

Life-Cycle Cost Analysis: A Practitioner's Approach

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Topics

- Fundamentals of Economic Analysis
- Tools and resources
- What to do now



Learning Objectives

By the end of this workshop you should:

- Be familiar with economic analysis concepts, methods and tools
- Where to get help



Project Alternatives for Bridges

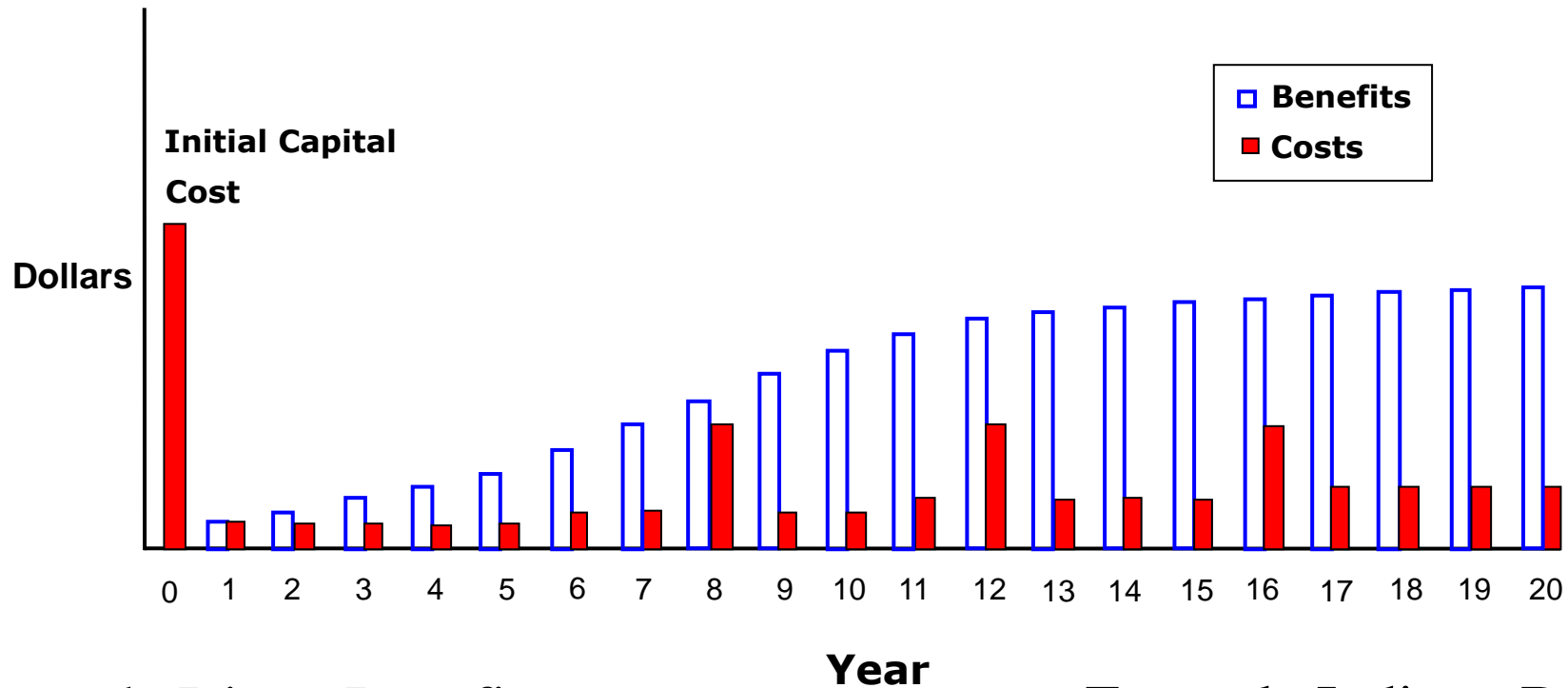


We consider a short list of alternatives for bridge at a project level:

- Replacement
- Rehabilitation
- Painting
- Seismic retrofit
- Systematic preventive maintenance
- Installation of scour countermeasures

