Chapter 6

LIFE-CYCLE COST CONSIDERATIONS: SUPPLEMENTAL INFORMATION

LIFE-CYCLE COST CONSIDERATIONS: SUPPLEMENTAL INFORMATION

Overview

This chapter provides a detailed description of the various processes involved in analyzing the life-cycle costs associated with the asset classes discussed in the TAMP. Two aspects of life-cycling costing are documented: 1) the data used to conduct the analysis and the process for gathering the information, and 2) the metrics and assumptions used in the analysis. In addition to the documentation of the tools used to model life-cycle strategies, examples (attachments) are provided at the end of the chapter.

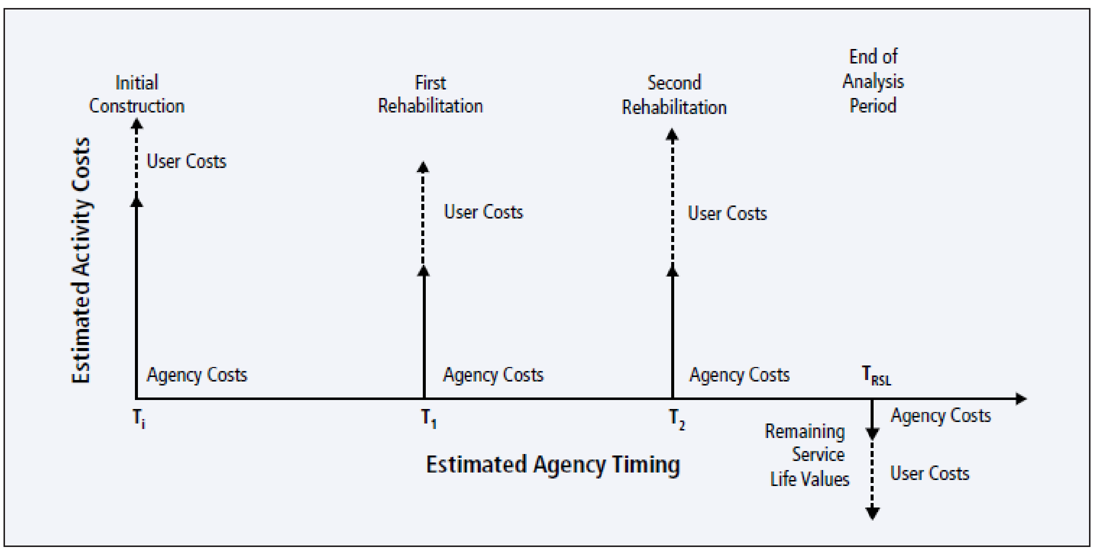
Process

The inputs for conducting a Life-Cycle Cost Analysis (LCCA) are presented first, followed by the key metrics/terms associated with an LCCA. The LCCA procedures used in developing the TAMP are then documented.

LCCA FUNDAMENTALS AND ANALYSIS COMPONENTS

The basic LCCA process requires the analyst to first define the schedule for initial and future activities associated with a specific strategy for managing an asset. Next, the costs associated with each of these activities are defined. The typical activity schedule and associated costs are used to develop a life-cycle cost stream (an example is shown in figure 6-1). Life-cycle cost stream diagrams are typically used in project-level LCCA, however, the same fundamental principles also apply to a network-level LCCA. Instead of programming treatment cycles and costs associated with a specific project, expert opinion provided by the asset Work Groups was used to estimate the same metrics at the network level (which were then scaled down to a unit level – e.g. costs per bridge or per lane-mile of pavement – to allow for comparison of life-cycle costs between various asset categories included in the TAMP).

Figure 6-1: Projected Life-Cycle Cost Stream Diagram[1]



Project-level LCCA typically includes both agency costs (direct costs to the agency as a result of the construction operations) and user costs (costs not directly borne by the agency but that affect the agency's customers, such as traffic delays during construction or maintenance activities, and can impact customer perceptions of agency performance). However, since a network-level LCCA was conducted as a part of the TAMP, user costs were not considered due to the significant variability and uncertainty that exists from project to project.

Key inputs required for conducting a network-level LCCA include:

- Asset Condition Deterioration Rates: The rate at which the condition of the asset deteriorates over time with and without the application of routine, reactive, and preventive maintenance treatments.
- Treatment Types, Costs, and Cycles: The various types of treatments applied to an asset over its life-cycle, including the type of the treatment (whether it is a routine maintenance, reactive maintenance, preventive maintenance, or major rehabilitation/replacement/reconstruction activity); the condition level (e.g. Good, Fair, or Poor) when the treatment is applied; and the resulting condition level after the application of the treatment; typical treatment costs; and treatment cycles.

This information was gathered through an assignment (discussed later) that was distributed to each of the asset Work Groups.

KEY METRICS/TERMS ASSOCIATED WITH LCCA

The key terms/metrics associated with the LCCA conducted in the TAMP are:

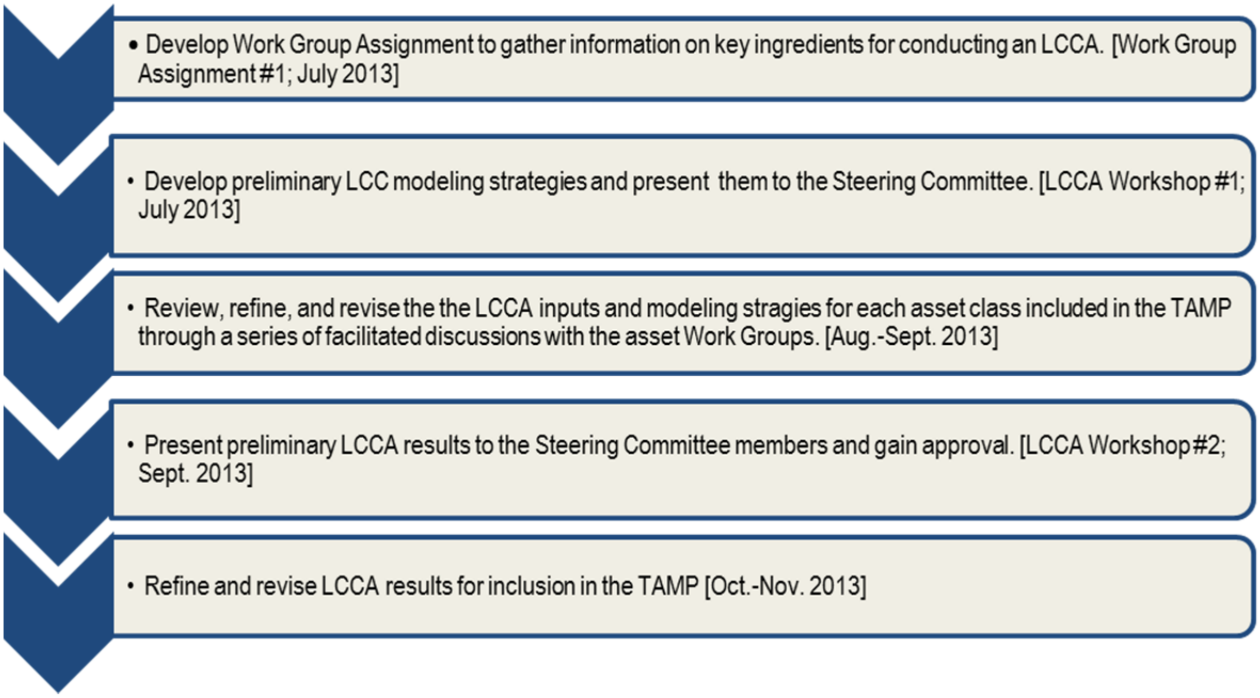
- Analysis Period: The timeframe over which the LCCA is performed. Theoretically, once a section of state highway is built, the agency is responsible for all future costs to keep that road in service, including the costs to reconstruct components of the road when they reach the end of their physical lives. However, because of discounting, costs in the far future have very little effect on any decisions made during the 10-year period covered by the TAMP. Forecasts of future deterioration and future needs become very unreliable if these predictions are extended too far into the future. In best practice, the analysis period of a life-cycle cost analysis should be as short as possible while still satisfying the following criteria:
    - Long enough that further costs make no significant difference in the results.
    - Long enough that at least the first complete asset replacement cycle is included.

  The reason for the second criterion is that replacement costs are typically much larger than any other costs during an asset's life, so these costs can remain significant even if discounted over a relatively long period. A fair comparison of alternatives should therefore include at least the first replacement cycle for each of the alternatives being compared.
- Discount Rate: Future costs converted into present day dollars using an economic technique known as "discounting". MnDOT's policy is to analyze all investments using a *real annual discount rate*, which is currently 2.2 percent. The term "real" means that the effects of inflation are removed from the computation in order to make the cost tradeoffs easier to understand.
- Life-Cycle Cost (in today's dollars): The total cost of asset ownership over the analysis period when the costs incurred in future years are converted to current dollars.
- Future Maintenance Costs as a Percent of Initial Investment: The total future agency costs (including maintenance, rehabilitation, and inspection, but not operations costs) as a fraction of the initial construction cost of the asset. This value represents the future cost commitment that MnDOT makes for every dollar spent on a capital project.
- Equivalent Uniform Annual Cost: The analysis method that shows the annual costs of a life-cycle management strategy if they occurred uniformly throughout the analysis period.

LIFE-CYCLE COST ANALYSIS PROCEDURE USED IN THE TAMP

The step-by-step approach used in analyzing life-cycle costs for the TAMP is illustrated in Figure 6-2.

Figure 6-2: TAMP Life-Cycle Analysis Process



WORK GROUP ASSIGNMENT #1: COMPILE DATA ON KEY INPUTS FOR LCCA (JULY 2013)

As discussed above, an assignment was distributed to each asset Work Group to compile the key inputs required to conduct a network-level LCCA. The inputs included asset condition deterioration rates, treatment types, treatment costs, and treatment cycles. The assignment was completed by each Work Group and a copy of the results is provided at the end of this chapter. The Work Group assignment was followed by a workshop (discussed in the next section) to discuss the modeling strategies and gain input, feedback, and buy-in from the TAMP Steering Committee.

LCCA WORKSHOP #1: FINALIZE LCCA METHODOLOGY FOR TAMP (JULY 2013)

This workshop built upon the data gathered during the Work Group assignment (discussed above) to finalize the deterioration rates, unit costs, and treatment strategies for each asset. Topics covered during this workshop included:

- The level of detail required to complete the assignment.
- The development of asset deterioration rates.
- Actual versus desired maintenance strategies.
- Definitions of various condition categories and performance metrics (where none existed).
- Process changes to better incorporate whole life costing into investment decisions, which involved:
  - Identifying appropriate planned maintenance regimes to ensure assets met design lives in a cost-effective manner.
  - Capturing information in computerized systems to assist in the analysis of current and future planning activities.

The major decision made during this workshop was that representative examples would be used to characterize the life-cycle strategies for each asset included in the TAMP. However, the representative examples would be based on detailed life-cycle cost calculations computed using actual MnDOT data. It was decided that the life-cycle portion of the TAMP would serve to:

- Describe life-cycle costs and explain why they are important.
- Explain typical MnDOT infrastructure life-cycle costs using examples of deterioration rates and preservation cycles.
- Describe strategies for managing assets over their whole lives, from inception to disposal, illustrating the use of a sequence of activities, including maintenance and preservation treatments. Illustrate how these actions are helpful in delaying or slowing deterioration and maximizing the service life of an asset.
- Document the tools that MnDOT has available to help forecast life-cycle costs for some assets.
- Document typical life-cycle cost of the assets included in the TAMP.
- Explain the commitment and steps MnDOT is taking to improve its effectiveness in minimizing life-cycle costs.
- Document the typical life-cycle cost of adding a new lane-mile of roadway and document a process for considering future maintenance costs when evaluating potential roadway expansion projects.

Following this workshop, several facilitated teleconferences were held with the Work Groups to review, refine, and revise the LCCA inputs and modeling strategies used in the TAMP and to develop preliminary asset life-cycle costs.

LCCA WORKSHOP #2: PRESENT PRELIMINARY LCCA RESULTS AND GAIN FEEDBACK FROM STEERING COMMITTEE (SEPTEMBER 2013)

The preliminary life-cycle costs developed for each asset were presented at this meeting to gain critical feedback from the TAMP Steering Committee and identify additional required information or analysis. The Steering Committee provided valuable suggestions for how the life-cycle costing strategies could be presented in the TAMP. The input and feedback from this meeting was used to finalize the LCCA results for the TAMP.

Supporting Data and Documentation

This section presents the LCCA assumptions and tools used to conduct the network-level LCCA.

LCCA INPUTS AND ASSUMPTIONS

As discussed in the TAMP, three LCCA modeling strategies were used to represent “Typical”, “Worst-First”, and “Desired” treatment strategies. The “Typical” strategy reflects MnDOT’s current practices for managing the assets and the “Worst-First” strategy assumes that no treatments are applied until the complete replacement of the asset when it deteriorates to a Poor condition. The “Desired” strategy (established only for pavements due to a lack of sufficient data for bridges, hydraulic infrastructure, overhead sign structures, and high-mast light tower structures) corresponds to the strategy that MnDOT aspires to adopt in order to further reduce total life-cycle costs.

PAVEMENTS

The key inputs and assumptions specific to pavements are summarized below:

- Analysis Period: 70 years; Discount Rate: 2.2 percent
- All costs presented in dollars per lane-mile
- Only direct agency costs considered in the LCCA model; inspection costs and other operational costs like debris removal, snow and ice removal, etc. not included.

- Flexible pavements and rigid pavement LCCA modeled separately and overall life-cycle costs combined into a single composite value based on weighted averages of percent of rigid and flexible pavements in MnDOT's roadway network (11 percent rigid pavements, 89 percent flexible pavements)
- Routine and reactive maintenance costs included in the LCCA model based on the following:
  - MnDOT spent approximately $1.4 Million in 2012 (in the Minneapolis-St. Paul Metro Region). This value was used to extrapolate costs for the pavement network considered in the LCCA.
  - Investments made by pavement condition category could not be determined; therefore, weighting factors were applied to maintenance costs (for each of the three pavement condition categories: Good, Fair, Poor) based on expert input from the Work Groups. The final weighting factors (Good: 0.8; Fair: 1.2; Poor: 1.8) resulted in the following maintenance costs per condition category: Good: $2,340 per lane-mile; Fair: $3,480 per lane-mile; Poor: $5,229 per lane-mile.

The assumptions specific to the "Worst-First" strategy for pavements are summarized below:

- Flexible Pavements: the end-of-life activity is expected to occur between 15 and 25 years, with a "most likely" age of 25 years when no preventive maintenance is performed. The end-of-life activity is expected to cost anywhere between $210,000 per lane-mile for a full-depth reclamation (FDR) activity to $2 million per lane-mile for complete reconstruction, with the typical cost being $210,000 per lane-mile.
- Rigid Pavements: the end-of-life activity is expected to occur between 25 and 35 years, with a "most likely" age of 30 years when no preventive maintenance is performed. The end-of-life activity is expected to cost anywhere between $450,000 per lane-mile for an unbonded overlay to $2 million per lane-mile for complete reconstruction, with the typical cost being $450,000 per lane-mile.

Figure 6-3 summarizes the "Typical" strategy used to manage flexible pavements and Figure 6-4 summarizes the "Desired" strategy for managing flexible pavements. Figure 6-5 summarizes the life-cycle management strategy for rigid pavements (the "Typical" and "Desired" strategies are the sam for rigid pavements).

