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San Diego, California

Using Integrated Asset Management System to perform Corridor-Level Analysis for Planning & Scheduling Bridge and Pavement Projects

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Acknowledgements

- **Neil Mastin**
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Agenda

- Goal & Vision
- Background
  - Bridge Management System (BMS)
  - Pavement Management System (PMS)
- Corridor-Level, Trade-off Analysis Methodology
- NCDOT I-40 Corridor Analysis
  - By Providing Outputs of BMS and PMS to Asset Trade-of Analyst
- Conclusions
  - Lessons Learned
  - Next Steps

Goal

NCDOT GOALS	FHWA GOALS
• Make our transportation network safer	Safety
• Make our transportation network move people and goods more efficiently	Mobility
• Make our infrastructure last longer	Health – Good Repair
• Make our organization a place that works well	
• Make our organization a great place to work	

Using Efficient & Advanced Techniques,

Processes & Management Systems

To Leverage Existing Practices & Technologies

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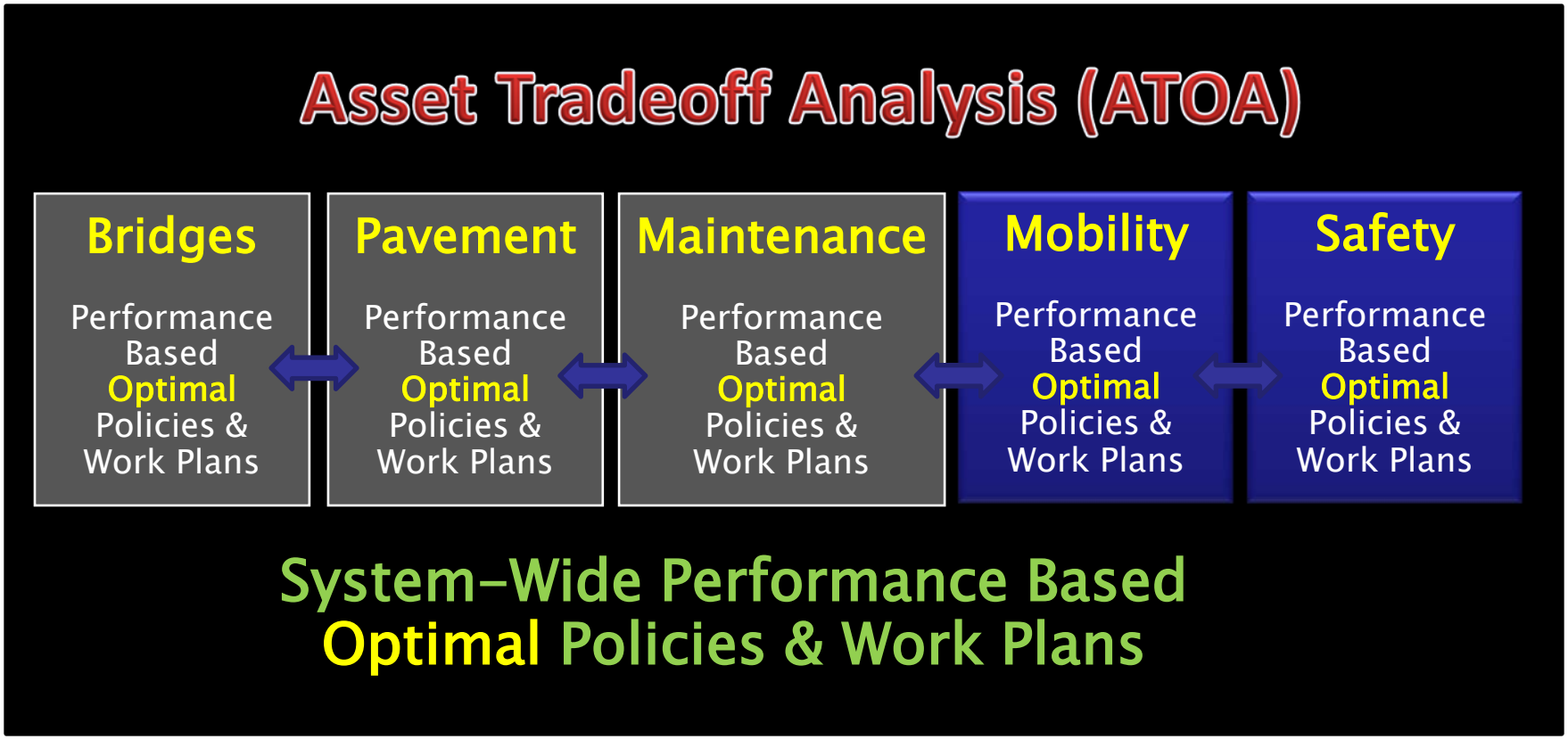
Vision


Asset Tradeoff Analysis (ATOA)
Bridges
Performance Based Optimal Policies & Work Plans
Pavement
Performance Based Optimal Policies & Work Plans
Maintenance
Performance Based Optimal Policies & Work Plans
Mobility
Performance Based Optimal Policies & Work Plans
Safety
Performance Based Optimal Policies & Work Plans
System-Wide Performance Based Optimal Policies & Work Plans

Background – NCDOT BMS / PMS

- **Bridge & Pavement Management Systems**
  - Inputs:
    - Centralized Inventory & Condition Database
    - Decision Trees
    - Performance / Deterioration Models
  - Methodology
    - Multi-Objective, Multi-Criteria Optimization Analysis
  - Output
    - **Project Level Life-Cycle Report**
    - Network Level Investment and Funding Strategy
    - Forecasted Condition at Network-Level & Project-Level
    - **Comparative Analysis of Investment Strategies**

So far, Individual Asset Networks have been Analyzed

Background – BMS/PMS Life Cycle Reports

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STRUCTURE LIFE CYCLE ANALYSIS REPORT