Life-Cycle Comparisons of Alternatives

Typical Life-Cycle Profile



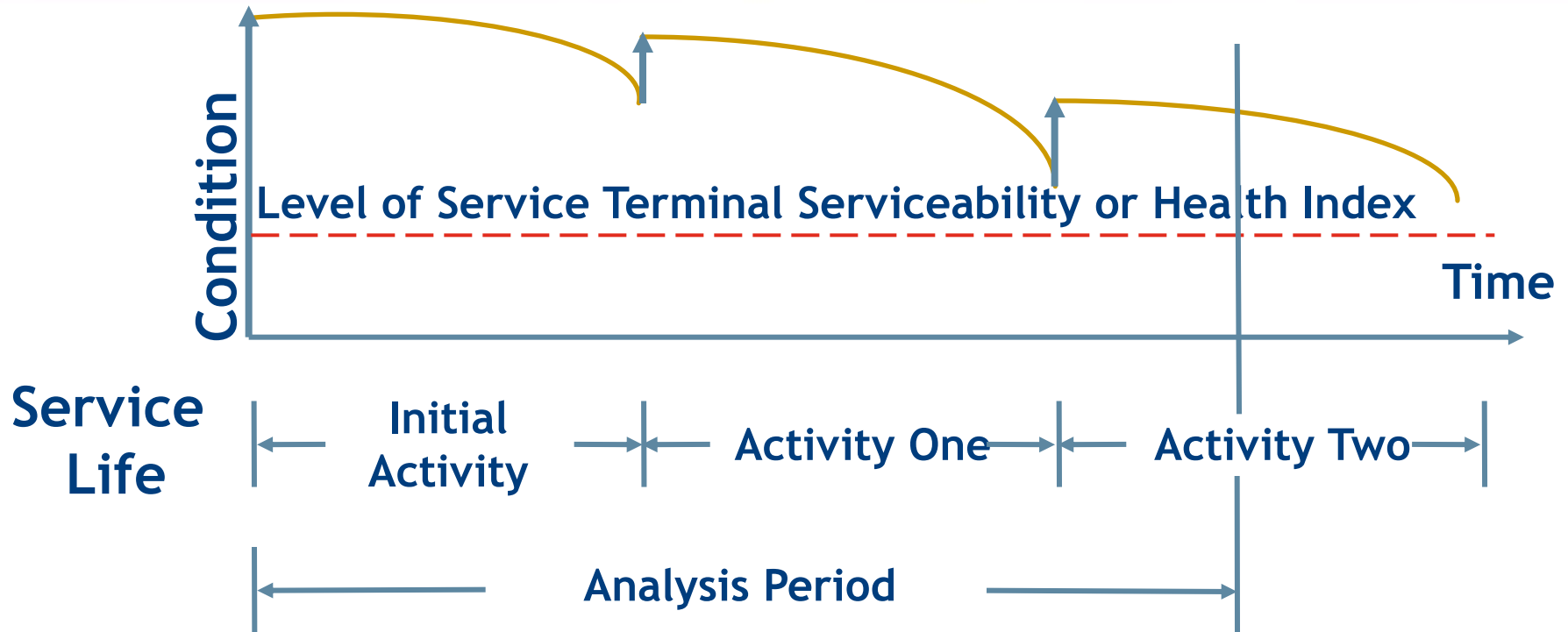
Example Direct Benefits

- Reduced Accident Costs
- Reductions in Delay Costs
- Reduced Life-Cycle Costs

Example Indirect Benefits

- Land use impacts
- Employment
- Non-user benefits

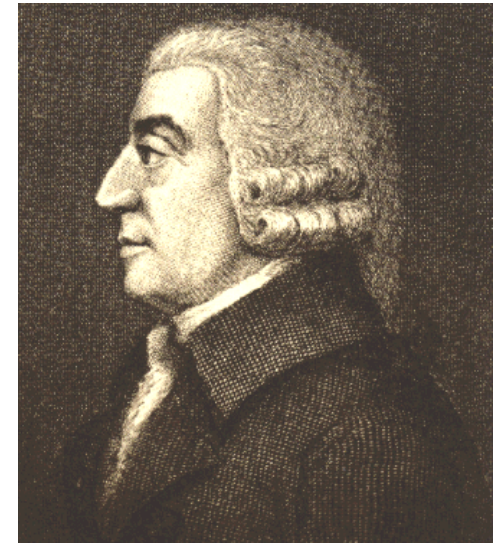
Life-Cycle Comparisons



When will the future deterioration countermeasures be required?

The Role of Economic Analysis

- Mechanism for monetizing, evaluating and comparing long-term costs and benefits of alternatives
- Economic analysis results
 - Help structure project and program level tradeoffs to ensure that resources are allocated efficiently to achieve the maximum ROI (Allocative Efficiency)
 - Quantify & Qualify costs and benefits to the agency and to roadway users
 - Support repeatable and transparent project justification and prioritization
- Does not provide THE decision. It provides a logical framework to support decisions



Adam Smith

Life-Cycle Comparisons

Dollar Now vs. Dollar Later

Two separate and distinct factors account for why the value of a dollar, as seen from the present, diminishes over time

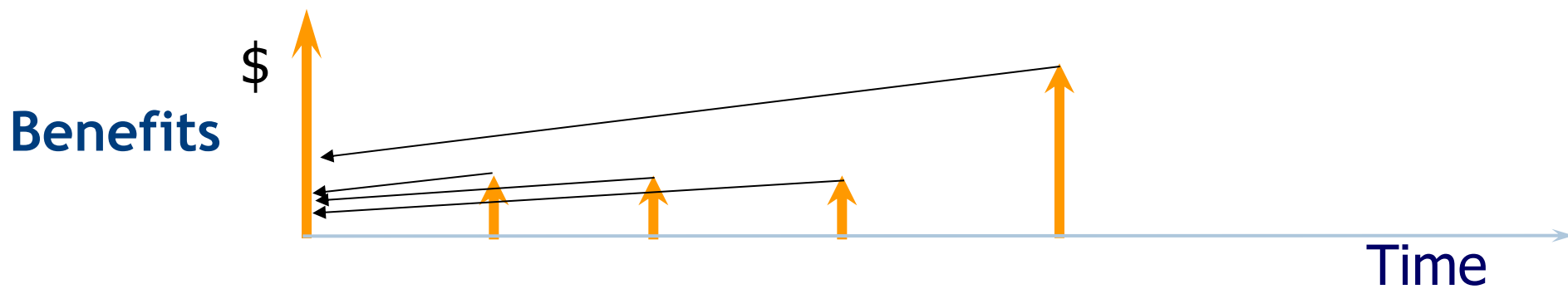
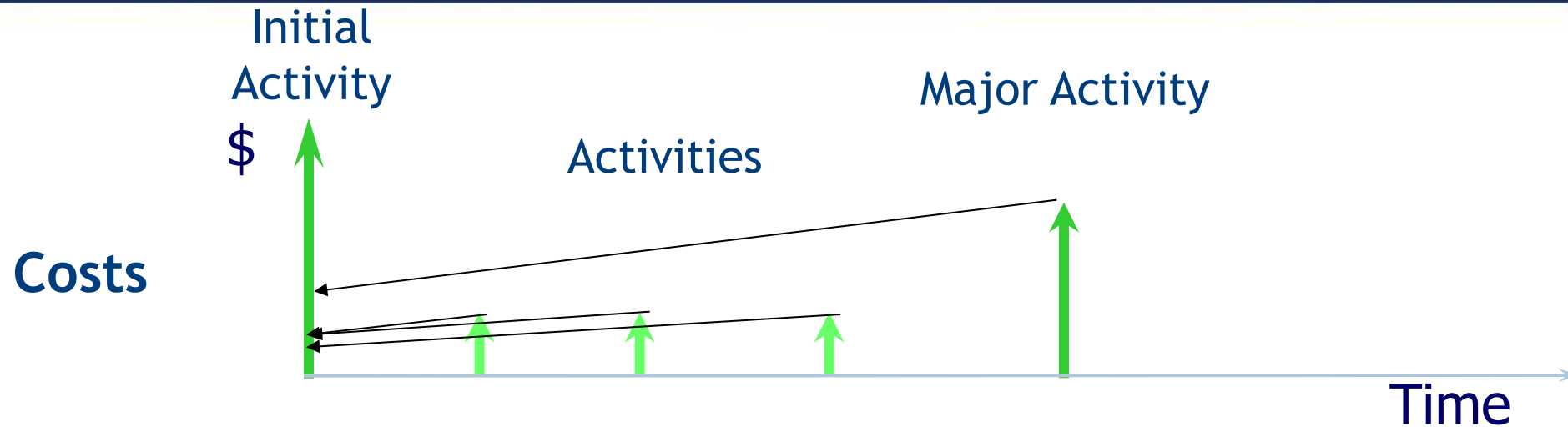
- Inflation



- Time value of a dollar (Discounting)



Calculate Present Values of Costs and Benefits



What is the present value of future sums?

Time Value of Resources

Guidance on Discount Rates

- Real discount rate of 3% with a sensitivity analysis ranging from 2% to 5% (More on “Sensitivity Analysis” later)
- States may select higher or lower rates, but rate should be justified. (e.g. borrowing or bond rates)
- Do not adjust discount rate for risk because the risk that society places on forgoing consumption is already built in. This is different from risk of returns in bond or stock markets

Definition of Benefit Cost Analysis



For public agencies benefit-cost analysis benefit-cost analysis is essentially ROI. Traditional benefit cost analysis and ROI analysis for transportation includes user benefits (time, cost, safety) for travelers and select environmental effects (air, quality, noise) along with capital, operations, and maintenance(O&M) costs.