Figure 6-3: "Typical" Life-Cycle Management Strategy for Flexible Pavements (Mill and Overlay Strategy)

Typical Pavement Age* (yrs)	Pavement Age Range** (yrs)	Treatment	Typical Condition When Applied	Typical Cost ($/ln-mi)***	Cost Range ($/ln-mi)***
0	0	Initial Construction	-	$657,500#	$210,000 - $2,000,000
8	6-10	Crack Treatment	Good	$6,000	$3,000 - $10,000
12	10-14	Surface Treatment	Good	$15,000	$10,000 - $30,000
20	18-22	Mill & Overlay (1st Overlay)	Fair	$155,000*	$145,000 - $175,000
24	21-25	Crack Treatment	Good	$6,000	$3,000 - $10,000
26	25-29	Surface Treatment	Fair	$15,000	$10,000 - $30,000
35	33-35	Mill & Overlay (2nd Overlay)	Fair	$155,000	$145,000 - $175,000
39	36-40	Crack Treatment	Good	$6,000	$3,000 - $10,000
41	39-43	Surface Treatment	Fair	$15,000	$10,000 - $30,000
47	45-49	Mill & Overlay (3rd Overlay)	Poor	$155,000	$145,000 - $175,000
51	49-53	Crack Treatment	Good	$6,000	$3,000 - $10,000
53	51-55	Surface Treatment	Fair	$15,000	$10,000 - $30,000
57	55-59	Mill & Overlay (4th Overlay)	Poor	$155,000	$145,000 - $175,000
61	59-63	Crack Treatment	Good	$6,000	$3,000 - $10,000
63	61-65	Surface Treatment	Fair	$15,000	$10,000 - $30,000
65	63-67	Mill & Overlay (5th Overlay)	Poor	$155,000	$145,000 - $175,000
68	66-70	Crack Treatment	Good	$6,000	$3,000 - $10,000
70	68-72	Reconstruction	Fair	$657,500#	$210,000 - $2,000,000

Notes:
* Based on Values from MnDOT Pavement Design Manual Chapter 7 and input provided by MnDOT TAMP Pavement Work Group
** Range assumed based on general input from MnDOT TAMP Pavement Work Group
***Cost data provided by MnDOT TAMP Pavement Work Group, some assumptions to develop cost ranges based on data provided
#Value based on assumption that typically, 75% of the projects involve FDR and 25% involve complete reconstruction

Figure 6-4: "Desired" Life-Cycle Management Strategy for Flexible Pavements (FDR strategy)

Typical Pavement Age* (yrs)	Pavement Age Range** (yrs)	Treatment	Typical Condition When Applied	Typical Cost ($/ln-mi)***	Cost Range ($/ln-mi)***
0	0	Initial Construction	-	$657,500[#]	$210,000 - $2,000,000
8	6-10	Crack Treatment	Good	$6,000	$3,000 - $10,000
12	10-14	Surface Treatment	Good	$15,000	$10,000 - $30,000
20	18-22	Mill & Overlay (1st Overlay)	Fair	$155,000	$145,000 - $175,000
23	21-25	Crack Treatment	Good	$6,000	$3,000 - $10,000
27	25-29	Surface Treatment	Fair	$15,000	$10,000 - $30,000
35	33-35	Mill & Overlay (2nd Overlay)	Fair	$155,000	$145,000 - $175,000
38	36-40	Crack Treatment	Good	$6,000	$3,000 - $10,000
43	41-45	Surface Treatment	Fair	$15,000	$10,000 - $30,000
50	47-53	FDR/Reconstruction	-	$657,500[#]	$210,000 - $2,000,000
58	56-60	Crack Treatment	Good	$6,000	$3,000 - $10,000
62	60-64	Surface Treatment	Good	$15,000	$10,000 - $30,000
70	68-72	Mill & Overlay (1st Overlay after FDR/Reconstruction)	Fair	$155,000	$145,000 - $175,000

Notes:
* Based on Values from MnDOT Pavement Design Manual Chapter 7 and input provided by MnDOT TAMP Pavement Work Group
** Range assumed based on general input from MnDOT TAMP Pavement Work Group
***Cost data provided by MnDOT TAMP Pavement Work Group, some assumptions to develop cost ranges based on data provided
[#]Value based on assumption that typically, 75% of the projects involve FDR and 25% involve complete reconstruction

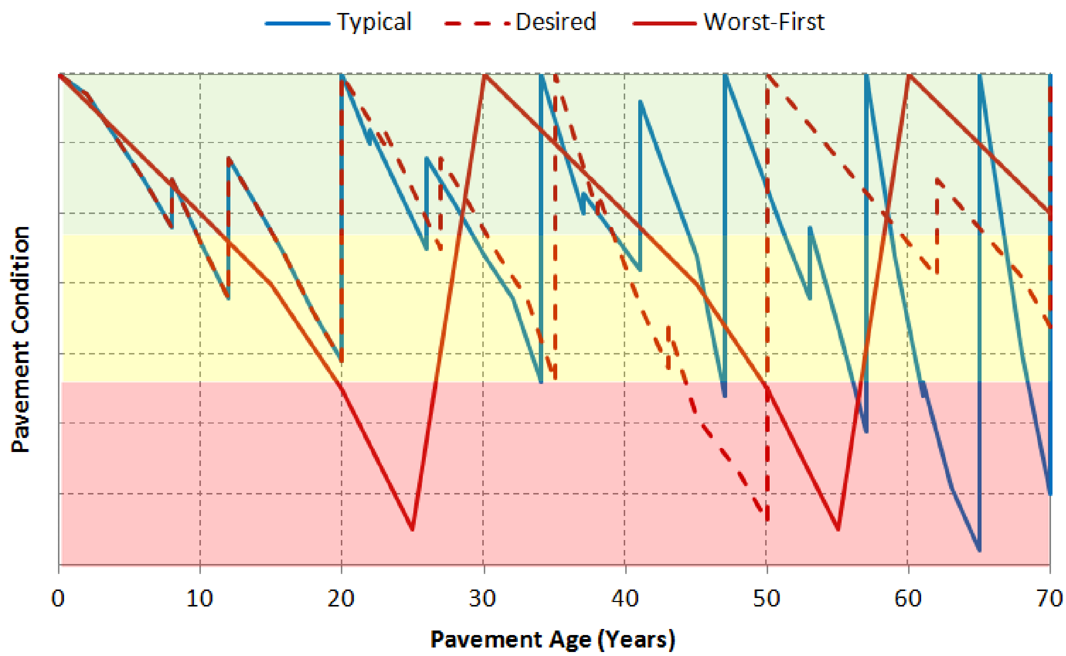
Figure 6-5: Life-Cycle Management Strategy for Rigid Pavements

Typical Pavement Age* (yrs)	Pavement Age Range** (yrs)	Treatment	Typical Condition When Applied	Typical Cost ($/ln-mi)***	Cost Range ($/ln-mi)***
0	0	Initial Construction	-	$450,000	$450,000 - $2,000,000
10	6 - 20	Reseal joints and partial depth repairs	Good	$10,000	$5000 - $15,000
16	13 - 31	Minor CPR (some full depth repairs)	Fair	$80,000	$55,000 - $80,000
26	8 - 26	Major CPR (and grinding)	Fair	$230,000	$135,000 - $230,000
50	46-54	Unbonded Overlay/Reconstruction	Poor	$450,000	$450,000 - $2,000,000
60	56 - 70	Reseal joints and partial depth repairs	Good	$10,000	$5000 - $15,000
66	63-81	Minor CPR (some full depth repairs)	Fair	$80,000	$55,000 - $80,000

Notes:
The Pavement Work Group indicated that the desired and typical life-cycle strategies are fairly close for rigid pavements and recommended using the same values for both
* Based on Values from MnDOT Pavement Design Manual Chapter 7 and input provided by MnDOT TAMP Pavement Work Group
** Range assumed based on general input from MnDOT TAMP Pavement Work Group
***Cost data provided by MnDOT TAMP Pavement Work Group, some assumptions to develop cost ranges based on data provided

An illustration of the deterioration models representing pavement performance over the 70-year analysis period for the three strategies considered is provided in Figure 6-6.

Figure 6-6: Deterioration Models for Various LCCA Scenarios (Pavements)



BRIDGE STRUCTURES (BRIDGES AND LARGE CULVERTS)

The key inputs and assumptions specific to bridge structures are summarized below:

- Analysis Period: 200 years; Discount Rate: 2.2 percent
- Markov models used to model condition deterioration based on expert input from the Bridge Work Group
- All costs presented in dollars per bridge and dollars per square foot (deck area)
- Routine maintenance activities applied to all bridges in appropriate condition, on a scheduled basis to slow the rate of deterioration
- Corrective action is used to repair defects and prevent further deterioration. Activities that fall under this category are considered to be infeasible when the structure is in Poor condition.
- Rehabilitation and replacement activities are performed when the service life of all or part of the structure cannot be extended. This activity is generally performed when the structure is in Poor condition.

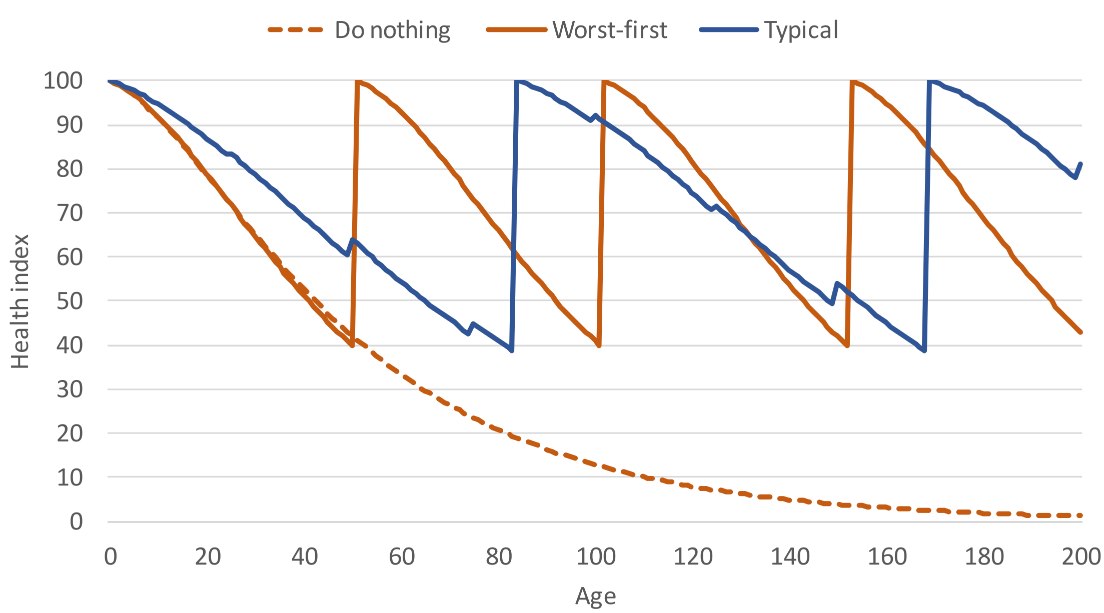
The costs and treatment strategies used in the LCCA model for bridge structures are summarized in Figure 6-7.

Figure 6-7: Costs and Treatment Strategies Used in the LCCA Model for Bridge Structures

Treatment	$/Bridge	% Bridges Acted Upon Annually			
		Good	Satisfactory	Fair	Poor
Routine Maintenance: Bridge Decks					
Joint sealing	$1,529	13%	13%	13%	
Deck sealing	$37,406	14%	14%	14%	
Crack Sealing	$1,500	20%	20%	20%	
Routine Maintenance: Bridge Superstructures					
Inspection	$1,111	60%	60%	60%	60%
Flushing	$500	75%	75%	75%	75%
Lube Bearings	$26,600	0.1%	0.2%		
Routine Maintenance: Bridge Culverts					
Inspection	$1,111	60%	60%	60%	60%
Corrective Action: Bridge Decks					
Joint repair (patch)	$38,215		1%	2%	
Deck repair	$16,833		2%	35%	15%
Overlay	$130,921			5%	2%
Rail repair/replace	$127,705		1%	5%	
Corrective Action: Bridge Substructures					
Patching	$56,070			10%	15%
Slope paving repair	$26,166		1%	1%	
Erosion/Scour Repair	$25,000			5%	5%
Corrective Action: Bridge Superstructures					
Spot Painting	$19,500		2%	5%	
Full Painting	$377,480		3%	5%	
Patching	$30,000		1%	3%	5%
Repair/Replace bearings	$46,549				5%
Repair Steel	$50,000			2%	5%
Corrective Action: Bridge Culverts					
Patching	$12,104			5%	10%
Rehab and Replacement: Bridge Decks					
Redeck	$1,122,184				5%
Rehab and Replacement: Bridge Substructures					
Replace Elements	$100,000				1%
Rehab and Replacement: Bridge Superstructures					
Replace Elements	$100,000				1%
Replace Structure	$2,702,941				20%
Rehab and Replacement: Bridge Culverts					
Replacement	$250,000				25%

An illustration of the deterioration models describing the performance of bridge structures over the 200-year analysis period is provided in Figure 6-8.

Figure 6-8: Deterioration Models for Various LCCA Scenarios (Bridge Structures)



CENTERLINE CULVERTS AND STORMWATER TUNNELS

The key inputs and assumptions specific to centerline culverts and stormwater tunnels are summarized below:

- Analysis Period: 200 years; Discount Rate: 2.2 percent
- Markov models used to model condition deterioration based on expert input from the Hydraulics Work Group
- All costs presented in dollars per structure
- Routine maintenance activities applied to all structures in appropriate condition, on a scheduled basis to slow the rate of deterioration
- Corrective action is used to repair defects and prevent further deterioration. Activities that fall under this category are infeasible when the structure is in Poor condition.
- Rehabilitation and replacement activities are performed when the service life of all or part of the structure cannot be extended. This activity is generally performed when the structure is in Poor condition.

The costs used in the LCCA model for centerline culverts and stormwater tunnels are summarized in Figure 6-9.

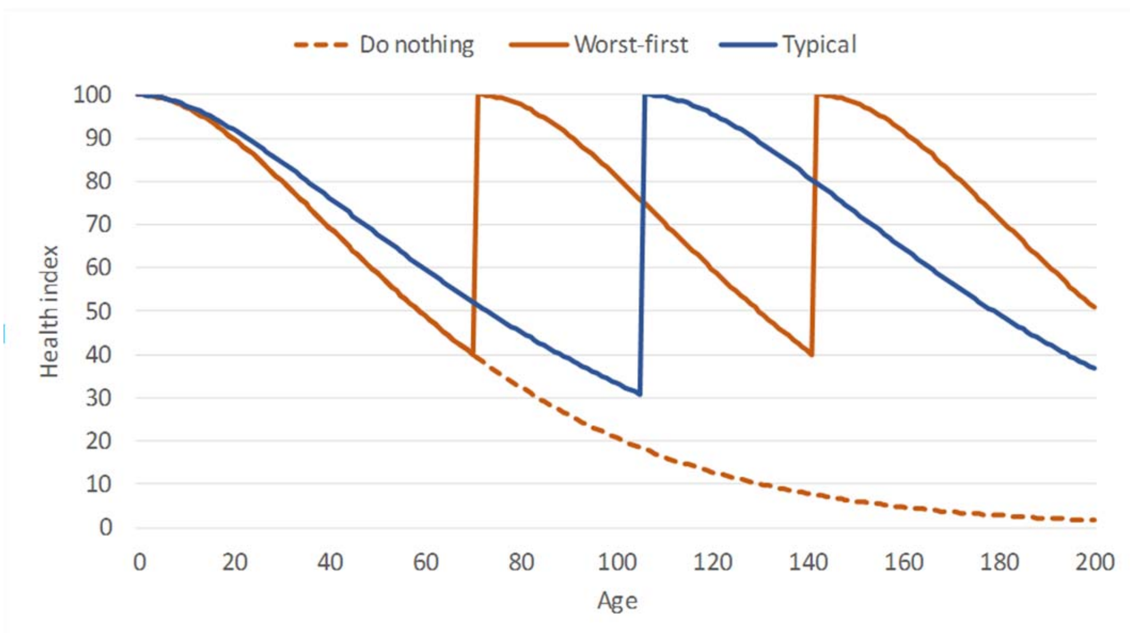
Figure 6-9: Life-Cycle Management Strategy for Centerline Culverts and Stormwater Tunnels

Treatment	$/Bridge	% Bridges Acted Upon Annually			
		Good	Satisfactory	Fair	Poor
Routine Maintenance: Centerline Culverts					
Inspection	$62	25%	25%	25%	25%
Cleaning	$100	10%	10%	10%	10%
Routine Maintenance: Stormwater Tunnels					
Inspection	$200,000	25%	25%	25%	25%
Corrective Action: Centerline Culverts					
Reset ends	$2,695		1%	2%	1%
Joint repair	$1,429		1%	1%	1%
Pave invert	$804			2%	1%
Corrective Action: Stormwater Tunnels					
Fill Voids and Cracks	$3.5 M				
Rehab and Replacement: Centerline Culverts					
Slipliner	$8,664				1%
CIPP	$6,418				2%
Replace - Trench	$32,235			1%	5%
Replace - Jack	$35,888			1%	2%
Rehab and Replacement: Stormwater Tunnels					
Replacement	$5,099,500				1%

Illustrations of the deterioration models describing the performance of centerline culverts and stormwater tunnels over the 200-year analysis period are provided in Figures 6-10 and 6-11, respectively.

