decision maker's preferences towards each general condition value.

Utility Value
A calculated number that quantifies the value (not necessarily monetary) of a bridge before and after a work alternative. Results from applying a utility function to the bridge attributes. When utility value is used to quantify the benefit of work alternatives, it may also be termed the benefit.

Utility Weighting
The practice of assigning relative weights to multiple criteria or objectives.