STRUCTURE#:140021

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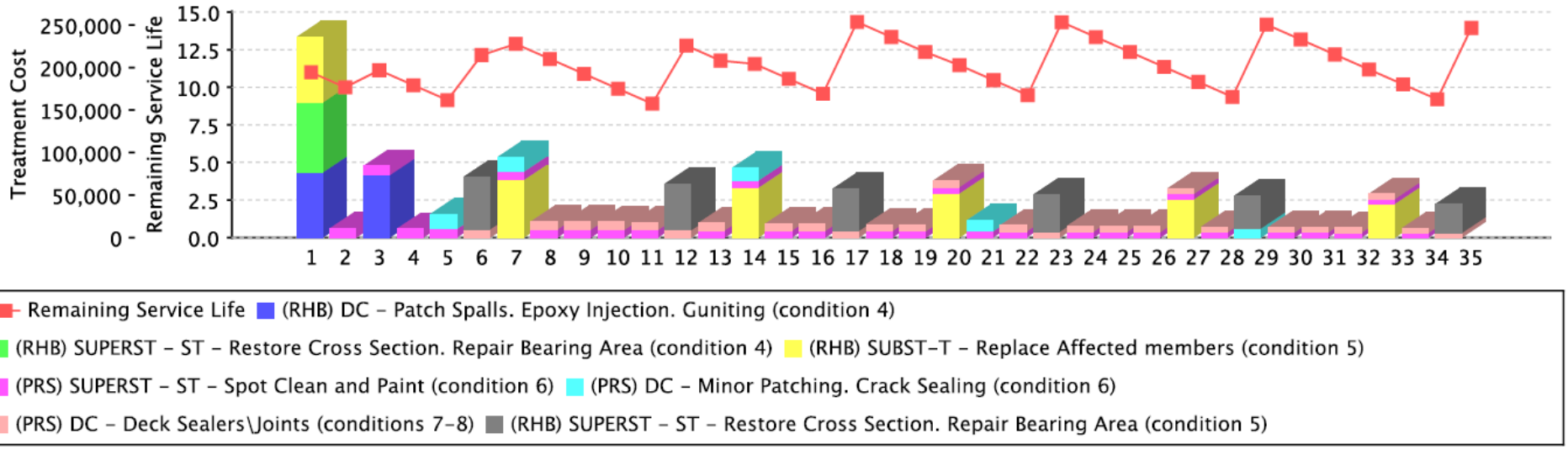
SCENARIO NAME :Maximize Network Condition given Budget (LC: 35 Years) 2011 TO 2046



ECONOMIC ANALYSIS RESULTS

Net Present Worth of Costs by Work & Element

SCENARIO ID : 760

	Preserve	Rehab.	Total
Deck	$ 285,426	$ 161,809	$ 447,235
SubSt.	$ 0	$ 366,000	$ 366,000
SuperSt.	$ 237,215	$ 392,086	$ 629,301
Total	$ 522,641	$ 919,895	$ 1,442,536

Cost Analysis

SCENARIO NAME : Maximize Network Condition given Budget (LC: 35 Years)

Number of Years in Analysis :	35
Average Interest Rate :	3 %
Average Inflation Rate :	1 %
Net Present Worth of all Costs (NPW) :	$ 1,442,536
Equivalent Uniform Annual Cost (EUAC) :	$ 67,135
Annual User Cost Savings (EUAUC) :	See NM

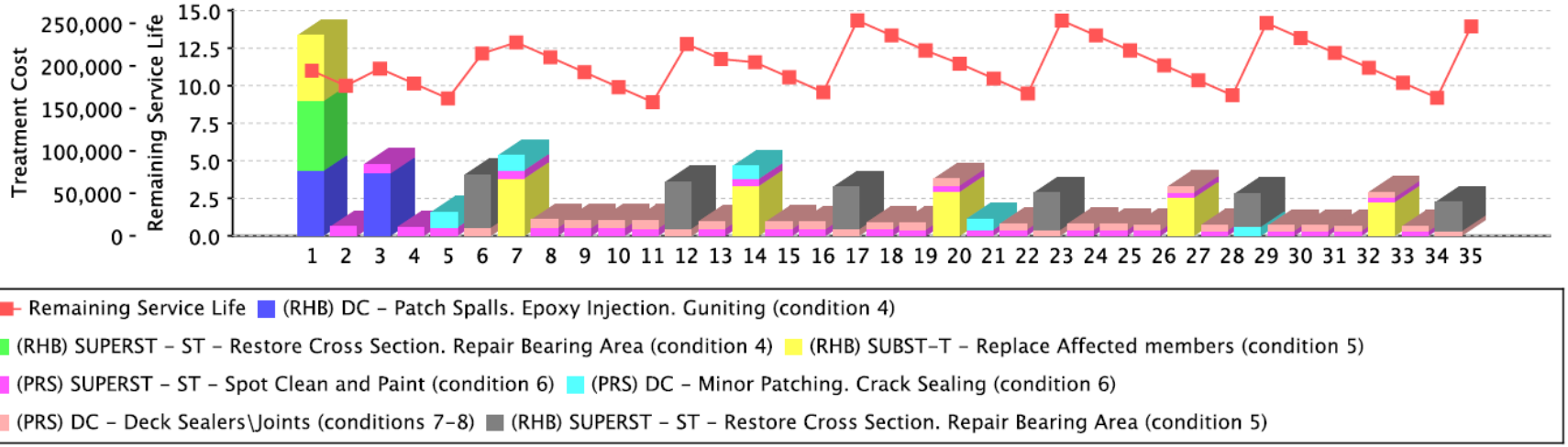
Benefit Analysis - Structure Condition

Element	Latest Inspection	During Life Cycle			
		MIN	AVG	MAX	END
Deck	4.00	4.67	6.36	7.00	6.04
SuperSt.	4.00	5.05	5.52	5.99	5.91
SubSt.	5.00	5.03	5.55	6.00	5.70
RSL	8.00	8.90	11.47	14.35	13.95