Figure 6-10: Deterioration Models for Various LCCA Scenarios (Centerline Culverts)

Figure 6-11: Deterioration Models for Various LCCA Scenarios (Stormwater Tunnels)



OVERHEAD SIGN STRUCTURES (OSS) AND HIGH-MAST LIGHT TOWER STRUCTURES (HMLTS)

The key inputs and assumptions specific to overhead sign structures and high-mast light tower structures are summarized below:

- Analysis Period: 100 years; Discount Rate: 2.2 percent
- All costs presented in dollars per structure

- Inspection costs are included in the LCCA model because they are considered an important maintenance activity. Other costs, such as traffic control and mobilization, were not explicitly considered.
  - Average inspection costs for OSS: $950/structure (applied on a 4 year cycle)
  - Average inspection costs for HMLTS: $1000/structure (applied on a 5 year cycle)

The "Worst-First" strategy for OSS and HMLTS involved the replacement of the structure on a 40-year cycle with routine inspections and minimal maintenance activities. The typical life-cycle management strategies used in the LCCA model for OSS and HMLTS are summarized in Figures 6-12 and 6-13, respectively.

Figure 6-12: "Typical" Life-Cycle Management Strategy for OSS

Typical Age (yrs)	Age Range (yrs)	Treatment	Treatment Cycle (yrs)	Typical Condition When Applied	Typical Cost ($/structure)	Cost Range ($/structure)
0	0	Initial Cost of Structure	100	Poor	$85,000	$60,000 - $110,000
4	3 - 5	Tighten Nuts	8	Poor	$200	$200 - $400
8	6 - 8	Remove Grout	8	Poor	$1,000	$800 - $1,200
20	15 - 25	Re-grade footing, replace weld, remove catwalks/lighting, new mounting posts	20	Poor	$3,000	$1700 - $6000
40	35 - 45	Replace foundation or replace truss or other elements	40	Poor	$25,000	$8,000 - $30,000
100	N/A	End of Analysis Period	N/A	N/A	N/A	N/A

Figure 6-13: "Typical" Life-Cycle Management Strategy for HMLTS

Typical Age (yrs)	Age Range (yrs)	Treatment	Treatment Cycle (yrs)	Typical Condition When Applied	Typical Cost ($/structure)	Cost Range ($/structure)
0	0	Initial Cost of Structure	100	-	$40,000	$30,000 - $60,000
5	3 - 7	Routine Maintenance	5	Fair	$500	$200 - $1000
100	N/A	End of Analysis Period	N/A	N/A	N/A	N/A

LCCA TOOLS USED

The Federal Highway Administration's RealCost tool[1] was used to conduct the network-level life-cycle cost analyses for pavements, OSS, and HMLTS. The bridge structures and hydraulic infrastructure models were developed specifically for this study. Examples of several of these models are included at the end of the chapter.

[1] FHWA RealCost Tool. (Web Link)

LIFE-CYCLE COST CONSIDERATION WORKSHOP
WORK GROUP ASSIGNMENT #1 (RESULTS)

LIFE-CYCLE COST CONSIDERATION WORKSHEET - PAVEMENTS

Pavement Subset (ex: NHS): All State Trunk Highways (NHS and Non-NHS, IS, US, MN)

Deterioration Rates

On average, what is the shortest length of time (in years) before these pavements are at a condition when they should be reconstructed (assuming no other capital improvements are conducted)? 15 years

On average, what is the longest length of time (in years) before these pavements are at a condition when they should be reconstructed (assuming no other capital improvements are conducted)? 40 years

On average, what would you estimate to be the most typical length of time for the asset to reach a condition when it should be reconstructed (assuming no other capital improvements are conducted)? 25 years

Does the point at which pavements needed to be reconstructed equate to your Poor condition category? (Yes or No) If No, please comment Yes

Inspection Costs

What is the estimated average annual cost to collect and process pavement condition data so it can be used for reporting performance?

Average annual collection/processing costs: $37 per roadway mile

Treatment Costs

Five categories of repair are listed in tables P-1 and P-2, for flexible and rigid pavements respectively. Composite pavements should be considered to be rigid pavements that have received a treatment. For each of the repair categories, identify representative treatments that fit within that category, the typical condition range when these treatments are applied (e.g., Good, Fair, or Poor), and the condition after the treatment has been constructed. Also provide the typical price range for the treatments in that category and a cost that your Work Group considers to be the most representative cost within the price range. Be sure to indicate the units used for your costs.

Table P-1. Typical treatments and costs for flexible pavements.

Treatment Category	Representative Treatments	Typical Condition Level When Applied (e.g., G/F/P)	Most Likely Condition After Treatment	Typical Cost Range ($/lane-mile)	Most Representative Cost ($/lane-mile)
Preventive Maintenance	Chip Seal Crack Seal Micro-surface	Good	Good	$3K-$30K	$15K (Chip Seal)
Minor Rehabilitation	Thin Mill/OL Rut Fill	Fair	Good	$55K-$75K	$75K (Thin M/O)
Major Rehabilitation	Medium Mill/OL Thick Mill/OL CIR	Fair/Poor	Good	$145-$175K	$155K (Med M/O)
Reconstruction	Reconstruction Reclaim	Poor	Good	$210K-$2M	$210K (Reclaim)

Table P-2. Typical treatments and costs for rigid pavements.

Treatment Category	Representative Treatments	Typical Condition Level When Applied (e.g., G/F/P)	Most Likely Condition After Treatment	Typical Cost Range ($/lane-mile)	Most Representative Cost ($/lane-mile)
Preventive Maintenance	Joint Seal Diamond Grind	Good/Fair	Good	$20K-$30K	$30K (Grind)
Minor Rehabilitation	Minor CPR Minor CPR/Grind	Fair	Good	$55K-$80K	$80K (Minor CPR/Grind)
Major Rehabilitation	Major CPR/Grind Thick OL	Fair/Poor	Good	$125K-$230K	$230K (Major CPR/Grind)
Reconstruction	Reconstruction Unbonded OL	Poor	Good	$450K-$2M	$450K (Unbonded)

Treatment Cycles

Tables P-3 and P-4 are provided for you to enter the treatment cycles for both flexible and rigid pavements within this category of pavements. For each type of pavement, enter the following information:

- Column A: The type of activity that is applied. You can enter a category of treatments or a specific treatment.
- Columns B and C: The range of years in which the treatment is first applied. In column B identify the range of years in which the first application of this treatment is typically applied in your agency. In column C enter the range of years in which you think the treatment should be applied if funding were not an issue.

- Columns D and E: The year in which the treatment is most commonly applied. Instead of entering a range, identify the single age at which the treatment is typically applied for the first time in column D (this may be the mean or median in a set of values). In column E enter the age at which you think the treatment should be applied for the first time.
- Columns F and G: The typical application cycle for that treatment. In column F enter the typical frequency with which the treatment is applied by your agency. In column G enter the preferred treatment cycle. Once you have entered a treatment cycle, you do NOT need to enter the treatment in the table again. For instance, in the example, crack sealing is typically applied first applied in year 8 and then in year 13, since it is applied on a 5-year cycle.

Table P-3. Flexible pavement treatment cycle.

Column A Activity	Range of Years During Which the Treatment is First Applied		Year in Which the Treatment is Most Commonly Applied		Application Cycle (in years)	
	Column B Typical	*Column C* Desired	*Column D* Typical	*Column E* Desired	*Column F* Typical	*Column G* Desired
Initial Construction			0	0		
Crack Seal	3 - 5		8	8		
Chip Seal	4 - 8		12	12		
Medium Mill/OL	10 - 20		20	20		
Crack Seal			23	23		
Chip Seal			27	27		
Medium Mill/OL			35	35		
Add more rows if necessary						
End of Life Reconstruction			50	∞		

Table P-4. Rigid pavement treatment cycle.

Activity	Typical Range of Years During Which the Treatment is Applied		Most Typical Year in Which the Treatment is Applied		Application Cycle (in years)	
	Typical	Desired	Typical	Desired	Typical	Desired
Initial Construction			0	0		
Reseal joints & partial depth repairs	6 - 20		17	17		
Minor CPR and some full depth repairs	13 - 31		27	27		
Major CPR/grind	8 - 26		40	40		
Add more rows if necessary						
End of Life Reconstruction			50	∞		

LIFE-CYCLE COST CONSIDERATION WORKSHEET - BRIDGES

Bridge Subset (ex: State, NHS, Non-NHS): All Decked Bridges for Deterioration; NHS for Maintenance Info

To simplify the lifecycle cost analysis, assume the following condition categories from the NBI ratings:

- Good condition: NBI rating 7 to 9.
- Satisfactory condition: NBI rating 6.
- Fair condition: NBI rating 5.
- Poor condition: NBI rating 4 or less.

Deterioration Rates

Bridge Decks

- Suppose 100 bridge decks on this subset are currently in Good (7 or greater) condition. After how many years will 50 of them have deteriorated to Satisfactory (6) or worse condition, if no preservation action has been taken? 20-25 years
- Suppose 100 bridge decks on this subset are currently in Satisfactory (6) condition. After how many years will 50 of them have deteriorated to Fair (5) or worse condition, if no preservation action has been taken? 5-10 years (25-35 years total)
- Suppose 100 bridge decks on this subset are currently in Fair (5) condition. After how many years will 50 of them have deteriorated to Poor (4 or less) or worse condition, if no preservation action has been taken? 5-10 years (35-45 years total)
- Suppose 100 bridge decks on this subset are currently in Poor condition. After how many years will 50 of them have deteriorated to Failed condition, if no preservation action has been taken? _____N/A__________________
  - Ranges due to ADT (>10K, 4-10K, <4K) and different bridge types
  - Includes bridges with decks; does not include culverts

Bridge Superstructures

- Suppose 100 bridge superstructures on this subset are currently in Good (7 or greater) condition. After how many years will 50 of them have deteriorated to Satisfactory (6) or worse condition, if no preservation action has been taken? 40-50 years
- Suppose 100 bridge superstructures on this subset are currently in Satisfactory (6) condition. After how many years will 50 of them have deteriorated to Fair (5) or worse condition, if no preservation action has been taken? 10-20 years (50-70 years)
- Suppose 100 bridge superstructures on this subset are currently in Fair (5) condition. After how many years will 50 of them have deteriorated to Poor (4 or less) or worse condition, if no preservation action has been taken? 10-30 years (60-100 years)
- Suppose 100 bridge superstructures on this subset are currently in Poor condition. After how many years will 50 of them have deteriorated to Failed condition, if no preservation action has been taken? ____N/A_________________
  - Assumptions: Ranges due to sampling from 1960's built to present day and different superstructure types

Bridge Substructures

- Suppose 100 bridge substructures on this subset are currently in Good (7 or greater) condition. After how many years will 50 of them have deteriorated to Satisfactory or worse condition, if no preservation action has been taken? 40-50 years
- Suppose 100 bridge substructures on this subset are currently in Satisfactory (6) condition. After how many years will 50 of them have deteriorated to Fair (5) or worse condition, if no preservation action has been taken? 10-20 years (50-70 years)
- Suppose 100 bridge substructures on this subset are currently in Fair (5) condition. After how many years will 50 of them have deteriorated to Poor (4 or less) or worse condition, if no preservation action has been taken? 10-30 years(60-100 years)
- Suppose 100 bridge substructures on this subset are currently in Poor condition. After how many years will 50 of them have deteriorated to Failed condition, if no preservation action has been taken? ________N/A_________________

Inspection Costs

What is the estimated average annual cost to collect and process bridge condition data so it can be used for reporting performance?

Average annual collection costs: $4.5 Million (includes culverts)

Average annual processing costs: $0.5 Million (includes culverts)

Treatment Costs

Five categories of repair are listed in tables B-1 through B-3, for bridge decks, superstructures, and substructures respectively. For each of the categories, identify representative treatments that fit within that category, the typical condition range when these treatments are applied (e.g., Good, Fair, or Poor), and the condition after the treatment has been constructed. Also provide the typical price range for the treatments in that category and a cost that your Work Group considers to be the most representative cost within the price range. Be sure to indicate the units used for your costs.

Table B-1. Typical treatments and costs for bridge decks.

Treatment Category	Representative Treatments	Typical Condition Level When Applied (e.g., Excellent, Good, Fair, or Poor)	Most Likely Condition After Treatment	Typical Cost Range	Most Representative Cost
Routine Maintenance (Subset of Preventive Maintenance)	Flushing Deck, Joints, Drains	All Bridges with Decks	Same but slows deterioration rate	$100 - $1500/ Bridge	$500/ Bridge (Flushing entire bridge)
	Crack Sealing	Fair (5) or greater; dependent on programming and element condition state	Fair (5) or greater but improved element condition state	$2.5 -$4/LF of Crack	$3/ LF of Crack
	Deck Sealing			$0.2 - $4/ SF of deck	Highly dependent on material used
	Joint Sealing			$3 - $5/ LF of joint	$4/ LF of joint
	Rail Sealing			$3-$4/ LF of rail	$3.50/ LF of rail
Preventive Maintenance	Poured Joint Repair	Fair (5) or greater; dependent on programming and element condition state	Fair (5) or greater but improved element condition state	$50 – $200/ LF of joint	$100/ LF of Joint
	Expansion Joint Repair (Gland)			$100 – $400/ LF of joint	$250/ LF of joint
	Replace Joint			$375-$750/ LF of joint	Depends on joint type
	Relief Joint Repair			$5 - $50/ LF of joint	Depends on Repair
Minor Rehabilitation (Reactive Maintenance)	Deck Repair	Fair to Poor	Satisfactory	$20 - $55/ SF of repair area	$30/ SF of repair area
	Underdeck-Remove loose concrete/ repair	Fair to Poor	Same	Infrequent Reactive Maint	Infrequent Reactive Maint
	Polymer Overlay	Good to Satisfactory	Same	$7/ SF of deck	$7/ SF of deck
	LS Overlay	Poor	Satisfactory to Fair	$6-$8/ SF of deck	$7/ SF of deck

	Rail Repair	Good to Fair; dependent on element condition state	Same; improves element condition state	$100 - $165/ LF of rail repair area	$150/ LF of rail repair area
	Approach Panels	Dependent on element condition state	Improves element condition state	$10 - $20/ SF of repair area	$15/ SF of repair area
	Underpin (Infrequent Reactive Maint)	Poor	Poor; preserve public safety	Infrequent Reactive Maint	Infrequent Reactive Maint
Major Rehabilitation	Replace Railing	Good to Fair; dependent on element condition state	Same; improves element condition state	$150 - $300/ LF of rail	$200/ LF of rail
	Redeck	Poor	Good	$50 -$70/ SF of deck	$60/SF of deck
Reconstruction (Entire Bridge)	Reconstruction	Poor	Good	Variable	$145/ SF

For each condition level, what percent of the time do you end up taking no action at all in a year and just allowing the bridge to deteriorate some more? *This analysis does not include routine maintenance, although routine maintenance, such as flushing, is performed annually to slow deterioration rates. Crack sealing is also performed to preserve the bridge deck and slow further deterioration.

- Good _100_%*
- Fair _70_%
- Poor _65_%

Table B-2. Typical treatments and costs for bridge superstructures.