Definition of LCCA

Life-Cycle Cost Analysis is a **process** for evaluating the total economic worth of a usable project segment by analyzing initial costs and discounted future costs, such as maintenance, user, reconstruction, rehabilitation, restoring, and resurfacing costs, over the life of the project segment.



*Source: Transportation Equity Act
for the 21st Century*

Cost Effectiveness Analysis(OMB Circular A-94)

- CEA compares alternatives on the basis of the ratio of their costs and a single quantified but not monetized effectiveness measure(e.g. dollars per lives saved Programs that cost less per life saved are more cost-effective than other programs)
- It is a measure of technical efficiency and is not necessarily a good measure of allocative efficiency.
 - Allocative efficiency - are funds directed to activities which will produce the greatest gains.(MAX ROI)
 - Technical efficiency - once resources are allocated, are they being combined to produce the greatest output (Spread The Butter Thin)

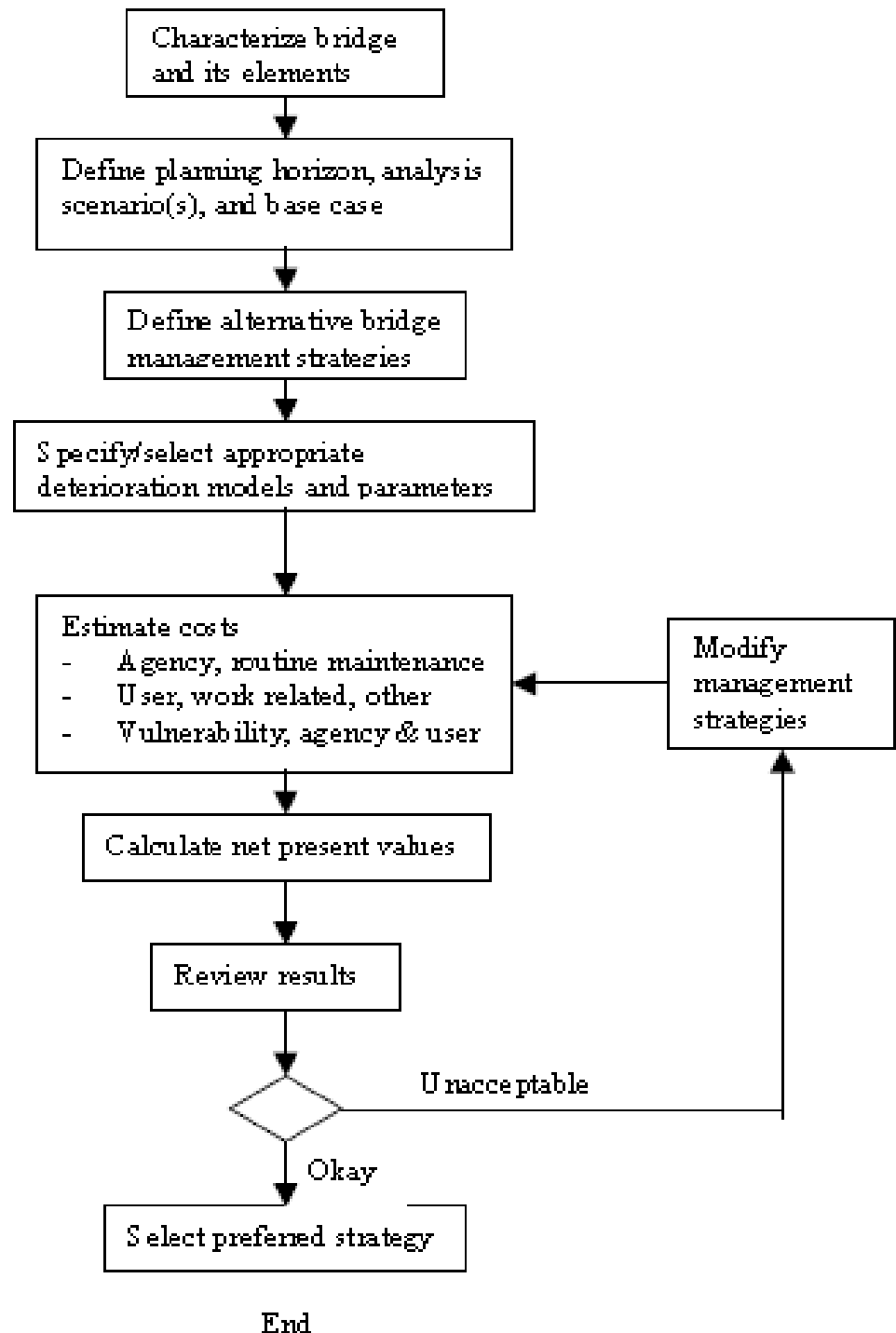


The Process

NCHRP
REPORT 483

NATIONAL
COOPERATIVE
HIGHWAY
RESEARCH
PROGRAM

Bridge Life-Cycle
Cost Analysis



Method

BCA Formula

- BCA is done using the basic multi-year discounting formula:

$$PV = \sum_{t=0}^N \left(\frac{1}{(1+r)^t} \right) (Benefit_t - Cost_t)$$

UBR Eligibility Determination - Compare Rehab Option vs Replacement Life Cycle Costs

Retain 20 year old bridge (BR_06282, constructed 1962) with deteriorated timber substructure (BR-31710/2592) versus replacement
 $PW=(1+r)^n/(1+i)^n$

Interest rate, i= 7%
 Inflation rate, f= 4%

Notes: Widened from 9.14 m roadway to 12.200 m roadway; actual widening = 3.0m x 124 m @ \$1950/m².
 1992-1997 9.20 accidents per year, total 46 (1 accident on the bridge between 1992 & 1997) @ \$10400/accident; accident cost \$2000/year*
 *Based upon cost/FOD accident = \$6400 & cost/injury accident = \$14400
 Replacement cost for 14.02 m x 124.766m structure based on Final Structure Cost Estimate.
 (Detour structure not required for either option.)