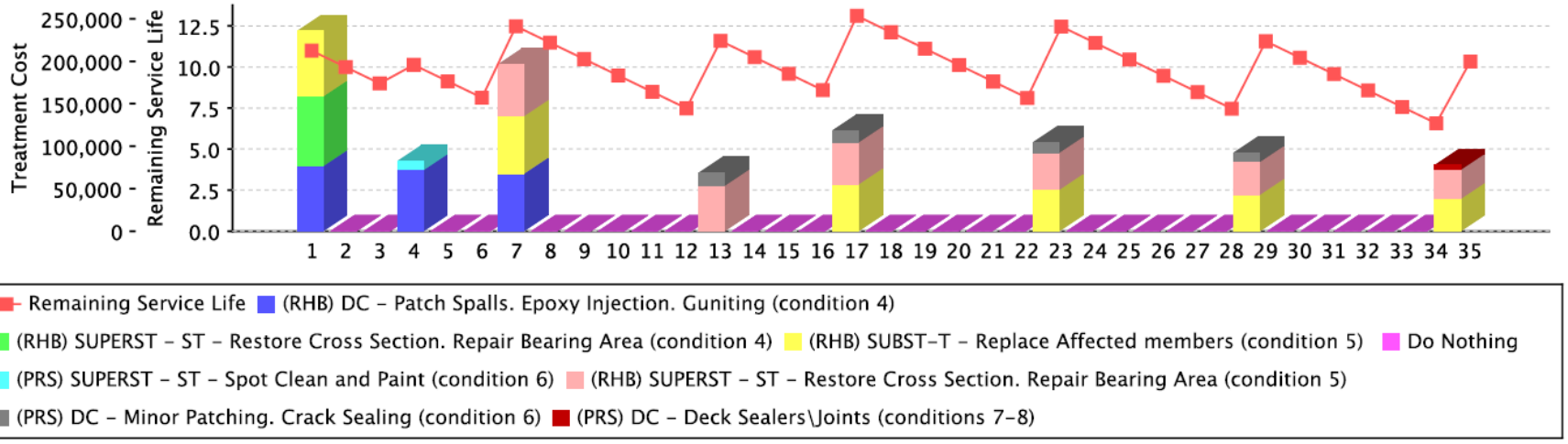
Background – BMS / PMS
Comparative Analysis of Investment Strategies

STRUCTURE LIFE CYCLE SCENARIOS COMPARISON | STRUCTURE #:140021

SCENARIO NAME :Maximize Network Condition given Budget (LC: 35 Years) 2011 TO 2046



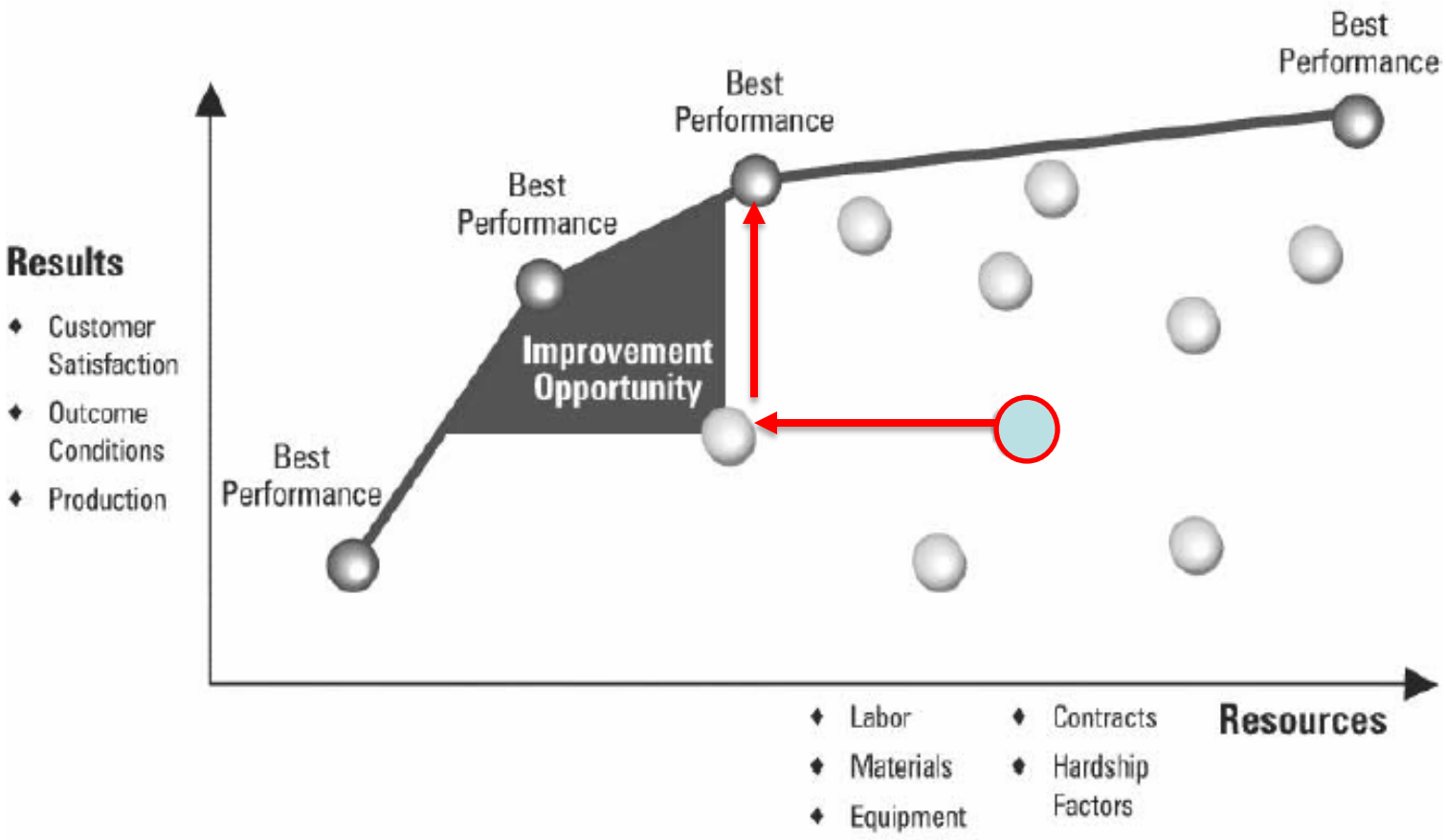
SCENARIO NAME :Least Cost to Maintain 140021 at CS-5 (LC: 35 Years) 2011 TO 2046



Trade-off Across Assets

Are we Utilizing Funds Optimally ?