Treatment Category	Representative Treatments	Typical Condition Level When Applied (e.g., Excellent, Good, Fair, or Poor)	Most Likely Condition After Treatment	Typical Cost Range	Most Representative Cost
Routine Maintenance (Subset of Preventive Maintenance)	Flushing Bearings, Beam Ends, Truss Members	All Bridges with Decks	Same but slows deterioration rate	$100 - $1500/ Bridge	$500/ Bridge (Flushing entire bridge)
	Clean and Lubricate Bearings	Good to Fair; dependent on element condition state	Good to Fair; improves element condition state	$800-$1100/ EACH Bearing	$1000/ EACH
Preventive Maintenance	Sealing/ Epoxy Injection	Good to Poor	Good to Fair	Infrequent Reactive Maint	Infrequent Reactive Maint
	Painting Beams	Good to Fair; dependent on element condition state	Good to Fair; improves element condition state	$12-$15/ SF of painted area	$13/ SF of painted area
Minor Rehabilitation (Reactive Maintenance)	Reset Bearings	Good to Fair; dependent on element condition state	Good to Fair; improves element condition state	$200-$500/ EACH Bearing	$300/ EACH Bearing
	Remove Loose Concrete	Fair to Poor; dependent on element condition state	Fair to Poor; improves element condition state	Infrequent Reactive Maint	Infrequent Reactive Maint
	Patching/ Gunite/Shot Crete	Fair to Poor; dependent on element condition state	Satisfactory to Fair; improves element condition state	$55 - $150/ SF of patch area	$100/ SF of patch area
	Arresting Fatigue Cracks	Poor	Fair	Infrequent Reactive Maint	Infrequent Reactive Maint
Major Rehabilitation	Repair/ Replace Bearings	Poor	Good to Fair	$1600 - $2000/ EACH Bearing	$1750/ EACH Bearing
	Heat Straightening (*Infrequent reactive maint; typically in response to	Fair to Poor	Satisfactory	$6,500 - $9,000 per day + mob*	$6,500 per day + mob*

	bridge hits)				
	Repair Steel Elements (splice plates, stiffeners, etc)	Fair to Poor	Satisfactory to Fair	In response to bridge hits or older trusses (smaller subset of bridges)	In response to bridge hits or older trusses (smaller subset of bridges)
	Widening (Performed in response to increased traffic needs)	Poor	Good to Satisfactory	$300/ SF of deck (includes super, sub and deck)	$300/ SF of deck (includes super, sub and deck)
	Replace Concrete and Steel Elements	Poor	Good to Satisfactory	Infrequent Reactive Maint	Infrequent Reactive Maint
	Repair/ Replace Connections	Poor	Good to Fair	In response to critical findings or advanced section	In response to critical findings or advanced section
Reconstruction (Entire Bridge)	Reconstruction	Poor	Good	Variable	$145/ SF

For each condition level, what percent of the time do you end up taking no action at all in a year and just allowing the bridge to deteriorate some more? *This analysis does not include routine maintenance, although routine maintenance, such as flushing, is performed annually to slow deterioration rates. Other routine maintenance, such as sealing, is performed as needed and can help slow deterioration.

- Good _100_%
- Fair _90_%
- Poor _75_%

Table B-3. Typical treatments and costs for bridge substructures.

Treatment Category	Representative Treatments	Typical Condition Level When Applied (e.g., Excellent, Good, Fair, or Poor)	Most Likely Condition After Treatment	Typical Cost Range	Most Representative Cost
Routine Maintenance (Subset of Preventive Maintenance)	Flushing bridge seats, pier caps	All Bridges with Decks	Same but slows deterioration rate	$100 - $1500/ Bridge	$500/ Bridge (Flushing entire bridge)
Preventive Maintenance	Sealing	Good to Poor	Good to Fair	Infrequent Reactive Maint	Infrequent Reactive Maint
	Painting	Good to Fair; dependent on element condition state	Good to Fair; improves element condition state	Infrequent Reactive Maint	Infrequent Reactive Maint
Reactive Maintenance	Debris Removal	All	Same, but prevents debris from causing more problems	Not applied directly to the substructure	Not applied directly to the substructure
Minor Rehabilitation (Reactive Maintenance)	Patching	Fair to Poor	Satisfactory to Fair	$55 - $150/ SF of patch area	$100/ SF of patch area
	Slope Paving Repair	Dependent on element condition state	Improves element condition state	$10 - $25/ SF of repair area	$20/ SF of repair area
	Riprap (Infrequent Reactive Maint)	Fair to Poor	Good to Satisfactory	$10,000 - $500,000	Depends on extent of project
Major Rehabilitation	Scour Repair	Fair to Poor	Good to Satisfactory	$50,000 - $500,000	Depends on extent of project
	Repair Steel Elements	Fair to Poor	Satisfactory to Fair	Infrequent Reactive Maint	Infrequent Reactive Maint
	Replace Steel Elements	Poor	Good to Satisfactory	Infrequent Reactive Maint	Infrequent Reactive Maint
	Replace Concrete Elements	Poor	Good to Satisfactory	Infrequent Reactive Maint	Infrequent Reactive Maint
Reconstruction (Entire Bridge)	Reconstruction	Poor	Good	Variable	$145/ SF

For each condition level, what percent of the time do you end up taking no action at all in a year and just allowing the bridge to deteriorate some more? *This analysis does not include routine maintenance, although routine maintenance, such as flushing, is performed annually to slow deterioration rates. Other routine maintenance, such as sealing, is performed as needed and can help slow deterioration.

- Good _100_%
- Fair _90_%
- Poor _75_%

Overall Health Index

Please answer the following question to tell us the relative value you would place on each condition level, considering the effect on routine maintenance needs and on the quality of service given to the public, including risk. If Excellent condition is worth 100 points and Failed condition is worth zero points, how much should the other levels be worth?

- Good condition 100 points.
- Satisfactory condition 80 points.
- Fair condition 50 points.
- Poor condition 0 points.

LIFE-CYCLE COST CONSIDERATION WORKSHEET – BRIDGE CULVERTS

Bridge Subset (ex: State, NHS, Non-NHS): Concrete Box Culverts > 10 FT

To simplify the lifecycle cost analysis, assume the following condition categories from the NBI ratings:

- Good condition: NBI rating 7 to 9.
- Satisfactory condition: NBI rating 6.
- Fair condition: NBI rating 5.
- Poor condition: NBI rating 4 or less.

Deterioration Rates

Culverts

- Suppose 100 culverts on this subset are currently in Good (7 or greater) condition. After how many years will 50 of them have deteriorated to Satisfactory (6) or worse condition, if no preservation action has been taken? 50 years
- Suppose 100 culverts on this subset are currently in Satisfactory (6) condition. After how many years will 50 of them have deteriorated to Fair (5) or worse condition, if no preservation action has been taken? 20 years (70 years total)
- Suppose 100 culverts on this subset are currently in Fair (5) condition. After how many years will 50 of them have deteriorated to Poor (4 or less) or worse condition, if no preservation action has been taken? 30 years (100 years total)
- Suppose 100 bridge decks on this subset are currently in Poor condition. After how many years will 50 of them have deteriorated to Failed condition, if no preservation action has been taken? _____N/A____________

Inspection Costs

What is the estimated average annual cost to collect and process bridge condition data so it can be used for reporting performance?

Average annual collection costs: $4.5 Million_(includes culverts)

Average annual processing costs: $0.5 Million_(includes culverts)

Treatment Costs

Five categories of repair are listed in tables B-4, for culverts. For each of the categories, identify representative treatments that fit within that category, the typical condition range when these treatments are applied (e.g., Good, Fair, or Poor), and the condition after the treatment has been constructed. Also provide the typical price range for the treatments in that category and a cost that your Work Group considers to be the most representative cost within the price range. Be sure to indicate the units used for your costs.

Table B-4. Typical treatments and costs for culverts.

Treatment Category	Representative Treatments	Typical Condition Level When Applied (e.g., Excellent, Good, Fair, or Poor)	Most Likely Condition After Treatment	Typical Cost Range	Most Representativ e Cost
Routine Maintenance	None				
Preventive Maintenance	None				
Minor Rehabilitation (Reactive Maintenance)	Patching/ Minor Repairs	Fair to Poor	Satisfactory to Fair	$20 - $55/ SF of repair area	$30/ SF of repair area
	Debris Removal	All	Same, but prevents debris from causing more problems	Not applied directly to the culvert	Not applied directly to the culvert
	Scour Repair	Fair to Poor	Good to Satisfactory	$1000 - $10,000	Depends on extent of project
Major Rehabilitation	Wingwall/Headwall Rehab	Poor	Satisfactory to Fair	Infrequent Reactive Maint	Infrequent Reactive Maint
	Extend	Good to Fair	Good to Fair	Variable	$200,000
Reconstruction	Reconstruction	Poor	Good	Variable	$250,000

For each condition level, what percent of the time do you end up taking no action at all in a year and just allowing the culvert to deteriorate some more?

- Good _100__%
- Fair _90__%
- Poor _55__%

LIFE-CYCLE COST CONSIDERATION WORKSHEET - HYDRAULICS

To simplify the lifecycle cost analysis, assume the following condition categories from the HydInfra ratings:

- Excellent (like new) condition: 1
- Fair condition: 2
- Poor condition: 3
- Very poor condition: 4

Deterioration Rates

Culverts

- Suppose 100 culverts are currently in Excellent condition. After how many years will 50 of them have deteriorated to Fair or worse condition, if no preservation action has been taken?
  - For Concrete Pipe: _____23________
  - For Metal Pipe: _______13_________
- Suppose 100 culverts are currently in Fair condition. After how many years will 50 of them have deteriorated to Poor or worse condition, if no preservation action has been taken?
  - For Concrete Pipe: _____33________
  - For Metal Pipe: ________16________
- Suppose 100 culverts are currently in Poor condition. After how many years will 50 of them have deteriorated to Very Poor condition, if no preservation action has been taken?
  - For Concrete Pipe: _____15________
  - For Metal Pipe: ________8________

Stormwater Tunnels

(Metro District has 7 stormwater tunnel systems that have been divided up into 50 segments. These tunnels were built between the early 1960's and late 1970's. The degradation of each tunnel is specific to the tunnel system. For example, the I-35W south tunnel is under a significant amount of pressure and it can go from good to fair to poor at a much higher rate than the other tunnels.)

Currently 32% of the 50 tunnel segments are rated fair, 42% are rated poor, and 26% are rated very poor.

Inspection Costs

What is the estimated average annual cost to collect and process culvert and tunnel condition data so it can be used for reporting performance?

Average annual collection costs for culverts: <u>7900 hours x $75/hr. (includes hourly rate $30 + 1.5 overhead rate) = $592,500 + $66,667 (consultant contract annualized over 3 years): Total $659,167 ($660K)</u>

Average annual processing costs for culverts: <u>880 hours (same as above) = $66,000</u>

Tunnel inspection costs (inspection and reports) are done via consultants. Typically $200,000 each year. The shared tunnels in the City of Minneapolis are on a 3-5 year inspection schedule.

Treatment Costs

Five categories of repair are listed in table H-1 and H-2 for culverts and tunnels, respectively. For each of the categories, identify representative treatments that fit within that category, the typical condition range when these treatments are applied (e.g., Good, Fair, or Poor) and the condition after the treatment has been constructed. Also provide the typical price range for the treatments in that category and a cost that your Work Group considers to be the most representative cost within the price range. Be sure to indicate the units used for your costs.

<u>Culverts</u>

Table H-1. Typical treatments and costs for culverts.

Treatment Category	Representative Treatments	Typical Condition Level When Applied (e.g., Excellent, Good, Fair, or Poor)	Most Likely Condition After Treatment	Typical Cost Range	Most Representative Cost
Routine Maintenance					
Preventive Maintenance					
Minor Rehabilitation		Poor or very poor	Fair		
	Reset ends				$2694.78 Each
	joint repair/Grout				$35.73/LF
	pave invert				$17.86/LF
Major Rehabilitation	Slipliner	Very poor	Excellent or Fair		$192.54
	CIPP				$142.62/LF
Replacement	Trench	Poor or very poor	Excellent		$71.91/LF + $28999.12/Ea
	Jack				$797.50/LF

Estimated repair costs based on 2010 Spreadsheet developed by Dave Solsrud/Dave Johnston of D8. Trench replacement cost includes the cost of the pavement replacement – will be much less expensive if done as part of a pavement project. Unit repair costs include the 10% contingency that was added in the spreadsheet estimation.

For each condition level, what percent of the time do you end up taking no action at all in a year and just allowing the culvert to deteriorate some more?

- Excellent __100___%
- Fair ___98_____%
- Poor ___95_____%
- Very poor __88_____%

Stormwater Tunnels

Table H-2. Typical treatments and costs for stormwater tunnels.

Treatment Category	Representative Treatments	Typical Age or Condition Level When Applied (e.g., Excellent, Good, Fair, or Poor)	Most Likely Condition After Treatment	Typical Cost Range	Most Representative Cost
Routine Maintenance	Remove sediment and debris	Not routinely done, only done when would cause plugging	Fair		
Preventive Maintenance	Seal cracks and infiltration points	Urgent	Fair		
Maintenance	Flush and grout voids, fill cracks	Urgent/poor	Good	Contractors can do $3.5 M per season	About $25M in needs that are known now
Major Maintenance	Repair broken crown/broken liner	Urgent/poor	Good		About $500,000 in needs that are known now
Replacement or Added Capacity	Replacement or Added Capacity	Never done this yet	Excellent		About $200M in needs that are known now

For each condition level, what percent of the time do you end up taking no action at all in a year and just allowing the tunnel to deteriorate some more?

- Excellent __100____%
- Fair ___100_____%
- Poor _99___%
- Very Poor ______%

Overall Health Index

Please answer the following question to tell us the relative value you would place on each condition level, considering the effect on routine maintenance needs and on the quality of service given to the public, including risk. If Excellent condition is worth 100 points and Failed condition is worth zero points, how much should the other levels be worth?

- Fair condition _____99______ points.
- Poor condition _____40______ points.
- Very Poor condition _____20______ points.

Deterioration Rates

Tracked condition summaries and available research used to make assumptions on structure deterioration. See table below.

Summary of Current Condition

Overall Condition Rating	Description	SRF - Number of structures per rating	Structures that have Maintenance work done and/or planned construction work will move from 2,3,4,5 to 6	**7-2-13** Structures per condition rating	% of total	Structures with loose anchorages/nuts from condition ratings 2, 3, 4*	total after fixing nuts & moving to satisfactory	% of total after fixing nuts	Combined %	Proposed Performance Measure
2	Critical	143	**26**	117	6%	85	32	2.3%		
3	Serious	257	**53**	204	11%	92	112	7.9%	10.2%	10% or less
4	Poor	423	**81**	342	18%	237	105	7.4%	17.6%	20% or less
5	Fair	357	**70**	287	15%	0	287	20.3%		
6	Satisfactory	200	*49*	**430**	23%	0	**844**	59.6%		
7	Good	32	*2*	32	2%	0	32	2.3%		
8	Very Good	3	0	3	0%	0	3	0.2%		
			281	1415		414	1415			
			230 moved to 6							

CO Active Structures	1857	663	414
Retired per Metro	4		0.624434389
Not inspected	**438**		
Condition Total	1415		

For structures not inspected, the most reasonable assumption would be to go with the Good/Fair/Poor distribution observed for the structures inspected. This can be revised in the Asset Register

Poor	36%	62% (414) of these have loose anchorages/nuts
Fair	15%	
Good	25%	

Modified percentages after structures statewide have been included. All remaining 510 structures are reported to be in 100% good condition.

Based on inspected structures:

Poor	249	17.6%	77		326	13.8%
Fair	287	20.3%	89		376	15.9%
Good	879	62.1%	272	510	1661	70.3%
Totals	**1415**		**438**		2363	

]

Use the results of any of your inspections to record the types of repairs needed. Use table S-1 to record your results. If you have had more than 7 inspections, please add rows to the table. We will use the results to establish preliminary rates of deterioration.

Table S-1. Repairs required based on overhead sign structure inspections.

Inspection Cycle	Year	No. of Structures Inspected	No of Structures Requiring:					
			No Maintenance	Routine Maintenance	Preventive Maintenance	Minor Rehabilitation	Major Rehabilitation	Replacement
1	2006-07	718	159	504	NA	25	14	16
2	2010-11	856	591	231	NA	15	2	17
3	2012	86	0	0	NA	0	0	0
4								
5								
6								
7								

Inspection Costs

What is the estimated average annual cost to collect and process condition data on overhead sign structures and high mast light towers so it can be used for reporting performance?

- 2006-07 Metro consultant contract to inspect/report on 718 cantilevers $460,197; $640/structure
- 2010-11 Metro… " "… on 856 non-cantilever $1,007,967; $1170/structure
- 2012 District 6 worked 90 hours of inspection time including ultrasonic inspection of anchor rods on their cantilever signs. At an average rate of n$50.00/hour this works out to an approximate cost of $4500.00

Treatment Costs

Five categories of repair are listed in tables S-3 and S-4 for overhead sign structures and high mast light towers, respectively. For each of the categories, identify representative treatments that fit within that category, the typical condition range when these treatments are applied (e.g., Good, Fair, or Poor) and the condition after the treatment has been constructed. Also provide the typical price range for the treatments in that category and a cost that your Work Group considers to be the most representative cost within the price range. Be sure to indicate the units used for your costs.