Retain and Widen Old Bridge, Bridge No. 06282

Year	PW Factor	Widening	New Rail #	Total Capital Cost	Accidents	PW Accident	Borings	Repl. Piles	Bracing	Girders	Rehab		PW Maint	Total PW
											Deck	Crails & Gutterlines		
0	1.000	1520000	0	1520000	20800	20800	0	596000	2000	3000	0	0	601000	2141800
10	0.752	0	0	0	20800	15652	1000	5000	500	3000	13000	15000	28218	43870
20	0.566	0	0	0	20800	11778	1000	10000	500	3000	13000	15000	24065	35842
30	0.426	0	0	0	20800	8862	500	876000	2000	3000	13000	15000	387516	396378
40	0.321	0	0	0	20800	6669	1000	5000	500	3000	13000	15000	12023	18692
50	0.241	0	0	0	20800	5018	1000	10000	500	3000	13000	15000	10253	15272
60	0.182	0	0	0	20800	3776	500	876000	2000	3000	13000	15000	165111	168887
70	0.137	0	0	0	20800	2841	1000	5000	500	3000	13000	15000	5123	7964
80	0.103	0	0	0	20800	2138	1000	10000	500	3000	13000	15000	4369	6507
#Rail cost included in widening costs													Total Present Worth=	\$2,835,212

Replace with New Bridge, Bridge No. 18628

Year	PW Factor	Capital Cost	Accidents	PW Accident	Annual Maintenance (cleaning)	PW Maint	Total PW
10	0.752	0	0	0	9000	6772	6772
20	0.566	0	0	0	9000	5096	5096
30	0.426	0	0	0	9000	3835	3835
40	0.321	0	0	0	9000	2886	2886
50	0.241	0	0	0	9000	2171	2171
60	0.182	0	0	0	9000	1634	1634
70	0.137	0	0	0	9000	1229	1229
80	0.103	0	0	0	9000	925	925
Total Present Value=							\$2,594,548

Recommendation: The present worth and comparison benefits, widen and maintain the bridge is greater than to replace it. Therefore we recommend BPA approval.

Benefit and Cost Elements

- **Agency Cost/Benefit**
 - Design and Engineering**
 - Land Acquisition**
 - Construction**
 - Reconstruction/Rehabilitation**
 - Preservation/Routine Maintenance**
 - Remaining Asset Value (end of analysis period)**
- **User Cost/Benefit**
 - Delay/Time Saving**
 - Crashes/Avoided Crashes**
 - Vehicle Operating Costs**
- **Externalities**

Roadway User Costs Components

Definition

Costs to highway users over the life of a Highway Project

Components

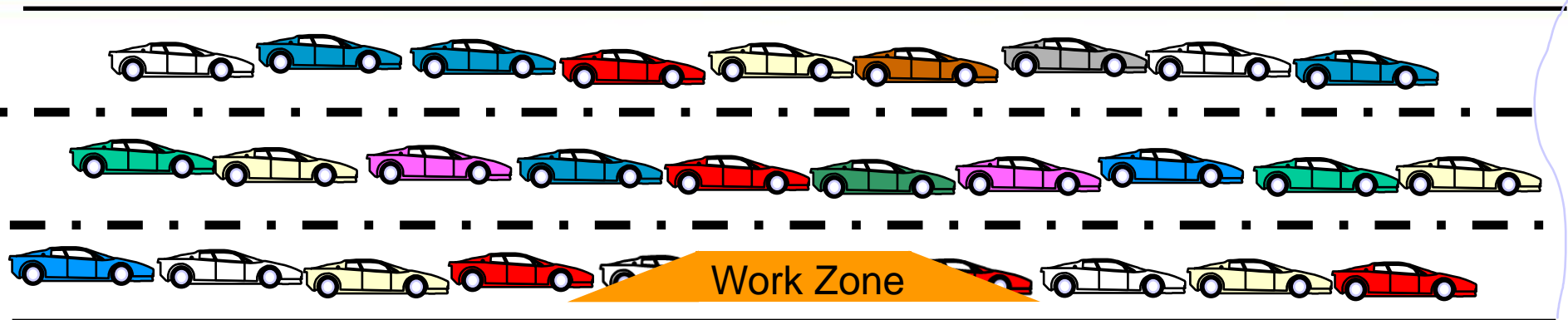
- **Delay Costs** – Costs associated with an increase (or decrease) in the amount of time it takes for a user to travel from point A to B. (In our case, navigating through or around a work zone)
- **Vehicle Operating Costs** – Costs attributable to the operation or maintenance of a vehicle (brake wear, idling, fuel consumption, tire wear, etc.)
- **Crash costs** – Cost resulting from property damage, injuries, or loss of life



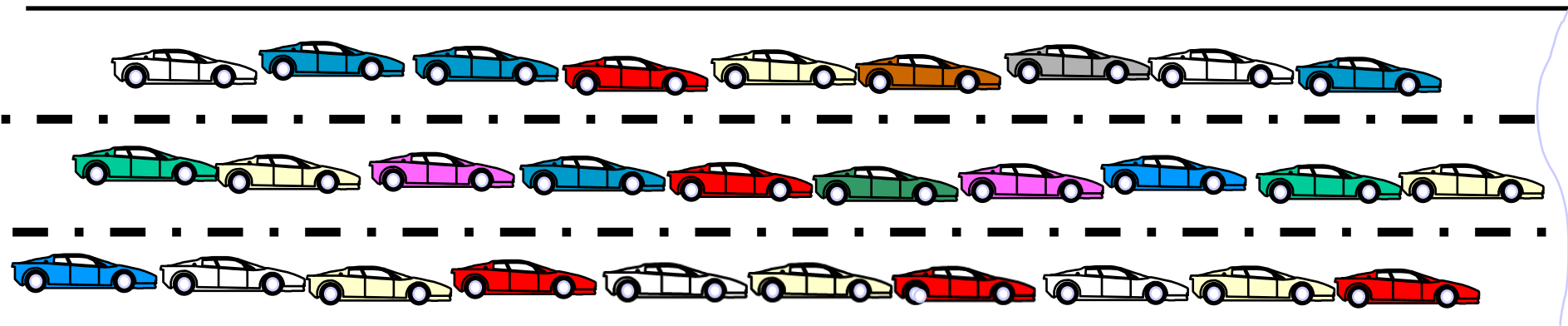
Comparing Work Zones Strategies

- Each construction/WZ strategy involves tradeoffs
 - Agency vs. user costs
 - Initial vs. long-term costs
- An analysis of roadway user costs permits comparison of cost tradeoffs