Compare Points on Efficient Frontier



NC: I-40 Corridor Analysis

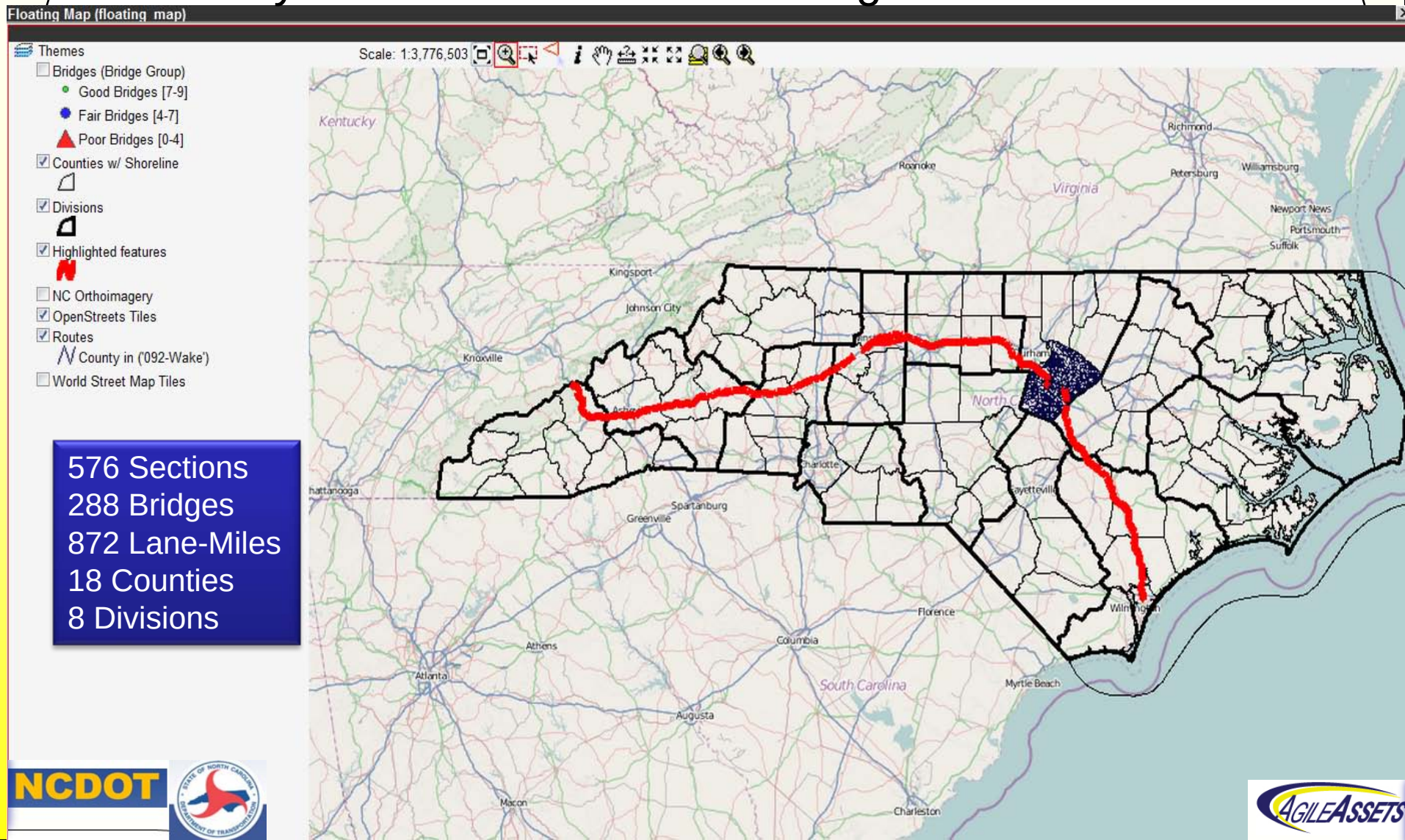
- Network: I-40 Corridor
- Objective:
  - Identify Optimal Pavement & Bridge Projects (25 Years)
    - Optimal =
      - » Maximize Bridge and Pavement Condition
      - » Meet Budget Constraints
      - » **Achieve System Optimal Solution**
  - Prepare Implementation Schedule and Re-evaluate System Optimal (5-Year Plan)
    - Do Bridge & Pavement Projects together where possible, when at a given location on the corridor
    - Estimate Traffic Control & Mobilization Cost Savings

Tradeoff Analysis Methodology

- **Step 1:** Define Network & Identify Pavements & Bridges in Network
- **Step 2:** Run Range of Candidate “Scenarios” in BMS, PMS
- **Step 3:** Develop Efficient Frontier to Analyze Scenario Combinations
- **Step 4:** Identify Preferred System Optimal Solution
- **Step 5:** Prepare Implementation Work Plan & Re-Evaluate Optimality

Step 1: Define I-40 Corridor

Identify Pavement Sections & Bridges on I-40 Corridor



Step 2: Run I-40 Corridor BMS & PMS Scenarios

BMS-BRIDGE MANAGEMENT SYSTEM

PMS-PAVEMENT MANAGEMENT SYSTEM

Tradeoff System

Step 2: Run I-40 Corridor BMS & PMS Scenarios

Multi-Constraint, Multi-Objective, Multi-Criteria Optimization Analysis

Scenario Number	* Scenario Name	* Year	Analysis Length	Analysis Type	Analysis Scope
1006	I-40 BMS Scenario - $30M - 25 Years	2010	25	Multi-Constraint	Corridor 40
1010	I-40 BMS Scenario - $40M - 25 Years	2010	25	Multi-Constraint	Corridor 40
1011	I-40 BMS Scenario - $50M - 25 Years	2010	25	Multi-Constraint	Corridor 40
1012	I-40 BMS Scenario - $60M - 25 Years	2010	25	Multi-Constraint	Corridor 40
1039	I-40 BMS Scenario - $70M - 25 Years	2010	25	Multi-Constraint	Corridor 40
1043	I-40 BMS Scenario - $1M - 25 Years	2010	25	Multi-Constraint	Corridor 40
1044	I-40 BMS Scenario - $15M - 25 Years	2010	25	Multi-Constraint	Corridor 40