We recognize that there are few preventive maintenance treatments that are applied to high mast tower light poles. Therefore, you may not have a response for each row in table S-4. As long as you provide us with information that tells us what types of repairs are needed, the typical age at which these repairs are made, and the average cost of the repairs, we will do our best to develop a life cycle treatment cycle for these structures.

Table S-3. Typical treatments and costs for overhead sign structures.

Treatment Category	Representative Treatments	Typical Age or Condition Level When Applied (e.g., Excellent, Good, Fair, or Poor)	Most Likely Condition After Treatment	Typical Cost Range	Most Representative Cost
Routine Maintenance (such as tightening bolts)	-Tighten base nuts -Remove Grout	Poor Poor	Fair Poor		(1) (2)
Preventive Maintenance (such as adding nuts/bolts to strengthen the structure and preserve life)	NA	NA	NA	NA	NA
Minor Rehabilitation (such as replacement of one or more minor structural components)	Re-grade footing, replace weld, remove catwalks/lighting, new mounting post	Poor	Fair - Good	$1700 - $6000	$3000
Major Rehabilitation (such as replacement of significant portions of the structure)	Replace foundation or replace truss or other elements	Poor	Good	$8,000-$30,000	$25,000
Replacement (including complete removal and replacement of the structure)	Replacement	40 years	New	$10,000-$110,000	(3)

(1) Our crews tightened nuts on 300 overhead structures: 1015 hours @ $50/person = $50,750 and $6800 Equipment Cost = $57550/300 = $200/structure* and $40,000 for wrench. * Does not include traffic control costs

(2) Mendota removed 15 signs with grout in their area; 276 hours @ $50/person = $14,000 and $1400 equipment cost = $15,400/15 signs = $1000/sign*. *Does not include traffic control costs.

(3) Metro assumes a scoping replacement cost of $10K for bridge mounts, $60K for scoping of cantilever replacement, and $110K for scoping of sign bridges. Contracts (does not include mobilization or traffic control: usually assumed to be 20% of total project cost):

  (4) 2009 – Minor Rehab = $6,000 (1 structure); Major rehab $8000 (1 structure)
  2010 – Minor Rehab = $1,700 (1); Major rehab $300,000 (13) $30K average
  2011 – Major $340,000 (14) $24K average
  2012 – Major $270,000 (18) $15K average

LIFE-CYCLE COST ANALYSES
MODELING EXAMPLES
(INPUTS AND RESULTS)

PAVEMENT MODEL*

INPUTS

*The Other Traffic Structures (Overhead Sign Structures and High-Mast Tower Lighting Structures) model included the same format spreadsheets.

INPUT WORKSHEET

1. Economic Variables

Value of Time for Passenger Cars ($/hour)	$2.00
Value of Time for Single Unit Trucks ($/hour)	$2.00
Value of Time for Combination Trucks ($/hour)	$2.00

2. Analysis Options

Include User Costs in Analysis	No
Include User Cost Remaining Life Value	Yes
Use Differential User Costs	Yes
User Cost Computation Method	Calculated
Include Agency Cost Remaining Life Value	Yes
Traffic Direction	Both
Analysis Period (Years)	50
Beginning of Analysis Period	2013
Discount Rate (%)	2.2
Number of Alternatives	5

3. Project Details

State Route	
Project Name	MnDOT LCCA: AC Pavements - Desired
Region	
County	
Analyzed By	
Mileposts	
Begin	
End	
Length of Project (miles)	0.00
Comments	

4. Traffic Data

AADT Construction Year (total for both directions)	2,000
Cars as Percentage of AADT (%)	96.0
Single Unit Trucks as Percentage of AADT (%)	2.0
Combination Trucks as Percentage of AADT (%)	2.0
Annual Growth Rate of Traffic (%)	2.0
Speed Limit Under Normal Operating Conditions (mph)	55
No of Lanes in Each Direction During Normal Conditions	1
Free Flow Capacity (vphpl)	2157
Rural or Urban Hourly Traffic Distribution	Rural
Queue Dissipation Capacity (vphpl)	200
Maximum AADT (total for both directions)	2,577
Maximum Queue Length (miles)	1.0

5. Construction

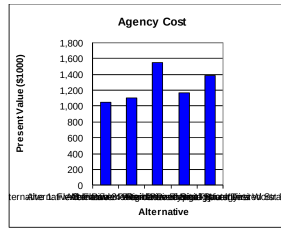
	Alternative 1	Alternative 2	Alternative 3
Alternative	Flexible Pavements - Desired Srategy	Flexible Pavements - Typical Strategy	Flexible Pavement - Worst First
Number of Activities	10	11	3
Activity 1	Initial Construction	Initial Construction	Initial Construction
Agency Construction Cost ($1000)	#NAME?	#NAME?	#NAME?
User Work Zone Costs ($1000)			
Work Zone Duration (days)	5	5	5
No of Lanes Open in Each Direction During Work Zone	1	1	1
Activity Service Life (years)	#NAME?	#NAME?	#NAME?
Activity Structural Life (years)	20.0	15.0	20.0
Maintenance Frequency (years)	3	3	3
Agency Maintenance Cost ($1000)	2.38	2.38	2.38
Work Zone Length (miles)	1.00	1.00	1.00
Work Zone Speed Limit (mph)	55	55	55
Work Zone Capacity (vphpl)	200	200	200
Traffic Hourly Distribution	Week Day 1	Week Day 1	Week Day 1
Time of Day of Lane Closures (use whole numbers based on a 24-hour clock)			
Inbound	Start / End	Start / End	Start / End
First period of lane closure			
Second period of lane closure			
Third period of lane closure			
Outbound	Start / End	Start / End	Start / End
First period of lane closure			
Second period of lane closure			
Third period of lane closure			
Activity 2	Crack Treatment	Crack Treatment	Reconstruction - 1
Agency Construction Cost ($1000)	#NAME?	#NAME?	#NAME?
User Work Zone Costs ($1000)			
Work Zone Duration (days)	5	5	5
No of Lanes Open in Each Direction During Work Zone	1	1	1
Activity Service Life (years)	#NAME?	#NAME?	#NAME?
Activity Structural Life (years)	0.0	0.0	20.0
Maintenance Frequency (years)	3	3	3
Agency Maintenance Cost ($1000)	2.38	2.38	2.38
Work Zone Length (miles)	1.00	1.00	1.00
Work Zone Speed Limit (mph)	55	55	55
Work Zone Capacity (vphpl)	200	200	200
Traffic Hourly Distribution	Week Day 1	Week Day 1	Week Day 1
Time of Day of Lane Closures (use whole numbers based on a 24-hour clock)			
Inbound	Start / End	Start / End	Start / End
First period of lane closure			
Second period of lane closure			
Third period of lane closure			
Outbound	Start / End	Start / End	Start / End
First period of lane closure			
Second period of lane closure			
Third period of lane closure			
Activity 3	Surface Treatment	Surface Treatment	Reconstruction - 2
Agency Construction Cost ($1000)	#NAME?	#NAME?	#NAME?
User Work Zone Costs ($1000)			
Work Zone Duration (days)	5	5	5
No of Lanes Open in Each Direction During Work Zone	1	1	1
Activity Service Life (years)	#NAME?	#NAME?	#NAME?
Activity Structural Life (years)	8.0	9.0	20.0
Maintenance Frequency (years)	3	3	3
Agency Maintenance Cost ($1000)	2.38	2.38	2.38
Work Zone Length (miles)	1.00	1.00	1.00
Work Zone Speed Limit (mph)	55	55	55
Work Zone Capacity (vphpl)	200	200	200
Traffic Hourly Distribution	Week Day 1	Week Day 1	Week Day 1
Time of Day of Lane Closures (use whole numbers based on a 24-hour clock)			
Inbound	Start / End	Start / End	Start / End
First period of lane closure			
Second period of lane closure			
Third period of lane closure			
Outbound	Start / End	Start / End	Start / End
First period of lane closure			
Second period of lane closure			
Third period of lane closure			

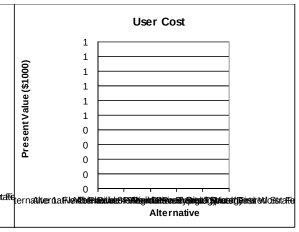
DETERMINISTIC RESULTS

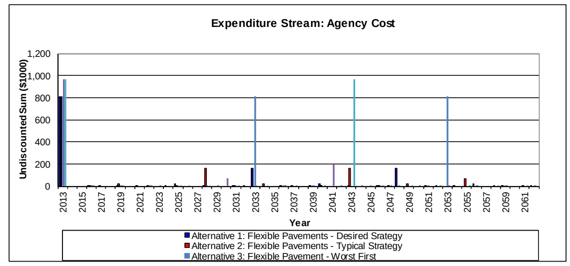
Total Cost										
	Alternative 1: Flexible Pavements - Desired Srategy		**Alternative 2: Flexible Pavements - Typical Strategy**		**Alternative 3: Flexible Pavement - Worst First**		**Alternative 4: Rigid Pavements Typical/Desired Strategy**		**Alternative 5: Rigid Pavements Worst First**	
Total Cost	Agency Cost ($1000)	User Cost ($1000)	Agency Cost ($1000)	User Cost ($1000)	Agency Cost ($1000)	User Cost ($1000)	Agency Cost ($1000)	User Cost ($1000)	Agency Cost ($1000)	User Cost ($1000)
Undiscounted Sum	*$1,233.07*	*$0.00*	*$1,302.42*	*$0.00*	*$2,052.37*	*$0.00*	*$1,305.62*	*$0.00*	*$1,656.11*	*$0.00*
Present Value	**$1,046.58**	**$0.00**	**$1,099.92**	**$0.00**	**$1,552.06**	**$0.00**	**$1,163.60**	**$0.00**	**$1,388.59**	**$0.00**
EUAC	$34.72	$0.00	$36.49	$0.00	$51.49	$0.00	$38.60	$0.00	$46.07	$0.00

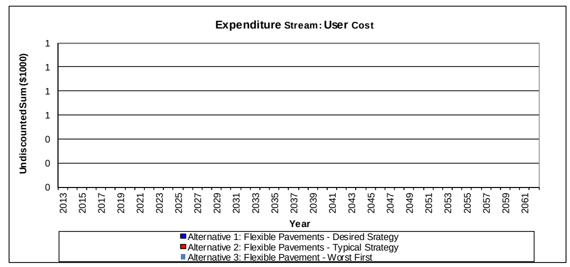
Lowest Present Value Agency Cost	**Alternative 1: Flexible Pavements - Desired Srategy**
Lowest Present Value User Cost	**Alternative 1: Flexible Pavements - Desired Srategy**

Expenditure Stream										
	ve 1: Flexible Pavements - Desire		**ve 2: Flexible Pavements - Typica**		**ative 3: Flexible Pavement - Wors**		**4: Rigid Pavements Typical/Desir**		**native 5: Rigid Pavements Worst**	
Year	Agency Cost ($1000)	User Cost ($1000)	Agency Cost ($1000)	User Cost ($1000)	Agency Cost ($1000)	User Cost ($1000)	Agency Cost ($1000)	User Cost ($1000)	Agency Cost ($1000)	User Cost ($1000)
2013	$806.67		$806.67		$806.67		$966.67		$966.67	
2014										
2015										
2016	$2.38		$2.38		$2.38		$2.38		$3.00	
2017			$6.33							
2018										
2019	$2.38		$18.33		$2.38		$2.38		$3.00	
2020										
2021	$6.33									
2022			$2.38		$2.38		$2.38		$3.00	
2023							$10.00			
2024	$2.38									
2025	$18.33		$2.38		$2.38				$3.00	
2026							$2.38			
2027										
2028	$2.38		$158.33		$2.38				$3.00	
2029							$2.38			
2030							$71.67			
2031	$2.38		$3.48		$2.38				$3.00	
2032			$6.33							
2033	$158.33				$806.67		$3.48			
2034			$18.33						$3.00	
2035										
2036	$6.33				$2.38		$3.48			
2037			$3.48						$3.00	
2038										
2039	$3.48				$2.38		$3.48			
2040	$18.33		$3.48						$3.00	
2041							$198.33			
2042					$2.38					
2043	$3.48		$158.33						$966.67	
2044							$5.23			
2045					$2.38					
2046	$3.48		$3.48						$3.00	
2047			$6.33				$5.23			
2048	$158.33				$2.38					
2049			$18.33						$3.00	
2050							$5.23			
2051	$6.33				$2.38					
2052			$5.23						$3.00	
2053					$806.67		$5.23			
2054	$5.23									
2055			$68.33						$3.00	
2056	$18.33				$2.38		$5.23			
2057										
2058			$5.23						$3.00	
2059	$5.23				$2.38		$5.23			
2060										
2061			$5.23						$3.00	
2062	$5.23				$2.38		$5.23			
2063	($2.29)				($403.33)				($322.22)	



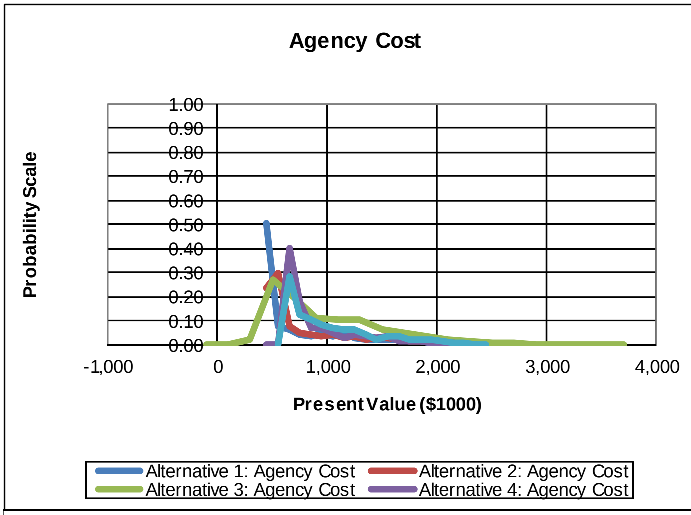


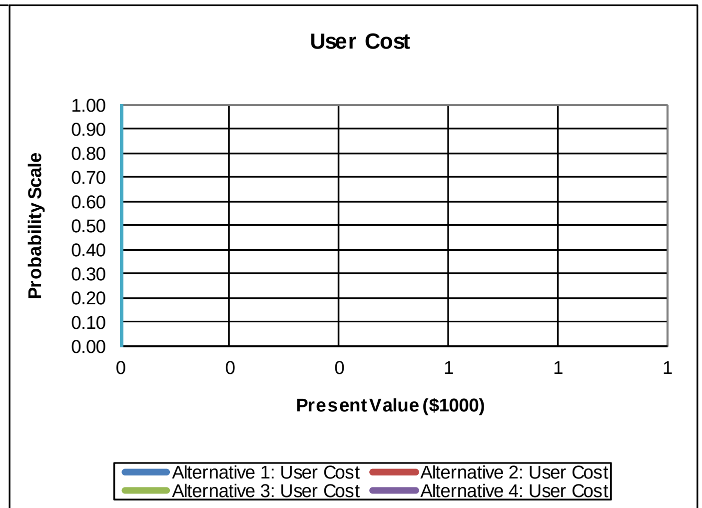


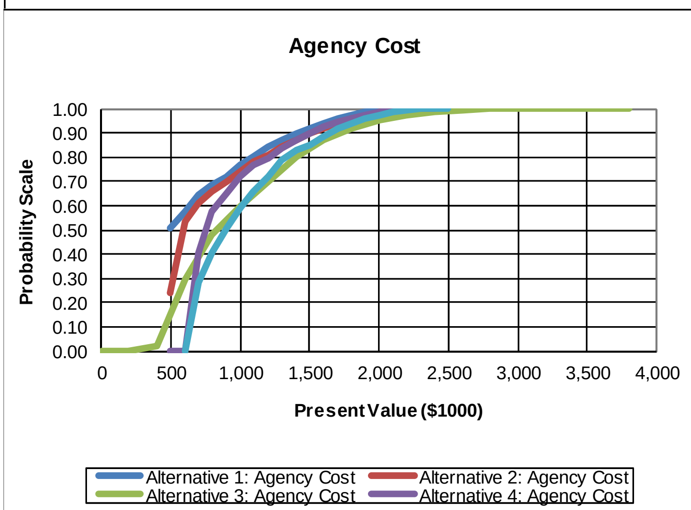


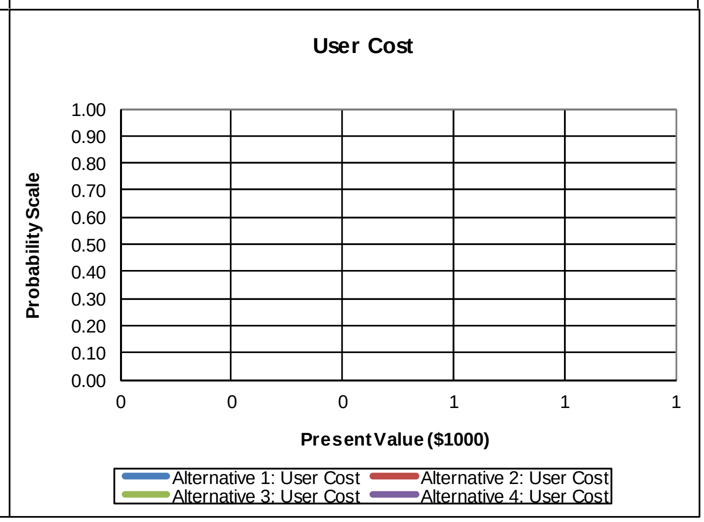
PROBABLISTIC RESULTS

Total Cost										
	Alternative 1: Flexible Pavements - Desired		Alternative 2: Flexible Pavements - Typical		Alternative 3: Flexible Pavement - Worst First		Alternative 4: Rigid Pavements		Alternative 5: Rigid Pavements Worst First	
Total Cost (Present Value)	Agency Cost ($1000)	User Cost ($1000)	Agency Cost ($1000)	User Cost ($1000)	Agency Cost ($1000)	User Cost ($1000)	Agency Cost ($1000)	User Cost ($1000)	Agency Cost ($1000)	User Cost ($1000)
Mean	$741.81	$0.00	$806.63	$0.00	$979.54	$0.00	$923.66	$0.00	$1,025.66	$0.00
Standard Deviation	$414.33	$0.00	$427.91	$0.00	$518.40	$0.00	$359.33	$0.00	$395.24	$0.00
Minimum	$408.66	$0.00	$455.56	$0.00	$371.45	$0.00	$611.75	$0.00	$612.54	$0.00
Maximum	$2,164.02	$0.00	$2,215.59	$0.00	$3,067.49	$0.00	$2,187.16	$0.00	$2,394.71	$0.00