WZ Impacts

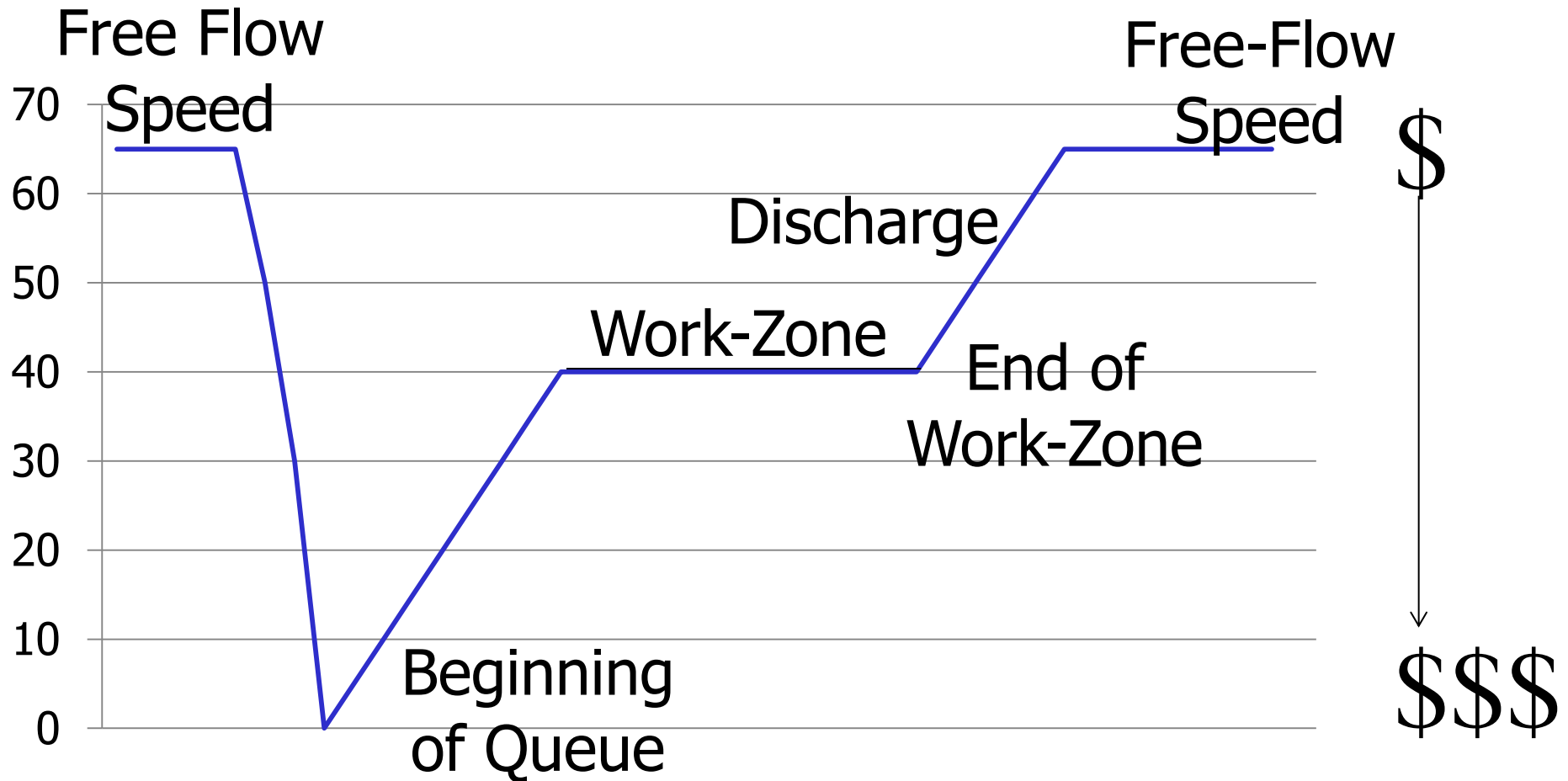


1. Existing Costs on construction Route(Pre-WZ)
2. Additional Costs from WZ



1. Existing cost on detour route(Pre-WZ)
2. Additional Costs of detoured traffic on Detour Route

Conceptual Work-Zone impact on travel speed



Comparing Benefits To Costs

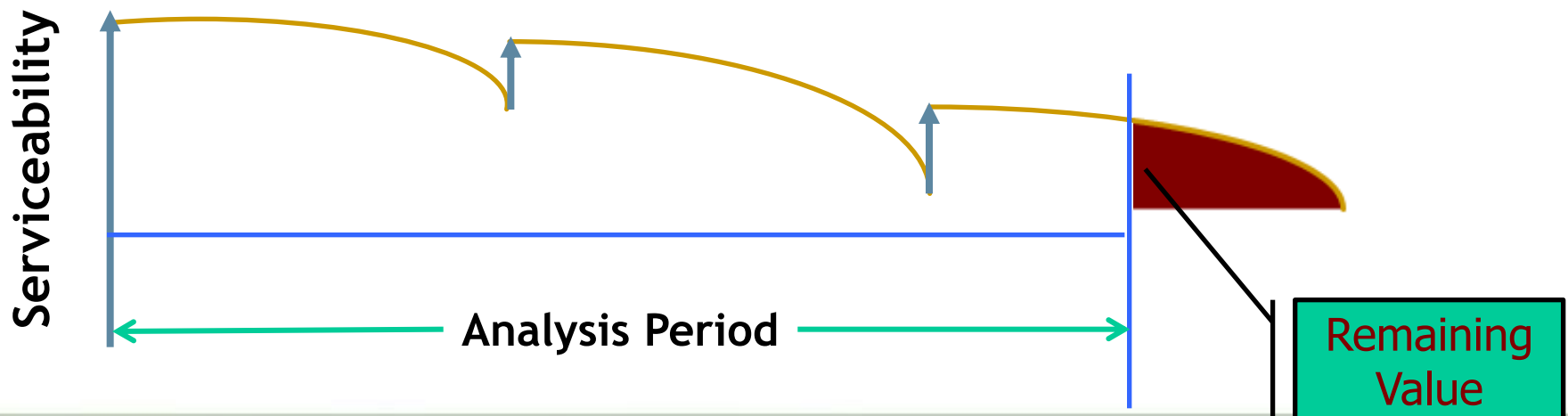
Different BCA Measures

- Net Present Value (NPV)
- Other measures include:
 - Equivalent Uniform Annual Value (EUAV)
 - Internal Rate of Return (IRR)

Remaining Value

The value of potential service remaining at the end of the analysis period

- Accounts for end-of-analysis period “differences” between alternatives
- Removes economic bias between alternatives



Salvage Value

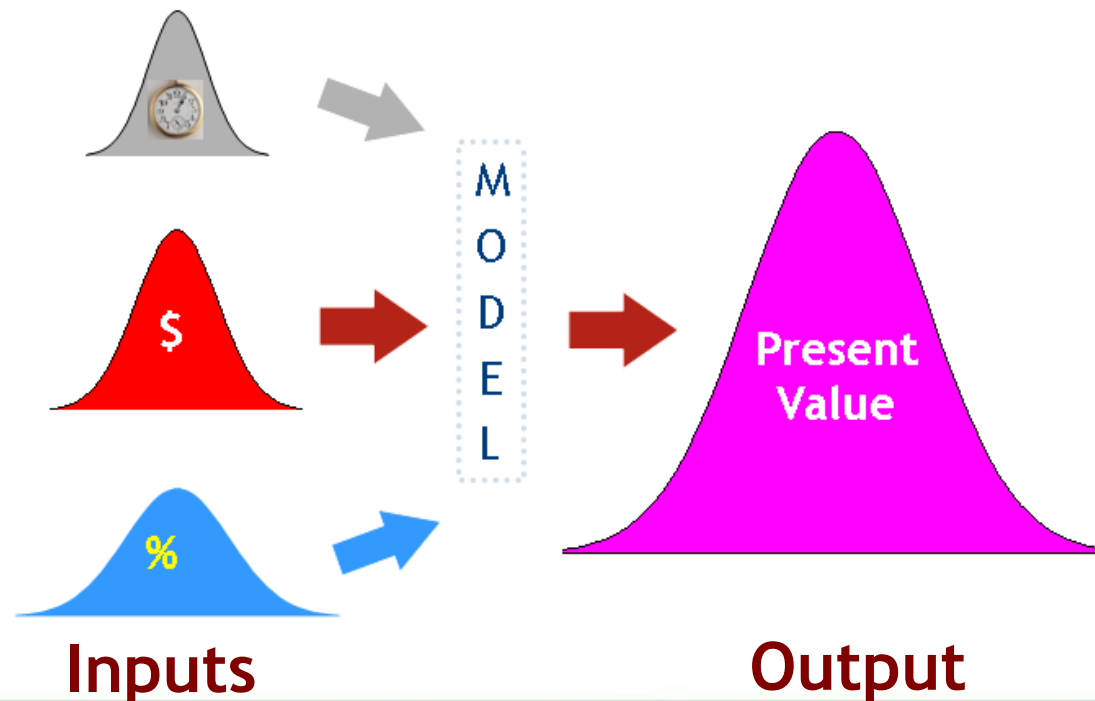
The value of recovered or recyclable materials