Scenario Number	* Scenario Name	* Year	Analysis Length	Analysis Scope	Analysis Type
887	I-40 PMS Scenario - $60M - 25 years	2010	25	Corridor 40	Multi-Constraint
1007	I-40 PMS Scenario - $30M - 25 years	2010	25	Corridor 40	Multi-Constraint
1008	I-40 PMS Scenario - $40M - 25 years	2010	25	Corridor 40	Multi-Constraint
1009	I-40 PMS Scenario - $50M - 25 years	2010	25	Corridor 40	Multi-Constraint
1045	I-40 PMS Scenario - $0M - 25 years	2010	25	Corridor 40	Multi-Constraint
1046	I-40 PMS Scenario - $15M - 25 years	2010	25	Corridor 40	Multi-Constraint
1054	I-40 PMS Scenario - $1M - 25 years	2010	25	Corridor 40	Multi-Constraint

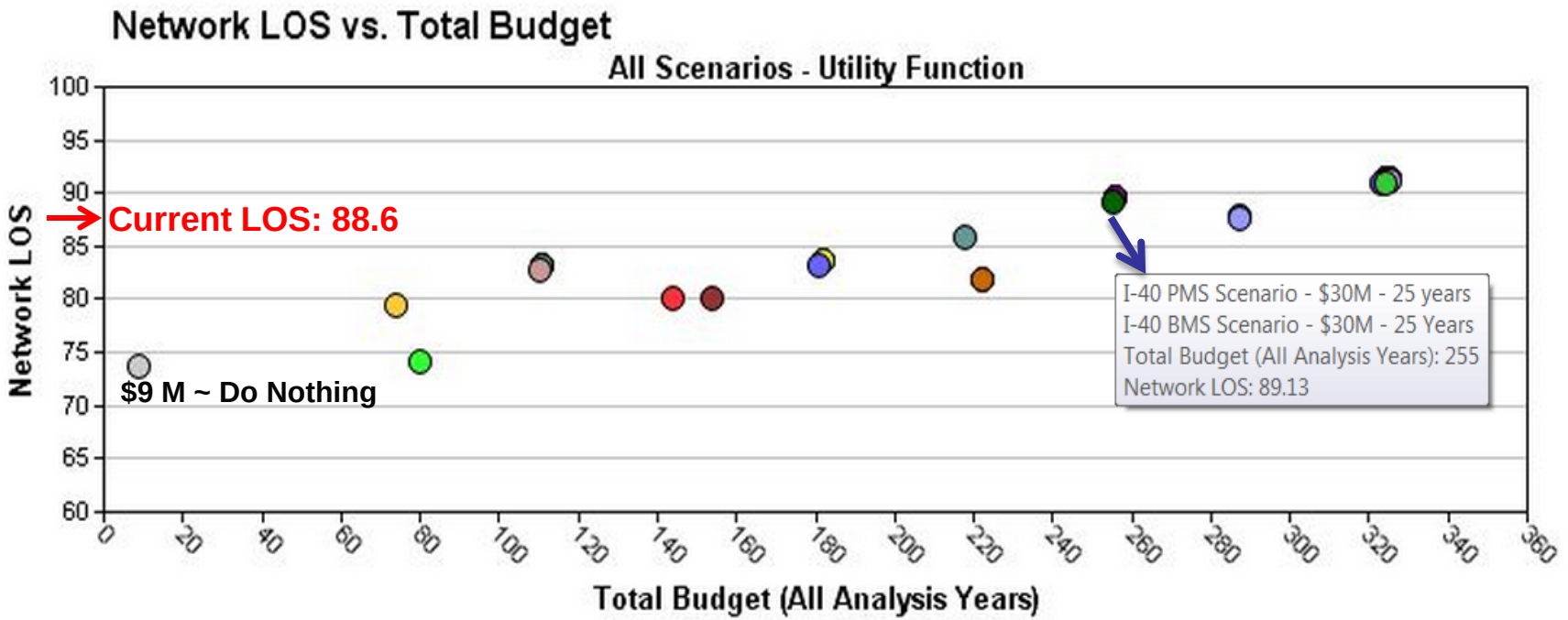
Trade-off Across Assets

Step 3: Develop Efficient Frontier to Analyze I-40 Scenario Combinations

Start Year 2010 Number of Years 5 Build Super Scenario

Selected
I-40 PMS Scenario - $30M - 25 years
I-40 BMS Scenario - $30M - 25 Years

Avg Utility | Utility By Year



Current LOS: 88.6

I-40 PMS Scenario - $30M / Year
I-40 BMS Scenario - $30M / Year
Total Expenditure: $255 M (5 Years)
Resulting Network LOS: 89.13