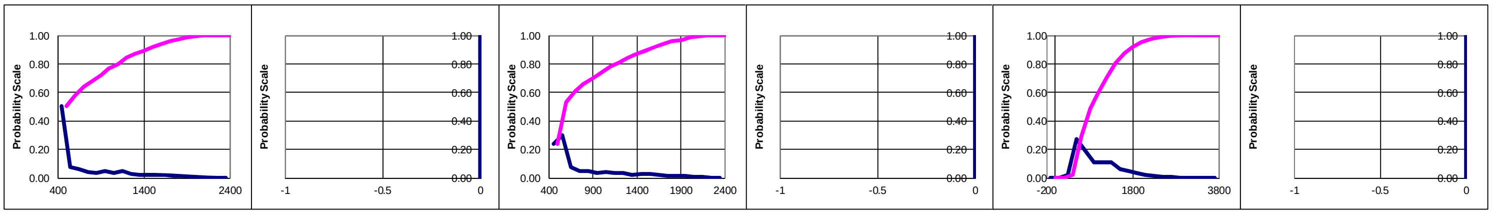


OUTPUT DISTRIBUTIONS

Alternative 1: Agency Cost				Alternative 1: User Cost			
Bin	Mid Point	Rel. Freq.	Cum. Rel. Freq.	Bin	Mid Point	Rel. Freq.	Cum. Rel. Freq.
500	450	0.50	0.50	0	0	1.00	1.00
600	550	0.07	0.58	0	0	0.00	1.00
700	650	0.06	0.64	0	0	0.00	1.00
800	750	0.04	0.68	0	0	0.00	1.00
900	850	0.04	0.72	0	0	0.00	1.00
1000	950	0.05	0.77	0	0	0.00	1.00
1100	1050	0.03	0.80	0	0	0.00	1.00
1200	1150	0.05	0.84	0	0	0.00	1.00
1300	1250	0.03	0.87	0	0	0.00	1.00
1400	1350	0.02	0.89	0	0	0.00	1.00
1500	1450	0.02	0.92	0	0	0.00	1.00
1600	1550	0.02	0.94	0	0	0.00	1.00
1700	1650	0.02	0.96	0	0	0.00	1.00
1800	1750	0.01	0.97	0	0	0.00	1.00
1900	1850	0.01	0.98	0	0	0.00	1.00
2000	1950	0.01	0.99	0	0	0.00	1.00
2100	2050	0.01	1.00	0	0	0.00	1.00
2200	2150	0.00	1.00	0	0	0.00	1.00
2300	2250	0.00	1.00	0	0	0.00	1.00
2400	2350	0.00	1.00	0	0	0.00	1.00

Alternative 2: Agency Cost				Alternative 2: User Cost			
Bin	Mid Point	Rel. Freq.	Cum. Rel. Freq.	Bin	Mid Point	Rel. Freq.	Cum. Rel. Freq.
500	450	0.24	0.24	0	0	1.00	1.00
600	550	0.30	0.53	0	0	0.00	1.00
700	650	0.07	0.61	0	0	0.00	1.00
800	750	0.05	0.66	0	0	0.00	1.00
900	850	0.04	0.70	0	0	0.00	1.00
1000	950	0.04	0.74	0	0	0.00	1.00
1100	1050	0.04	0.78	0	0	0.00	1.00
1200	1150	0.03	0.81	0	0	0.00	1.00
1300	1250	0.03	0.85	0	0	0.00	1.00
1400	1350	0.02	0.87	0	0	0.00	1.00
1500	1450	0.03	0.89	0	0	0.00	1.00
1600	1550	0.03	0.92	0	0	0.00	1.00
1700	1650	0.02	0.94	0	0	0.00	1.00
1800	1750	0.02	0.96	0	0	0.00	1.00
1900	1850	0.01	0.97	0	0	0.00	1.00
2000	1950	0.02	0.98	0	0	0.00	1.00
2100	2050	0.01	0.99	0	0	0.00	1.00
2200	2150	0.01	1.00	0	0	0.00	1.00
2300	2250	0.00	1.00	0	0	0.00	1.00
2400	2350	0.00	1.00	0	0	0.00	1.00

Alternative 3: Agency Cost				Alternative 3: User Cost			
Bin	Mid Point	Rel. Freq.	Cum. Rel. Freq.	Bin	Mid Point	Rel. Freq.	Cum. Rel. Freq.
0	-100	0.00	0.00	0	0	1.00	1.00
200	100	0.00	0.00	0	0	0.00	1.00
400	300	0.02	0.02	0	0	0.00	1.00
600	500	0.27	0.29	0	0	0.00	1.00
800	700	0.19	0.48	0	0	0.00	1.00
1000	900	0.11	0.59	0	0	0.00	1.00
1200	1100	0.11	0.70	0	0	0.00	1.00
1400	1300	0.11	0.80	0	0	0.00	1.00
1600	1500	0.06	0.87	0	0	0.00	1.00
1800	1700	0.05	0.92	0	0	0.00	1.00
2000	1900	0.04	0.95	0	0	0.00	1.00
2200	2100	0.02	0.97	0	0	0.00	1.00
2400	2300	0.01	0.99	0	0	0.00	1.00
2600	2500	0.01	0.99	0	0	0.00	1.00
2800	2700	0.00	1.00	0	0	0.00	1.00
3000	2900	0.00	1.00	0	0	0.00	1.00
3200	3100	0.00	1.00	0	0	0.00	1.00
3400	3300	0.00	1.00	0	0	0.00	1.00
3600	3500	0.00	1.00	0	0	0.00	1.00
3800	3700	0.00	1.00	0	0	0.00	1.00



EXTREME TAIL ANALAYSIS

Input Variable		Alternative 1: Agency Cost				Alternative 1: User Cost			
Name	Probability Function	5%	10%	90%	95%	5%	10%	90%	95%
Alternative 1: Activity 1: Agency (	LCCATRIANG(210,210,2000)	-0.01	-0.01	2.89	3.31	-0.01	-0.01	2.89	3.31
Alternative 2: Activity 1: Agency (	LCCATRIANG(210,210,2000)	0.17	0.07	0.08	0.07	0.17	0.07	0.08	0.07
Alternative 3: Activity 1: Agency (	LCCATRIANG(210,210,2000)	0.09	0.01	0.20	0.37	0.09	0.01	0.20	0.37
Alternative 4: Activity 1: Agency (	LCCATRIANG(450,450,2000)	0.00	0.00	0.01	0.25	0.00	0.00	0.01	0.25
Alternative 5: Activity 1: Agency (	LCCATRIANG(450,450,2000)	-0.01	0.18	0.01	-0.01	-0.01	0.18	0.01	-0.01
Alternative 1: Activity 1: Service L	LCCATRIANG(6,8,10)	1.08	0.82	0.07	0.13	1.08	0.82	0.07	0.13
Alternative 2: Activity 1: Service L	LCCATRIANG(3,4,5)	-0.12	-0.09	-0.16	-0.16	-0.12	-0.09	-0.16	-0.16
Alternative 3: Activity 1: Service L	LCCATRIANG(15,20,25)	-0.05	-0.09	-0.21	-0.13	-0.05	-0.09	-0.21	-0.13
Alternative 4: Activity 1: Service L	LCCATRIANG(8,10,12)	-0.08	-0.06	0.02	0.15	-0.08	-0.06	0.02	0.15
Alternative 5: Activity 1: Service L	LCCATRIANG(25,30,35)	0.04	-0.04	0.09	0.00	0.04	-0.04	0.09	0.00
Alternative 1: Activity 2: Agency (	LCCATRIANG(3,6,10)	-0.04	-0.12	0.00	-0.04	-0.04	-0.12	0.00	-0.04
Alternative 2: Activity 2: Agency (	LCCATRIANG(3,6,10)	-0.20	-0.08	0.11	0.11	-0.20	-0.08	0.11	0.11
Alternative 3: Activity 2: Agency (	LCCATRIANG(210,210,2000)	0.00	0.00	0.00	0.18	0.00	0.00	0.00	0.18
Alternative 4: Activity 2: Agency (	LCCATRIANG(5,10,15)	0.05	0.12	0.10	-0.04	0.05	0.12	0.10	-0.04
Alternative 5: Activity 2: Agency (	LCCATRIANG(450,450,2000)	-0.06	-0.06	0.14	0.13	-0.06	-0.06	0.14	0.13
Alternative 1: Activity 2: Service L	LCCATRIANG(3,4,5)	0.44	0.39	-0.01	-0.17	0.44	0.39	-0.01	-0.17
Alternative 2: Activity 2: Service L	LCCATRIANG(1,2,3)	-0.11	0.00	0.07	-0.08	-0.11	0.00	0.07	-0.08
Alternative 3: Activity 2: Service L	LCCATRIANG(15,20,25)	-0.07	0.08	-0.02	-0.02	-0.07	0.08	-0.02	-0.02
Alternative 4: Activity 2: Service L	LCCATRIANG(6,6,8)	0.57	0.14	0.03	0.02	0.57	0.14	0.03	0.02
Alternative 5: Activity 2: Service L	LCCATRIANG(25,30,35)	0.30	0.08	-0.28	-0.46	0.30	0.08	-0.28	-0.46

SIMULATION OUTPUT

Statistics	LCCAOutput: Alternative 1: Agency Cost	LCCAOutput: Alternative 1: User Cost	LCCAOutput :Alternative 2: Agency Cost	LCCAOutput :Alternative 2: User Cost	LCCAOutput :Alternative 3: Agency Cost	LCCAOutpu t:Alternative 3: User Cost
Probability Function						
Minimum	$408.66	$0.00	$455.56	$0.00	$371.45	$0.00
Maximum	$2,164.02	$0.00	$2,215.59	$0.00	$3,067.49	$0.00
Mean	$741.81	$0.00	$806.63	$0.00	$979.54	$0.00
Median	$495.19	$0.00	$557.84	$0.00	$842.96	$0.00
Standard Deviation	$414.33	$0.00	$427.91	$0.00	$518.40	$0.00
Percentile (5%)	$425.12	$0.00	$482.63	$0.00	$412.15	$0.00
Percentile (10%)	$431.22	$0.00	$488.23	$0.00	$428.70	$0.00
Percentile (90%)	$1,412.54	$0.00	$1,521.90	$0.00	$1,733.18	$0.00
Percentile (95%)	$1,647.93	$0.00	$1,734.60	$0.00	$1,980.51	$0.00
Iteration 1	$608.58	$0.00	$2,215.59	$0.00	$662.11	$0.00
2	$1,327.23	$0.00	$877.60	$0.00	$540.96	$0.00
3	$924.45	$0.00	$590.15	$0.00	$1,012.94	$0.00
4	$413.46	$0.00	$720.77	$0.00	$816.52	$0.00
5	$476.86	$0.00	$1,783.80	$0.00	$703.60	$0.00
6	$1,147.69	$0.00	$487.28	$0.00	$1,662.16	$0.00
7	$451.26	$0.00	$562.08	$0.00	$1,485.15	$0.00
8	$1,789.60	$0.00	$1,542.13	$0.00	$812.27	$0.00
9	$797.38	$0.00	$475.61	$0.00	$595.76	$0.00
10	$1,540.23	$0.00	$560.27	$0.00	$632.49	$0.00

PAVEMENT LCCA RESULTS

Deterministic Analysis			
	FDR/Reconstruct	Mill OL	Worst-First
Undiscounted Sum	$766,261	$984,441	$1,988,023
Net Present Value (NPV)	$386,180	$409,698	$976,317
Equivalent Uniform Annual Cost (EUAC)	$10,864	$11,526	$27,466
% of initial cost	111%	142%	287%
Probabilistic Analysis			
Mean Net Present value (NPV)	$375,668	$392,754	$635,313
Standard Deviation	$34,609	$33,862	$314,516

Note: All costs in $/lane-mi

Initial costs not included in analysis

BRIDGE MODEL*

BRIDGE DECK INPUTS

Life cycle cost inputs - Bridge decks

General	Good	Satis	Fair	Poor	Total			
Number of bridges	1029	283	74	15	1401	Deck area	26.203	million sq.ft
Health index weight	100	80	50	0		Joint quantity	535398	LF
Discount rate	2.2%					Rail quantity	1118213	LF

MnDOT Modified

Comments:
1. Modified Bridge Counts, Deck Area, Joint Qty and Rail Qty based on Thomas' email from 8/14
2. Added Crack Sealing to Routine Maintenance
3. Added Gland Repair/Replace to Corrective Action
4. Added Redeck to Rehab/Replacement
5. Modified percentages based on maintenance data and typical frequencies
6. Modified deck repair unit/bridge based on bridge maintenance supervisor input

Deterioration model - without preservation	Years	Good	Satis	Fair	Poor
Good	18	96.2%	3.8%	0.0%	0.0%
Satis	5		87.1%	12.9%	0.0%
Fair	5			87.1%	12.9%
Poor	--				100%

Deterioration model - with preservation	Years	Good	Satis	Fair	Poor
Good	22.5	97.0%	3.0%	0.0%	0.0%
Satis	7.5		91.2%	8.8%	0.0%
Fair	7.5			91.2%	8.8%
Poor	--				100%

Routine maintenance					% bridges acted upon in a year				Real ✓								
Treatment	Units	$/unit	Unit/br	$k/br	Good	Satis	Fair	Poor	$M/yr	Good	Satis	Fair	Poor	Totals			
Inspection	Bridge	1111	0	0.0	60%	60%	60%	60%	0.0	617.4	169.8	44.4	9	840.6	4500 state bridges over 10 ft (including culverts)		
Flushing	Bridge	500	0	0.0	75%	75%	75%	75%	0.0	771.75	212.25	55.5	11.25	1050.8	350.25	560.4	375.5
Joint sealing	LF	4	382	1.5	13%	13%	13%		0.3	128.63	35.375	9.25	0	173.25	175.13	12.50%	(8 year cycle)
Deck sealing	SF	2	18703	37.4	14%	14%	14%		7.3	144.06	39.62	10.36	0	194.04	200.34	14.30%	(7 year cycle
Crack Sealing	LF	3	500	1.5	20%	20%	20%		0.4	205.8	56.6	14.8	0	277.2	280.2	20%	(5 year cycle)
Annual cost per bridge - no preservation ($k)					0.0	0.0	0.0	0.0	0.0								
Annual cost per bridge - preservation scenario ($k)					5.7	5.7	5.7	0.0	7.9								

Corrective action					% bridges acted upon in a year				Real ✓	Percent improved											
Treatment	Units	$/unit	Unit/br	$k/br	Good	Satis	Fair	Poor	$M/yr	Effect	Good	Satis	Fair	Poor	Satis	Fair	Poor	Totals	From Maint	Total	0.3111
Joint repair (patch)	SF	100	382	38.2		1%	2%		0.2	0.3	0.0%	0.3%	0.6%	0.0%	2.83	1.48	0	4.31	11.75	3.525	
Gland Repair/Replace	LF	250	382			1%	5%		0.0	0.5	0.0%	0.5%	2.5%	0.0%	2.83	3.7	0	6.53		0	
Deck repair	SF	30	561	16.8		2%	35%	15%	0.6	0.5	0.0%	1.0%	17.5%	7.5%	5.66	25.9	2.25	33.81	130	39	0.0241
Overlay	Each	7	18703	130.9		0%	5%	2%	0.5	0.8	0.0%	0.0%	4.0%	1.6%	0	3.7	0.3	4	7	2.1	
Rail repair/replace	Bridge	160	798	127.7		1%	5%		0.8	0.2	0.0%	0.2%	1.0%	0.0%	2.83	3.7	0	6.53	22.5	6.75	
Total percent acted upon					0%	5%	52%	17%							14.15	38.48	2.55	55.18			
Annual cost per bridge ($k)					0.0	2.0	19.6	5.1	2.1		0.0%	2.0%	25.6%	9.1%							
Approximate interval (years)									25.4												

Rehab/replacement					% bridges acted upon in a year				Real ✓	Resulting condition			
Treatment	Units	$/unit	Unit/br	$k/br	Good	Satis	Fair	Poor	$M/yr	Good	Satis	Fair	Poor
Redeck	SF	60	18703	1122.2				5%	0.8	100%			
Replace Structure	SF	145	0	0.0				20%	0.0	100%			
Total percent acted upon					0%	0%	0%	25%					
Annual cost per bridge ($k)					0.0	0.0	0.0	56.1	0.8	100.0%	0.0%		
								42%		0.0222			
										0.0107			

*The Hydraulic Infrastructure (highway culverts and deep stormwater tunnels) model included the same format spreadsheets.