- Assumes material is removed from service at the end the analysis period
- Salvage value is only realized when materials are actually reclaimed

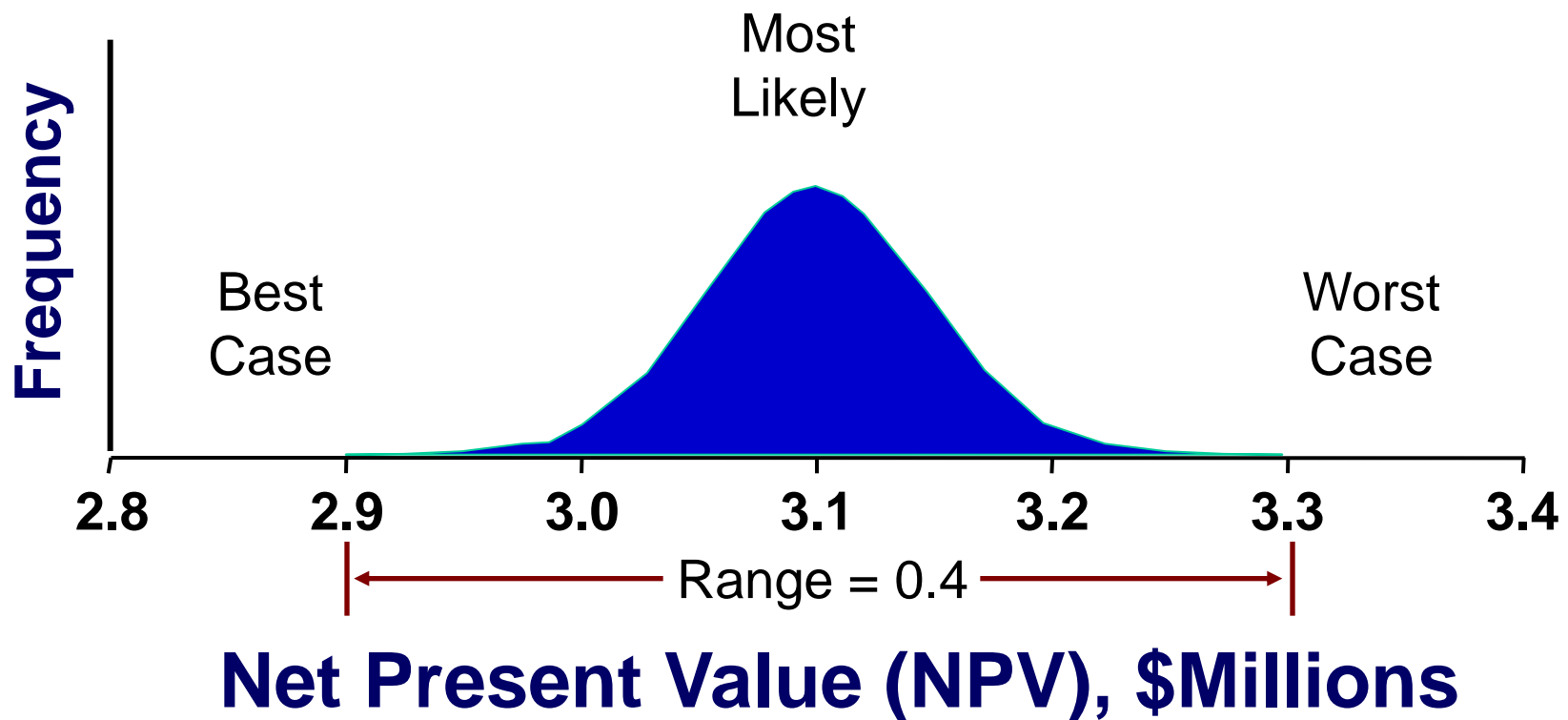


Probabilistic Analysis







- Inputs are defined by their range of values and probability of occurrence (probability distribution)
- Through simulation, outputs are expressed as ranges of values with probabilities of occurrence



Simulation Results: Histogram



Comparing BCA and EIA Metrics

Metric	BCA/LCCA	EIA(NEPA)
User Benefits		
Societal Benefits		
Net Benefits		
Jobs		
Income		
GDP		

Economic Analysis Tools

Tools to assist organizations with economic analysis

- **BLCCA 2** (NCHRP 483 Software Revamped)
- **NBIAs:** network level pavement needs assessment tool
- **FHWA Division Bridge Engineer:** Simple spread sheet in their Bridge Manual



BLCCA2 –Project Level

U.S. Department of Transportation
Federal Highway Administration
Bridge Life Cycle Cost Analysis - BLCCA2
Start Screen

Alternative #1: Rehab right away

	Treatment	Year
Scenario settings	Rehabilitation	2013
Summary results	Deck repairs	2025
	Spot recoating	2040
	Bridge replacement	2060

Life cycle cost (\$000)

Agency: 15,560

User: 23,495

Vulnerability: 29,331

Total: 68,387

Alternative #2: Replace later

	Treatment	Year
Scenario settings	Replacement	2020
Summary results	Rehabilitation	2035
	Light maintenance	2060

Life cycle cost (\$000)

Agency: 27,816

User: 384,546

Vulnerability: 128,259

Total: 540,621

Bridges [2]

Type a structure num: 11 0011,11 0029 Select

Bridge name: WALKER CREEK

Facility carried: STATE ROUTE 162

Feature intersected: WALKER CREEK

Dimensions: Length 135 ft, Width 36 ft.