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Trade-off Across Assets

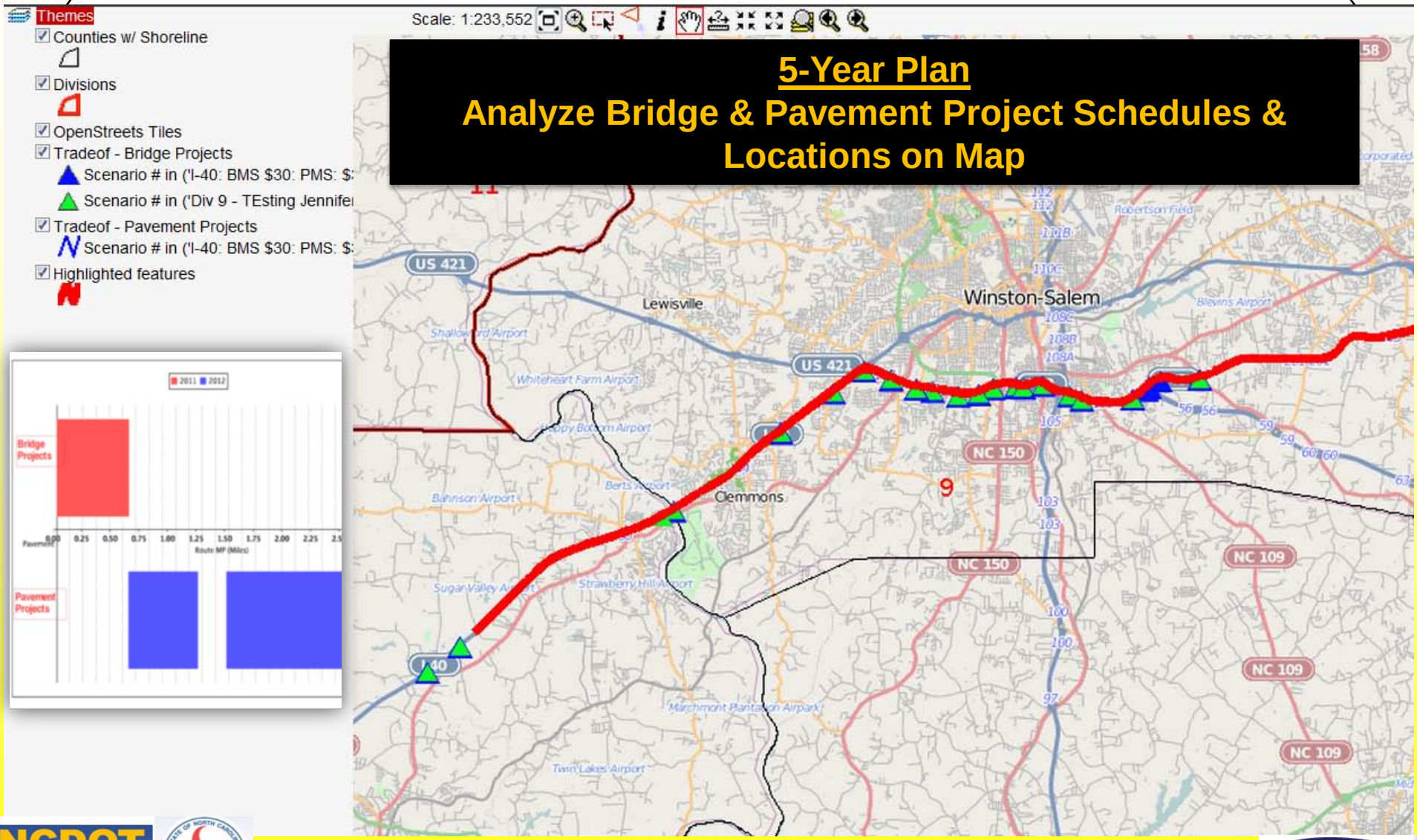
Step 4: Identify and Analyze System Optimal Work Plan

Distribution of Recommended Projects in the Selected Optimal Solution

Plan Year	BMS Preservation	BMS Rehabilitation	BMS Replacement	PMS Interstate Maintenance	PMS Reconstruction	PMS Rehabilitation	Grand Total
1	745	14		38		17	814
2	3		4	28		25	60
3	99		2	23	1	18	143
4	593			180			773
5	113			91	1	5	210
Grand Total	1553	14	6	360	2	65	2000

Trade-off Across Assets

Step 4: Identify and Analyze System Optimal Work Plan



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Trade-off Across Assets

Step 5: Compare Multiple I-40 BMS-PMS Super-Scenario(s)

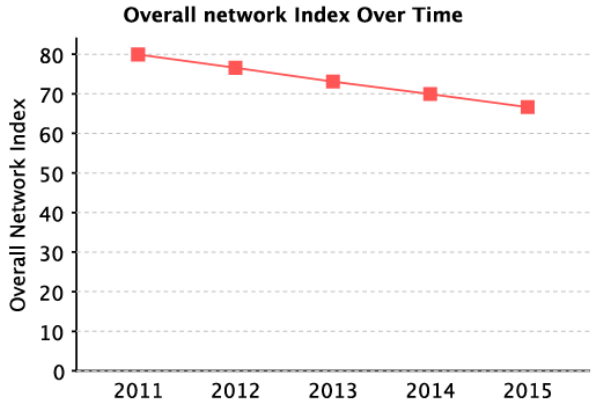
Evaluate Impact on Bridge, Pavement and Overall System

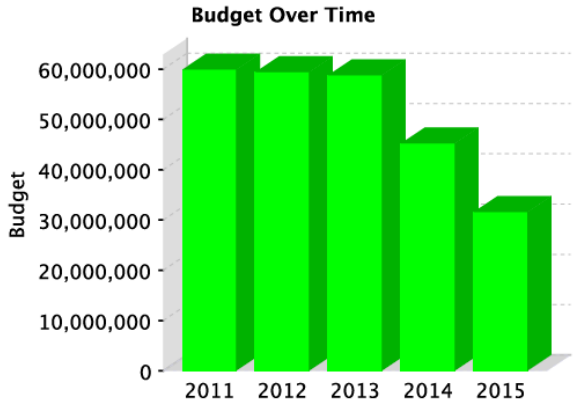
Tradeoff Analysis - Scenario: I-40 5-YRS BMS-30M PMS-30M