Life cycle cost inputs - Bridge superstructures

General	Good	Satis	Fair	Poor	Total			
Number of bridges	1047	272	65	17	1401	Deck area	26.116	million sq.ft
Health index weight	100	80	50	0		Bearing count	37,266	
Discount rate	2.2%							

MnDOT Modified

Comments:
1. Modified Bridge Counts, Deck Area, Joint Qty and Rail Qty based on Thomas' email from 8/14
2. Added Full Painting to list of corrective action
3. Modified percentages based on maintenance data, contract data and typical frequencies
4. Modified Painting and Patching Unit/Br based on bridge maintenance supervisor input

Deterioration model - without preservation	Years	Good	Satis	Fair	Poor
Good	30	97.7%	2.3%	0.0%	0.0%
Satis	10		93.3%	6.7%	0.0%
Fair	10			93.3%	6.7%
Poor	--				100%

Deterioration model - with preservation	Years	Good	Satis	Fair	Poor
Good	45	98.5%	1.5%	0.0%	0.0%
Satis	15		95.5%	4.5%	0.0%
Fair	20			96.6%	3.4%
Poor	--				100%

Routine maintenance					% bridges acted upon in a year				Real ✓							
Treatment	Units	$/unit	Unit/br	$k/br	Good	Satis	Fair	Poor	$M/yr	Good	Satisfactory	Fair	Poor	Totals		
Inspection	Bridge	1111	1	1.1	60%	60%	60%	60%	0.9	628.2	163.2	39	10.2	840.6	602-752	
Flushing	Bridge	500	1	0.5	75%	75%	75%	75%	0.5	785.25	204	48.75	12.75	1050.8		
Lube bearings	Each	1000	27	26.6	0%	0%	0%		0.0	1.047	0.544	0	0	1.591	6	1.8
Annual cost per bridge - no preservation ($k)					0.7	0.7	0.7	0.7	0.9							2%
Annual cost per bridge - preservation scenario ($k)					1.1	1.1	1.0	1.0	1.5							

Corrective action					% bridges acted upon in a year				Real ✓	Percent improved											
Treatment	Units	$/unit	Unit/br	$k/br	Good	Satis	Fair	Poor	$M/yr	Effect	Good	Satis	Fair	Poor	Good	Satis	Fair	Poor	Totals	From Maint Data	
Spot Painting	SF	13	1500	19.5		2%	5%		0.2	0.7	0.0%	1.4%	3.5%	0.0%	0	5.44	3.25	0	8.69	33	9.9
Full Painting	SF	14	27961	377.5		3%	5%		4.3	1	0.0%	3.0%	5.0%	0.0%	0	8.16	3.25	0	11.41	13	
Patching	SF	100	300	30.0		1%	3%	5%	0.2	0.5	0.0%	0.5%	1.5%	2.5%	0	2.72	1.95	0.85	5.52	16	4.8
Repair/repl bearings	Each	1750	27	46.5				5%	0.0	0.6	0.0%	0.0%	0.0%	3.0%	0	0	0	0.85	0.85	3	0.9
Repair steel	Bridge	50000	1	50.0			2%	5%	0.1	0.3	0.0%	0.0%	0.6%	1.5%	0	0	1.3	0.85	2.15	7	2.1
Total percent acted upon					0%	6%	15%	15%							0	16.32	9.75	2.55	28.62		
Annual cost per bridge ($k)					0.0	12.0	21.7	6.3	4.8		0.0%	4.9%	10.6%	7.0%					0.0204		
Approximate interval (years)									49.0												

Rehab/replacement					% bridges acted upon in a year				Real ✓	Resulting condition				
Treatment	Units	$/unit	Unit/br	$k/br	Good	Satis	Fair	Poor	$M/yr	Good	Satis	Fair	Poor	Poor
Replace elements	Bridge	100000	1	100.0				1%	0.0	90%	10%			0.085
Replace structure	SF	145	18641	2702.9				20%	9.2	100%				3.4
Total percent acted upon					0%	0%	0%	21%						
Annual cost per bridge ($k)					0.0	0.0	0.0	541.1	9.2	99.8%	0.2%			
								36%						

Life cycle cost inputs - Bridge substructures

General	Good	Satis	Fair	Poor	Total		
Number of bridges	1061	271	62	9	1403	Deck area 26.222	million sq.ft
Health index weight	100	80	50	0			
Discount rate	2.2%						

MnDOT Modified

Comments:
1. Modified Bridge Counts, Deck Area, Joint Qty and Rail Qty based on Thomas' email from 8/14
2. Modified action title "Scour repair" to "Erosion/scour repair". Modified cost because there may be smaller projects involved.
3. Modified percentages based on maintenance data, contract data and typical frequencies
4. Modified patching and slope paving repair unit/br based on bridge

Deterioration model - without preservation	Years	Good	Satis	Fair	Poor
Good	30	97.7%	2.3%	0.0%	0.0%
Satis	10		93.3%	6.7%	0.0%
Fair	10			93.3%	6.7%
Poor	--				100%

Deterioration model - with preservation	Years	Good	Satis	Fair	Poor
Good	45	98.5%	1.5%	0.0%	0.0%
Satis	15		95.5%	4.5%	0.0%
Fair	20			96.6%	3.4%
Poor	--				100%

Routine maintenance					% bridges acted upon in a year				Real ✓
Treatment	Units	$/unit	Unit/br	$k/br	Good	Satis	Fair	Poor	$M/yr
Inspection	Bridge	1111	0	0.0	60%	60%	60%	60%	0.0
Flushing	Bridge	500	0	0.0	75%	75%	75%	75%	0.0
Not used	Each	0	1	0.0					0.0
Annual cost per bridge - no preservation ($k)					0.0	0.0	0.0	0.0	0.0
Annual cost per bridge - preservation scenario ($k)					0.0	0.0	0.0	0.0	0.0

Corrective action					% bridges acted upon in a year				Real ✓	Percent improved											
Treatment	Units	$/unit	Unit/br	$k/br	Good	Satis	Fair	Poor	$M/yr	Effect	Good	Satis	Fair	Poor	Good	Satis	Fair	Poor	Totals	From Maintenance Data	
Patching	SF	100	561	56.1			10%	15%	0.4	0.5	0.0%	0.0%	5.0%	7.5%	0	0	6.2	1.35	7.55	29	8.7
Slope paving repair	SF	20	1308	26.2		1%	1%		0.1	0.2	0.0%	0.1%	0.2%	0.0%	0	1.355	0.62	0	1.975	5	1.5
Erosion/Scour Repair	Each	25000	1	25.0			5%	5%	0.1	0.1	0.0%	0.0%	0.5%	0.5%	0	0	3.1	0.45	3.55	15	4.5
Not used	Each	0	1	0.0					0.0		0.0%	0.0%	0.0%	0.0%	0	0	0	0	0		
Total percent acted upon					0%	1%	16%	20%							0	1.355	9.92	1.8	13.075		
Annual cost per bridge ($k)					0.0	0.1	7.1	9.7	0.6		0.0%	0.1%	5.7%	8.0%							
Approximate interval (years)									107.3												

Rehab/replacement					% bridges acted upon in a year				Real ✓	Resulting condition				
Treatment	Units	$/unit	Unit/br	$k/br	Good	Satis	Fair	Poor	$M/yr	Good	Satis	Fair	Poor	Poor
Replace elements	Bridge	100000	1	100.0				1%	0.0	90%	10%			0.045
Replace structure	SF	145	0	0.0				20%	0.0	100%				1.8
Total percent acted upon					0%	0%	0%	21%						
Annual cost per bridge ($k)					0.0	0.0	0.0	0.5	0.0	99.8%	0.2%			
								41%						

BRIDGE DECK PROJECTIONS (20 OF 200 YEAR ANALYSIS)

Forecast condition and cost - Bridge decks

	Pure deterioration - no maint					Pure deterioration - routine maint					Worst-first scenario					($M)	Worst-first - typical bridge					Preservation scenario					($M)	Preservation - typical bridge				
Year	Good	Satis	Fair	Poor	Health	Good	Satis	Fair	Poor	Health	Good	Satis	Fair	Poor	Cost	PV$	Good	Satis	Fair	Poor	Health	Good	Satis	Fair	Poor	Cost	PV$	Good	Satis	Fair	Poor	Health
0	1.000	0.000	0.000	0.000	100.0	1.000	0.000	0.000	0.000	100.0	1.000	0.000	0.000	0.000	0.00	0.00	1.000	0.000	0.000	0.000	100.0	1.000	0.000	0.000	0.000	8.02	8.02	1.000	0.000	0.000	0.000	100.0
1	0.962	0.038	0.000	0.000	99.24	0.970	0.030	0.000	0.000	99.39	0.962	0.038	0.000	0.000	0.00	0.00	0.962	0.038	0.000	0.000	99.24	0.970	0.030	0.000	0.000	8.11	7.94	0.970	0.030	0.000	0.000	99.39
2	0.926	0.069	0.005	0.000	98.37	0.940	0.057	0.003	0.000	98.72	0.926	0.069	0.005	0.000	0.00	0.00	0.926	0.069	0.005	0.000	98.37	0.941	0.057	0.003	0.000	8.25	7.90	0.940	0.057	0.003	0.000	98.72
3	0.891	0.095	0.013	0.001	97.37	0.912	0.081	0.007	0.000	97.99	0.891	0.095	0.013	0.001	0.05	0.05	0.891	0.095	0.013	0.001	97.37	0.913	0.080	0.007	0.000	8.44	7.91	0.912	0.081	0.007	0.000	97.99
4	0.857	0.117	0.024	0.002	96.24	0.884	0.101	0.014	0.001	97.19	0.857	0.117	0.024	0.002	0.17	0.16	0.857	0.117	0.024	0.002	96.24	0.887	0.101	0.011	0.001	8.66	7.94	0.884	0.101	0.014	0.001	97.19
5	0.825	0.134	0.036	0.005	94.99	0.857	0.119	0.022	0.002	96.33	0.826	0.134	0.036	0.005	0.37	0.33	0.825	0.134	0.036	0.005	94.99	0.863	0.120	0.017	0.001	8.90	7.98	0.857	0.119	0.022	0.002	96.33
6	0.794	0.148	0.049	0.010	93.61	0.831	0.135	0.030	0.004	95.40	0.796	0.148	0.049	0.008	0.64	0.56	0.794	0.148	0.049	0.010	93.61	0.839	0.137	0.022	0.002	9.15	8.03	0.831	0.135	0.030	0.004	95.40
7	0.764	0.159	0.061	0.016	92.13	0.806	0.148	0.039	0.007	94.40	0.768	0.159	0.061	0.012	0.98	0.84	0.764	0.159	0.061	0.016	92.13	0.817	0.154	0.027	0.003	9.39	8.07	0.806	0.148	0.039	0.007	94.40
8	0.735	0.167	0.074	0.024	90.54	0.782	0.159	0.049	0.010	93.35	0.742	0.167	0.074	0.017	1.36	1.14	0.735	0.167	0.074	0.024	90.54	0.796	0.169	0.032	0.003	9.64	8.10	0.782	0.159	0.049	0.010	93.35
9	0.707	0.173	0.086	0.034	88.85	0.758	0.169	0.059	0.015	92.23	0.718	0.173	0.086	0.023	1.77	1.46	0.707	0.173	0.086	0.034	88.85	0.776	0.183	0.036	0.004	9.88	8.12	0.758	0.169	0.059	0.015	92.23
10	0.680	0.177	0.097	0.045	87.09	0.735	0.177	0.068	0.020	91.07	0.696	0.178	0.097	0.028	2.20	1.77	0.680	0.177	0.097	0.045	87.09	0.757	0.197	0.041	0.005	10.11	8.13	0.735	0.177	0.068	0.020	91.07
11	0.655	0.180	0.108	0.058	85.26	0.713	0.184	0.078	0.026	89.85	0.677	0.181	0.108	0.034	2.64	2.08	0.655	0.180	0.108	0.058	85.26	0.739	0.209	0.045	0.006	10.33	8.13	0.713	0.184	0.078	0.026	89.85
12	0.630	0.182	0.117	0.072	83.37	0.691	0.189	0.087	0.033	88.59	0.660	0.184	0.117	0.039	3.08	2.37	0.630	0.182	0.117	0.072	83.37	0.723	0.221	0.049	0.007	10.54	8.12	0.691	0.189	0.087	0.033	88.59
13	0.606	0.182	0.125	0.087	81.43	0.670	0.193	0.096	0.040	87.28	0.645	0.185	0.126	0.045	3.50	2.64	0.606	0.182	0.125	0.087	81.43	0.707	0.232	0.053	0.008	10.75	8.10	0.670	0.193	0.096	0.040	87.28
14	0.583	0.181	0.133	0.103	79.45	0.650	0.197	0.105	0.049	85.94	0.632	0.185	0.134	0.050	3.91	2.88	0.583	0.181	0.133	0.103	79.45	0.692	0.242	0.057	0.009	10.94	8.07	0.650	0.197	0.105	0.049	85.94
15	0.561	0.180	0.139	0.120	77.45	0.630	0.199	0.113	0.058	84.56	0.620	0.185	0.140	0.055	4.29	3.10	0.561	0.180	0.139	0.120	77.45	0.678	0.252	0.060	0.009	11.12	8.02	0.630	0.199	0.113	0.058	84.56
16	0.540	0.178	0.144	0.138	75.43	0.611	0.200	0.121	0.068	83.15	0.610	0.185	0.146	0.059	4.64	3.28	0.540	0.178	0.144	0.138	75.43	0.665	0.261	0.064	0.010	11.29	7.97	0.611	0.200	0.121	0.068	83.15
17	0.520	0.175	0.149	0.157	73.40	0.592	0.201	0.128	0.079	81.72	0.602	0.184	0.151	0.063	4.97	3.43	0.520	0.175	0.149	0.157	73.40	0.653	0.270	0.067	0.011	11.46	7.91	0.592	0.201	0.128	0.079	81.72
18	0.500	0.172	0.152	0.176	71.36	0.574	0.202	0.134	0.090	80.26	0.595	0.183	0.155	0.067	5.26	3.56	0.500	0.172	0.152	0.176	71.36	0.641	0.278	0.070	0.012	11.61	7.85	0.574	0.202	0.134	0.090	80.26
19	0.481	0.169	0.155	0.196	69.33	0.557	0.201	0.140	0.102	78.79	0.589	0.181	0.159	0.070	5.53	3.66	0.481	0.169	0.155	0.196	69.33	0.630	0.286	0.072	0.012	11.76	7.77	0.557	0.201	0.140	0.102	78.79
20	0.463	0.165	0.156	0.216	67.32	0.540	0.200	0.145	0.114	77.30	0.585	0.180	0.162	0.073	5.76	3.73	0.463	0.165	0.156	0.216	67.32	0.620	0.293	0.075	0.013	11.89	7.70	0.540	0.200	0.145	0.114	77.30