Conditions: Deck: 7, Super: 7, Sub: 7

Main structure: 2 Concrete Continuous 01 Slab

Data valid as of 03/24/2013 04:02 PM [Data set](#)

Roadways [2] [Data set](#)

Total ADT 10600

Elements [12] [Data set](#)

Current health index 98.5

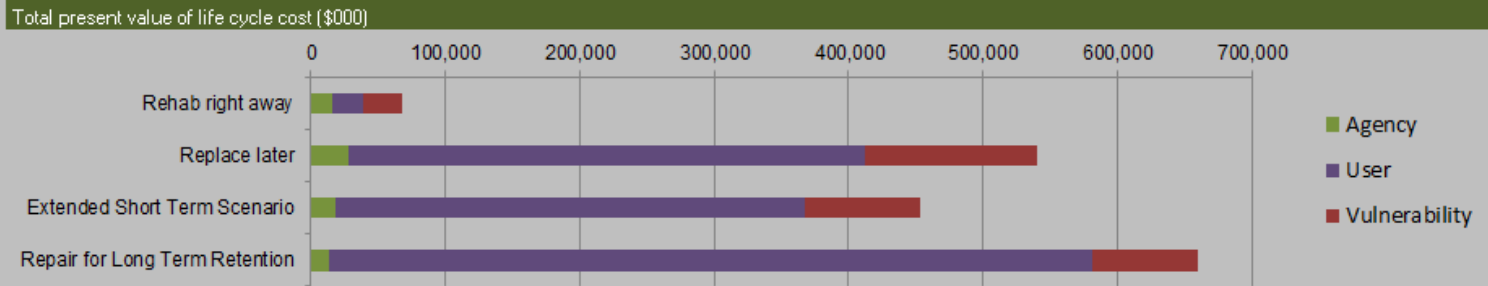
Health index

Year	Alt 1	Alt 2
2012	100	100
2017	85	80
2022	70	65
2027	55	50
2032	40	60
2037	28	95
2042	20	80
2047	15	65
2052	10	50
2057	8	35
2062	95	20
2067	80	15
2072	65	10
2077	50	8
2082	35	6
2087	25	4
2092	18	3
2097	12	2
2102	8	1
2107	5	1

BLCCA2 –Project Level

Main

Scenario description: Pattullo Bridge Draft Assessment
 Bridges included: 11 0011,11 0029



Summary	Present value life cycle costs (\$000)				Health Index	Remarks
	Agency	User	Vulnerability	Total		
Rehab right away	15,560	23,495	29,331	68,387	23.7	
Replace later	27,816	384,546	128,259	540,621	9.9	
Extended Short Term Scenario	18,854	348,399	85,643	452,896	3.7	
Repair for Long Term Retention	13,511	567,713	78,426	659,650	3.7	

Annual forecast for ALT1	Rehab right away			Health Load capy index	Load capy (psf)	Life cycle costs (\$000)		User cost						
	Year	On	Under			ADT Total	Initial	Annual	Total	Width	Height	Weight	Connect	Environ

MAP-21

- Transportation Performance Management:
 - States will manage Their Networks so that no more than 10% bridges by deck are structurally deficient
 - Risk Based Asset Management Plan
 - Performance Targets
 - Progress Assessment Reports
 - States & MPOs
- Element Inspections
- Management Systems
- Value Engineering
(LCCA Required for Bridges)




National Bridge Investment Analysis System(NBIAS)

NBIAS: Element Transition Probabilities

Federal Highway Administration National Bridge Investment Allocation System (NBIAS) version 3.5

Log in Database Import Elements MR&R Model Replacement Rules Scenario Editor Settings



Welcome to NBIAS

NBIAS Database

Database: NBIAS 3.5 2009 SCREENED SQLSRVX Database Management...

Exit Help

Federal Highway Administration National Bridge Investment Allocation System (NB...)

Log in Database Import Elements MR&R Model Replacement Rules Scenario Editor Settings

Database: NBIAS 3.4 2009 SCREENED MR&R Model: MRR2009

Element: 12 - Concrete Deck - Bare

Climate Environment: 04 - Intermediate; Freeze

User Cost Group: 1 2 3 4

U.S. State: National Average

Cost coefficients: Agency: 1.000, User: 1.000

Discount Rate: 4 Equivalent Factor: 0.961538

Cost Model

CS	Agency 0	Agency 1	Agency 2	User
1	0.00	219.12		0.00
2	0.00	41.39	231.29	0.45
3	0.00	52.34	253.20	0.86
4	0.00	85.21	267.81	1.73
5	0.00	304.33	427.28	3.63

Failure Costs

Agency: 718.61

User: 676.85

Transition Probabilities

Action 0 (do nothing)						Action 1						Action 2					
CS	1	2	3	4	5	CS	1	2	3	4	5	CS	1	2	3	4	5
1	87.06	12.94				1	97.03	2.97				1					
2		94.39	5.61			2	41.00	55.24	3.76			2	64.21	33.74	2.05		
3			93.30	6.70		3	29.50	10.50	55.77	4.23		3	71.32	11.89	16.79		
4				87.06	12.94	4	25.00	5.00	8.33	53.09	8.58	4	74.50	8.13	0.68	16.69	
5					87.06	5	41.67	6.67	1.67	0.83	49.16	5	100.00				

Failure Probability: 12.94

Optimization Results

CS	A	Cost	Total Benefit	Agency Benefit	User Benefit	B/C Ratio
1	0	0.00	0.00	0.00	0.00	0.000000
2	0	0.00	0.00	0.00	0.00	0.000000
3	0	0.00	0.00	0.00	0.00	0.000000
4	1	85.21	92.34	91.47	0.87	1.083685
5	2	427.28	517.67	431.25	86.42	1.211555