Start Year = 2010; Number of Years = 5

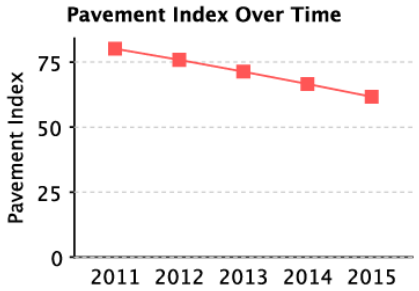
Date:04/16/2012
Time:10:34 PM

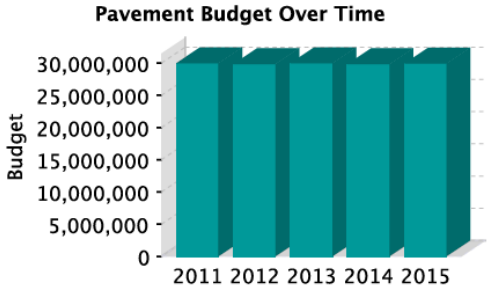
NETWORK



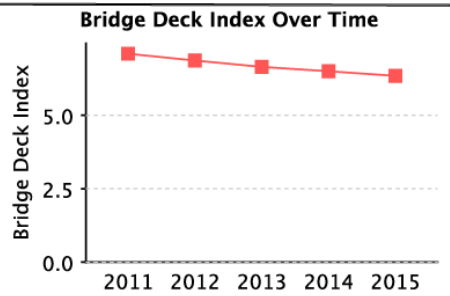


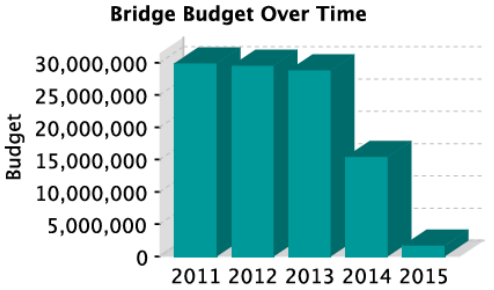
PAVEMENTS





BRIDGES





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Trade-off Across Assets

Step 5: Re-Evaluate System Optimal After Adjusting Implementation Schedule

- **Optimal Solution – Based on Efficient Frontier**
  - Implementation Schedules Not Coordinated
- **Implementation Alternative 1**
  - Coordinated Bridge Preservation and Pavement Maintenance Activities
  - Estimated Traffic Control & Mobilization Cost Savings (0.3%)
- **Implementation Alternative 2**
  - Coordinated Bridge Rehabilitation / Replacement and Pavement Rehabilitation / Reconstruction Activities
  - Estimated Traffic Control & Mobilization Cost Savings (2.7%)
- **Implementation Alternative 3**
  - Coordinated All Possible Bridge and Pavement Activities
  - Estimated Traffic Control & Mobilization Cost Savings (4.3%)

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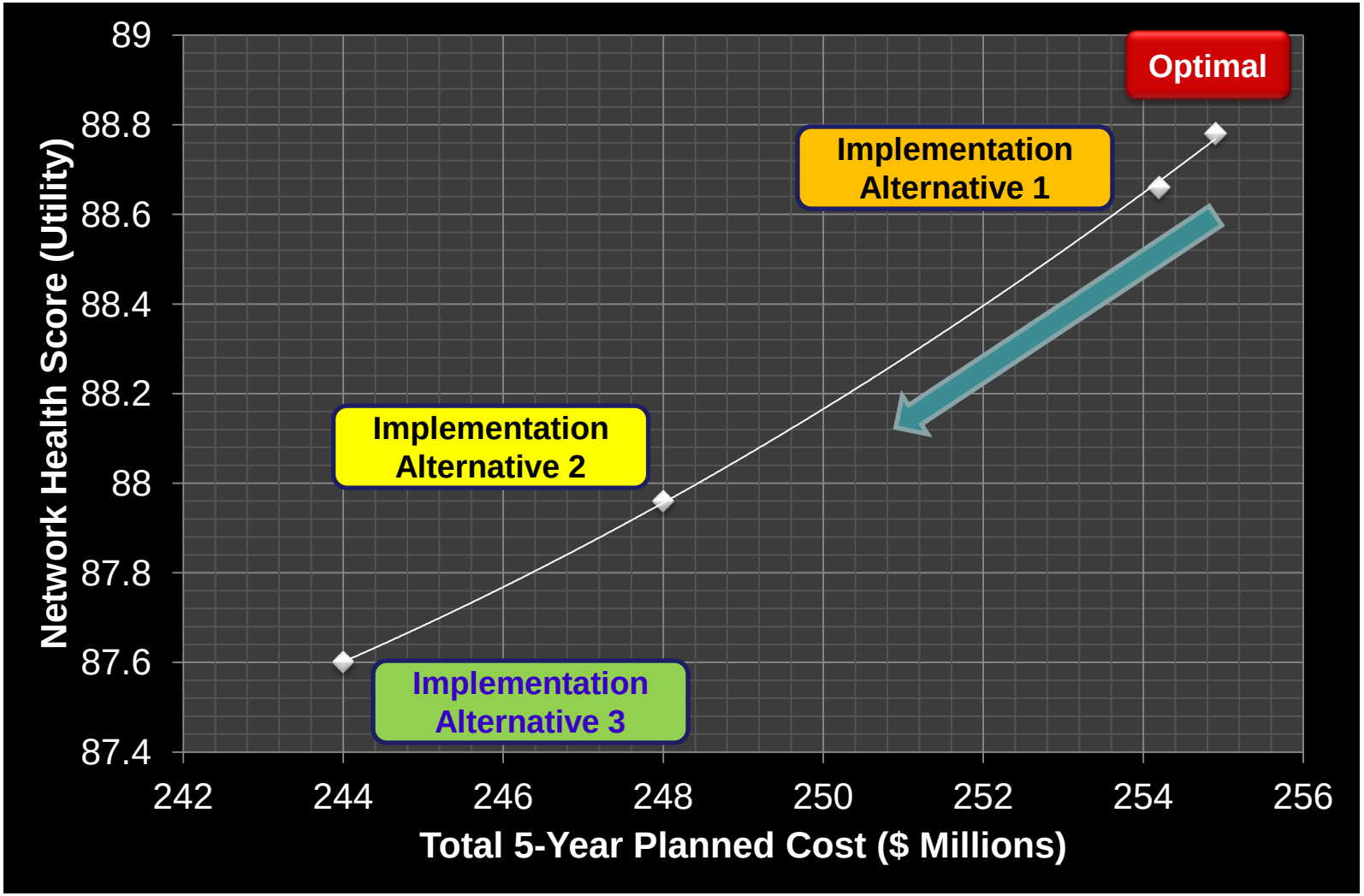
Trade-off Across Assets