BRIDGE SUPERSTRUCTURE PROJECTIONS (20 OF 200 YEAR ANALYSIS)

Forecast condition and cost - Bridge superstructures

	Pure deterioration - no maint					Pure deterioration - routine maint					Worst-first scenario					($M)	Worst-first - typical bridge					Preservation scenario					($M)	Preservation - typical bridge				
Year	Good	Satis	Fair	Poor	Health	Good	Satis	Fair	Poor	Health	Good	Satis	Fair	Poor	Cost	PV$	Good	Satis	Fair	Poor	Health	Good	Satis	Fair	Poor	Cost	PV$	Good	Satis	Fair	Poor	Health
0	1.000	0.000	0.000	0.000	100.0	1.000	0.000	0.000	0.000	100.0	1.000	0.000	0.000	0.000	0.93	0.93	1.000	0.000	0.000	0.000	100.0	1.000	0.000	0.000	0.000	1.50	1.50	1.000	0.000	0.000	0.000	100.0
1	0.977	0.023	0.000	0.000	99.54	0.985	0.015	0.000	0.000	99.69	0.977	0.023	0.000	0.000	0.93	0.91	0.977	0.023	0.000	0.000	99.54	0.985	0.015	0.000	0.000	1.75	1.72	0.985	0.015	0.000	0.000	99.69
2	0.955	0.044	0.002	0.000	99.05	0.970	0.030	0.001	0.000	99.37	0.955	0.044	0.002	0.000	0.93	0.89	0.955	0.044	0.002	0.000	99.05	0.970	0.029	0.001	0.000	2.00	1.92	0.970	0.030	0.001	0.000	99.37
3	0.933	0.063	0.004	0.000	98.52	0.955	0.043	0.002	0.000	99.03	0.933	0.063	0.004	0.000	1.01	0.95	0.933	0.063	0.004	0.000	98.52	0.957	0.041	0.002	0.000	2.26	2.12	0.955	0.043	0.002	0.000	99.03
4	0.912	0.080	0.008	0.000	97.96	0.940	0.056	0.004	0.000	98.68	0.912	0.080	0.008	0.000	1.22	1.12	0.912	0.080	0.008	0.000	97.96	0.944	0.052	0.003	0.000	2.53	2.32	0.940	0.056	0.004	0.000	98.68
5	0.891	0.095	0.013	0.001	97.35	0.926	0.068	0.006	0.000	98.31	0.891	0.095	0.013	0.001	1.58	1.41	0.891	0.095	0.013	0.001	97.35	0.933	0.062	0.005	0.000	2.82	2.53	0.926	0.068	0.006	0.000	98.31
6	0.871	0.109	0.019	0.002	96.71	0.912	0.079	0.009	0.000	97.93	0.871	0.109	0.019	0.002	2.11	1.85	0.871	0.109	0.019	0.002	96.71	0.921	0.071	0.007	0.000	3.12	2.74	0.912	0.079	0.009	0.000	97.93
7	0.851	0.122	0.025	0.003	96.03	0.898	0.089	0.012	0.001	97.53	0.851	0.122	0.025	0.002	2.81	2.41	0.851	0.122	0.025	0.003	96.03	0.911	0.080	0.009	0.000	3.43	2.95	0.898	0.089	0.012	0.001	97.53
8	0.831	0.133	0.031	0.005	95.32	0.884	0.099	0.016	0.001	97.11	0.832	0.133	0.031	0.004	3.67	3.08	0.831	0.133	0.031	0.005	95.32	0.901	0.087	0.011	0.001	3.76	3.16	0.884	0.099	0.016	0.001	97.11
9	0.812	0.143	0.038	0.007	94.56	0.871	0.108	0.020	0.002	96.68	0.814	0.143	0.038	0.005	4.69	3.85	0.812	0.143	0.038	0.007	94.56	0.891	0.094	0.014	0.001	4.09	3.36	0.871	0.108	0.020	0.002	96.68
10	0.794	0.152	0.045	0.009	93.78	0.857	0.116	0.024	0.002	96.23	0.796	0.152	0.045	0.006	5.84	4.70	0.794	0.152	0.045	0.009	93.78	0.883	0.101	0.016	0.001	4.42	3.56	0.857	0.116	0.024	0.002	96.23
11	0.776	0.160	0.052	0.012	92.96	0.844	0.124	0.029	0.003	95.77	0.780	0.160	0.052	0.008	7.12	5.60	0.776	0.160	0.052	0.012	92.96	0.874	0.106	0.018	0.001	4.75	3.74	0.844	0.124	0.029	0.003	95.77
12	0.758	0.167	0.059	0.016	92.11	0.831	0.131	0.033	0.004	95.30	0.763	0.167	0.059	0.010	8.50	6.55	0.758	0.167	0.059	0.016	92.11	0.866	0.112	0.020	0.001	5.08	3.92	0.831	0.131	0.033	0.004	95.30
13	0.741	0.173	0.067	0.020	91.23	0.819	0.138	0.038	0.005	94.81	0.748	0.173	0.067	0.012	9.96	7.51	0.741	0.173	0.067	0.020	91.23	0.859	0.117	0.022	0.002	5.41	4.08	0.819	0.138	0.038	0.005	94.81
14	0.724	0.178	0.074	0.024	90.32	0.806	0.144	0.043	0.007	94.31	0.733	0.179	0.074	0.014	11.49	8.47	0.724	0.178	0.074	0.024	90.32	0.852	0.122	0.024	0.002	5.73	4.23	0.806	0.144	0.043	0.007	94.31
15	0.707	0.183	0.081	0.029	89.39	0.794	0.150	0.048	0.008	93.79	0.720	0.184	0.081	0.016	13.07	9.43	0.707	0.183	0.081	0.029	89.39	0.845	0.126	0.027	0.002	6.05	4.36	0.794	0.150	0.048	0.008	93.79
16	0.691	0.187	0.088	0.035	88.42	0.782	0.156	0.053	0.010	93.26	0.706	0.188	0.088	0.018	14.68	10.37	0.691	0.187	0.088	0.035	88.42	0.839	0.130	0.028	0.002	6.35	4.48	0.782	0.156	0.053	0.010	93.26
17	0.675	0.190	0.094	0.040	87.44	0.770	0.161	0.058	0.012	92.72	0.694	0.191	0.094	0.020	16.32	11.27	0.675	0.190	0.094	0.040	87.44	0.833	0.134	0.030	0.003	6.65	4.59	0.770	0.161	0.058	0.012	92.72
18	0.660	0.193	0.101	0.047	86.43	0.758	0.165	0.064	0.013	92.17	0.682	0.194	0.101	0.022	17.95	12.14	0.660	0.193	0.101	0.047	86.43	0.827	0.138	0.032	0.003	6.93	4.68	0.758	0.165	0.064	0.013	92.17
19	0.645	0.195	0.107	0.054	85.41	0.746	0.169	0.069	0.016	91.61	0.671	0.197	0.107	0.025	19.59	12.95	0.645	0.195	0.107	0.054	85.41	0.822	0.141	0.034	0.003	7.20	4.76	0.746	0.169	0.069	0.016	91.61
20	0.630	0.197	0.113	0.061	84.37	0.735	0.173	0.074	0.018	91.03	0.661	0.199	0.113	0.027	21.20	13.72	0.630	0.197	0.113	0.061	84.37	0.817	0.144	0.036	0.003	7.47	4.83	0.735	0.173	0.074	0.018	91.03

BRIDGE SUBSTRUCTURE PROJECTIONS (20 OF 200 YEAR ANALYSIS)

Forecast condition and cost - Bridge substructures

	Pure deterioration - no maint					Pure deterioration - routine maint					Worst-first scenario					($M)	Worst-first - typical bridge					Preservation scenario					($M)	Preservation - typical bridge				
Year	Good	Satis	Fair	Poor	Health	Good	Satis	Fair	Poor	Health	Good	Satis	Fair	Poor	Cost	PV$	Good	Satis	Fair	Poor	Health	Good	Satis	Fair	Poor	Cost	PV$	Good	Satis	Fair	Poor	Health
0	1.000	0.000	0.000	0.000	100.0	1.000	0.000	0.000	0.000	100.0	1.000	0.000	0.000	0.000	0.00	0.00	1.000	0.000	0.000	0.000	100.0	1.000	0.000	0.000	0.000	0.00	0.00	1.000	0.000	0.000	0.000	100.0
1	0.977	0.023	0.000	0.000	99.54	0.985	0.015	0.000	0.000	99.69	0.977	0.023	0.000	0.000	0.00	0.00	0.977	0.023	0.000	0.000	99.54	0.985	0.015	0.000	0.000	0.00	0.00	0.985	0.015	0.000	0.000	99.69
2	0.955	0.044	0.002	0.000	99.05	0.970	0.030	0.001	0.000	99.37	0.955	0.044	0.002	0.000	0.00	0.00	0.955	0.044	0.002	0.000	99.05	0.970	0.030	0.001	0.000	0.01	0.01	0.970	0.030	0.001	0.000	99.37
3	0.933	0.063	0.004	0.000	98.52	0.955	0.043	0.002	0.000	99.03	0.933	0.063	0.004	0.000	0.00	0.00	0.933	0.063	0.004	0.000	98.52	0.955	0.043	0.002	0.000	0.03	0.03	0.955	0.043	0.002	0.000	99.03
4	0.912	0.080	0.008	0.000	97.96	0.940	0.056	0.004	0.000	98.68	0.912	0.080	0.008	0.000	0.00	0.00	0.912	0.080	0.008	0.000	97.96	0.940	0.056	0.004	0.000	0.05	0.04	0.940	0.056	0.004	0.000	98.68
5	0.891	0.095	0.013	0.001	97.35	0.926	0.068	0.006	0.000	98.31	0.891	0.095	0.013	0.001	0.00	0.00	0.891	0.095	0.013	0.001	97.35	0.926	0.068	0.006	0.000	0.07	0.07	0.926	0.068	0.006	0.000	98.31
6	0.871	0.109	0.019	0.002	96.71	0.912	0.079	0.009	0.000	97.93	0.871	0.109	0.019	0.002	0.00	0.00	0.871	0.109	0.019	0.002	96.71	0.912	0.079	0.008	0.000	0.10	0.09	0.912	0.079	0.009	0.000	97.93
7	0.851	0.122	0.025	0.003	96.03	0.898	0.089	0.012	0.001	97.53	0.851	0.122	0.025	0.002	0.00	0.00	0.851	0.122	0.025	0.003	96.03	0.898	0.090	0.011	0.000	0.14	0.12	0.898	0.089	0.012	0.001	97.53
8	0.831	0.133	0.031	0.005	95.32	0.884	0.099	0.016	0.001	97.11	0.832	0.133	0.031	0.004	0.00	0.00	0.831	0.133	0.031	0.005	95.32	0.885	0.100	0.014	0.001	0.17	0.15	0.884	0.099	0.016	0.001	97.11
9	0.812	0.143	0.038	0.007	94.56	0.871	0.108	0.020	0.002	96.68	0.814	0.143	0.038	0.005	0.00	0.00	0.812	0.143	0.038	0.007	94.56	0.871	0.110	0.018	0.001	0.21	0.17	0.871	0.108	0.020	0.002	96.68
10	0.794	0.152	0.045	0.009	93.78	0.857	0.116	0.024	0.002	96.23	0.796	0.152	0.045	0.006	0.00	0.00	0.794	0.152	0.045	0.009	93.78	0.858	0.119	0.021	0.001	0.25	0.20	0.857	0.116	0.024	0.002	96.23
11	0.776	0.160	0.052	0.012	92.96	0.844	0.124	0.029	0.003	95.77	0.780	0.160	0.052	0.008	0.01	0.00	0.776	0.160	0.052	0.012	92.96	0.846	0.128	0.025	0.002	0.29	0.23	0.844	0.124	0.029	0.003	95.77
12	0.758	0.167	0.059	0.016	92.11	0.831	0.131	0.033	0.004	95.30	0.763	0.167	0.059	0.010	0.01	0.01	0.758	0.167	0.059	0.016	92.11	0.833	0.136	0.028	0.002	0.34	0.26	0.831	0.131	0.033	0.004	95.30
13	0.741	0.173	0.067	0.020	91.23	0.819	0.138	0.038	0.005	94.81	0.748	0.173	0.067	0.012	0.01	0.01	0.741	0.173	0.067	0.020	91.23	0.821	0.145	0.032	0.002	0.38	0.29	0.819	0.138	0.038	0.005	94.81
14	0.724	0.178	0.074	0.024	90.32	0.806	0.144	0.043	0.007	94.31	0.733	0.179	0.074	0.014	0.01	0.01	0.724	0.178	0.074	0.024	90.32	0.809	0.152	0.036	0.003	0.43	0.31	0.806	0.144	0.043	0.007	94.31
15	0.707	0.183	0.081	0.029	89.39	0.794	0.150	0.048	0.008	93.79	0.720	0.184	0.081	0.016	0.01	0.01	0.707	0.183	0.081	0.029	89.39	0.797	0.160	0.040	0.003	0.47	0.34	0.794	0.150	0.048	0.008	93.79
16	0.691	0.187	0.088	0.035	88.42	0.782	0.156	0.053	0.010	93.26	0.706	0.188	0.088	0.018	0.01	0.01	0.691	0.187	0.088	0.035	88.42	0.786	0.167	0.044	0.003	0.52	0.37	0.782	0.156	0.053	0.010	93.26
17	0.675	0.190	0.094	0.040	87.44	0.770	0.161	0.058	0.012	92.72	0.694	0.191	0.094	0.020	0.01	0.01	0.675	0.190	0.094	0.040	87.44	0.775	0.174	0.048	0.004	0.56	0.39	0.770	0.161	0.058	0.012	92.72
18	0.660	0.193	0.101	0.047	86.43	0.758	0.165	0.064	0.013	92.17	0.682	0.194	0.101	0.022	0.02	0.01	0.660	0.193	0.101	0.047	86.43	0.764	0.180	0.052	0.004	0.61	0.41	0.758	0.165	0.064	0.013	92.17
19	0.645	0.195	0.107	0.054	85.41	0.746	0.169	0.069	0.016	91.61	0.671	0.197	0.107	0.025	0.02	0.01	0.645	0.195	0.107	0.054	85.41	0.753	0.186	0.055	0.005	0.66	0.43	0.746	0.169	0.069	0.016	91.61
20	0.630	0.197	0.113	0.061	84.37	0.735	0.173	0.074	0.018	91.03	0.661	0.199	0.113	0.027	0.02	0.01	0.630	0.197	0.113	0.061	84.37	0.743	0.193	0.059	0.005	0.70	0.45	0.735	0.173	0.074	0.018	91.03

Bridge Decks		
	Typical	Worst First
Undiscounted Sum	4,307,399	9,890,119
Net Present Value (NPV)	801,887	1,803,674
Equivalent Uniform Annual Cost (EUAC)	17,872	40,198
% of initial cost	159%	365%
Bridge Superstructures		
	Typical	Worst First
Undiscounted Sum	1,599,110	6,088,156
Net Present Value (NPV)	277,749	962,546
Equivalent Uniform Annual Cost (EUAC)	6,190	21,452
% of initial cost	59%	225%
Bridge Substructures		
	Typical	Worst First
Undiscounted Sum	2,555,022	6,103,786
Net Present Value (NPV)	347,826	964,992
Equivalent Uniform Annual Cost (EUAC)	7,752	21,507
% of initial cost	94%	225%

Note: All costs in $/bridge
Initial costs not included in analysis