Optimize Optimize All

Revert Report

Save Delete

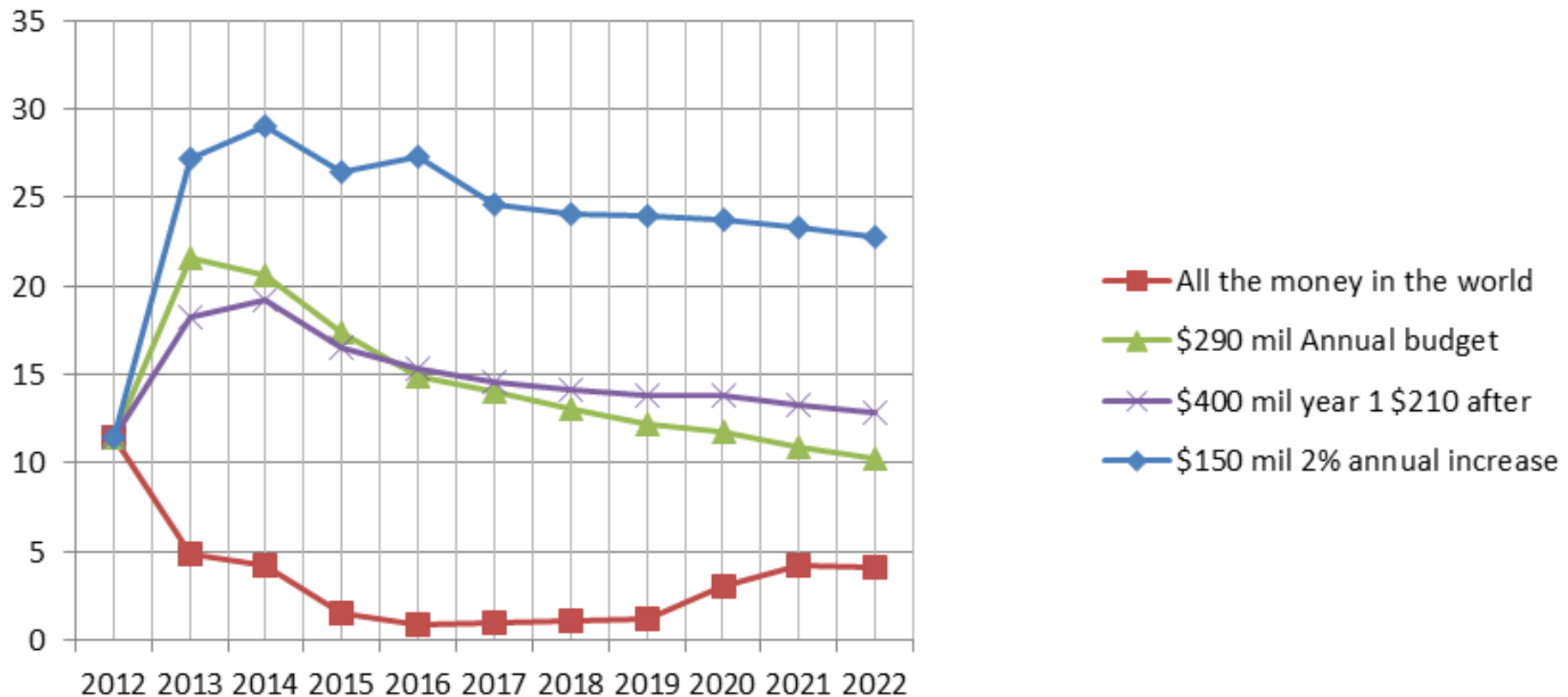
Save As...

Update from Database

Exit Help

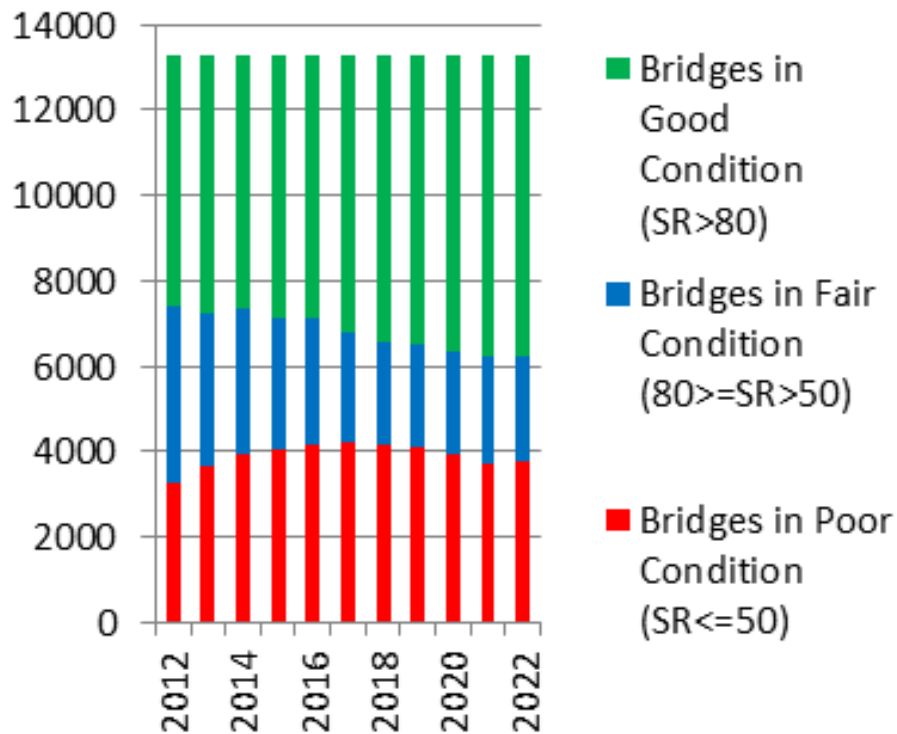
NBIAS Risk Based Bridge Investment Analysis

Figure 2: Deck area percentage of structurally deficient bridges

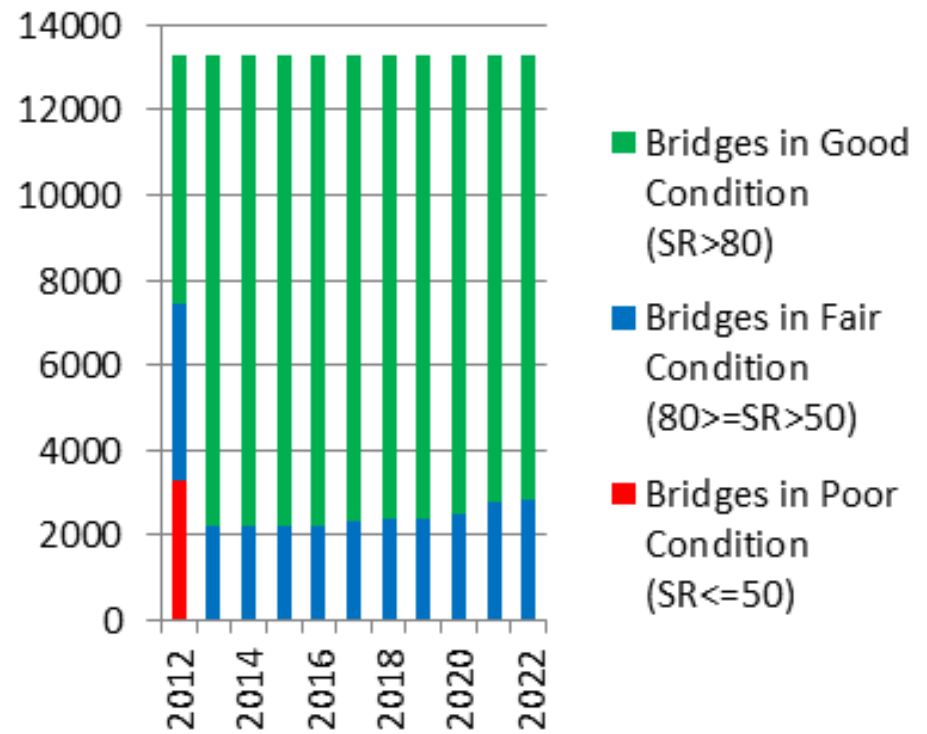


NBIAS Risk Based Bridge Investment Analysis

Bridge population distribution by condition under Scenario 1



Bridge population distribution by condition under Scenario 2



Thank You

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<http://www.fhwa.dot.gov/infrastructure/asstmgmt/economic.cfm>