Step 5: Re-Evaluate System Optimal After Adjusting Implementation Schedule



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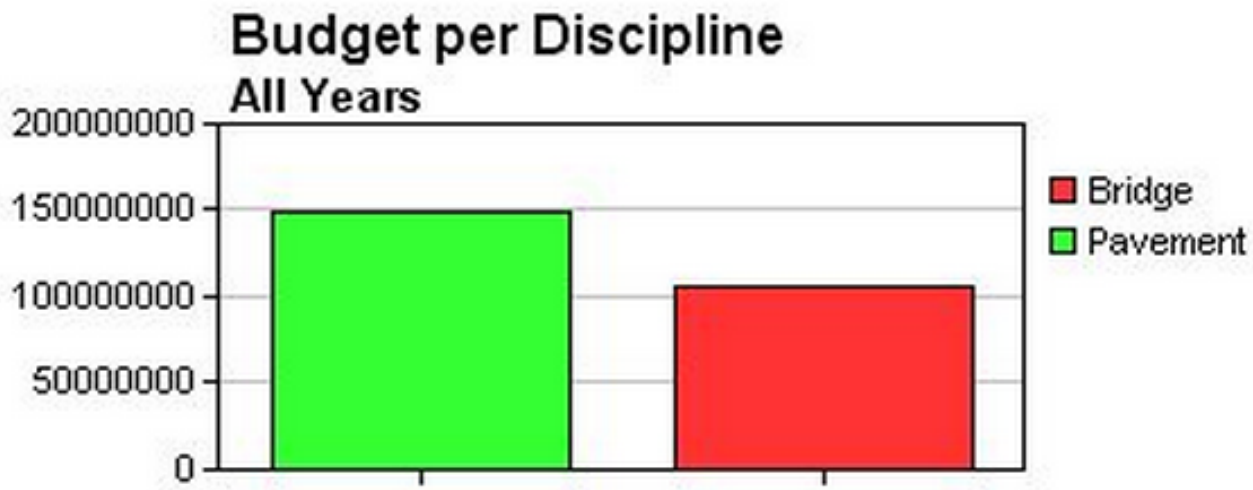
Trade-off Across Assets

Step 5: Re-Evaluate System Optimal After Adjusting Implementation Schedule

Final Split of Funds Across Assets Based on Corridor Trade-of Analysis



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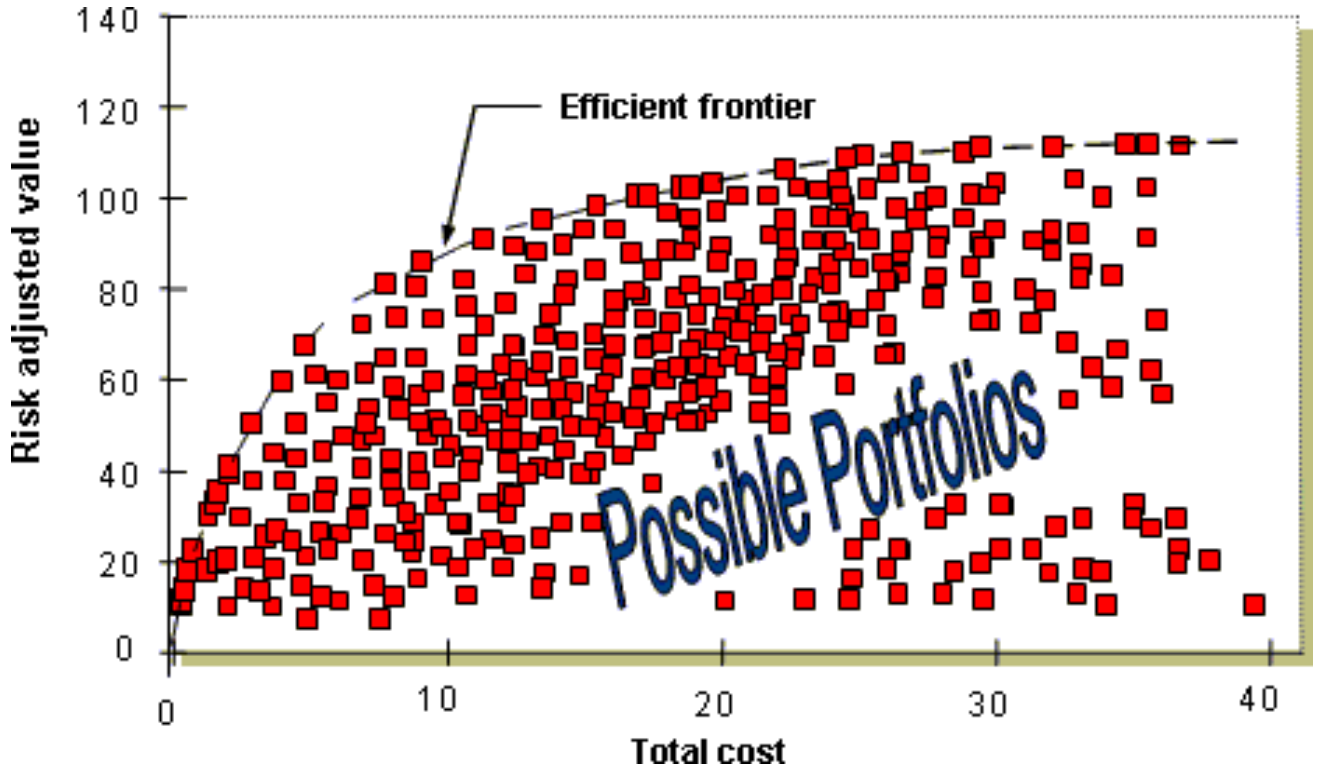
Conclusion

- **Lessons Learned**
  - BMS Optimal + PMS Optimal NOT ALWAYS System Optimal
  - Need to Analyze further to Identify System Optimal Solutions



Conclusion

- **Lessons Learned**
  - Combining Performance Measures across Assets
  - Cross-Asset Analysis is an Evolutionary Process
  - **Integrate** Asset Management Systems (AMSs) for Data-Driven, Cross Asset Tradeoff Analysis
  - AMSs should be able to exchange information at all levels

- **Next Steps**
  - Involving and Educating more people in the Alternatives Evaluation Process
  - Teach the System - More Business Logic and Rules

Questions

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