9th International Conference on MANAGING PAVEMENT ASSETS (ICMPA9)

AGILEASSETS

Developing Optimized Maintenance Work Programs for an Urban Roadway Network using Pavement Management System

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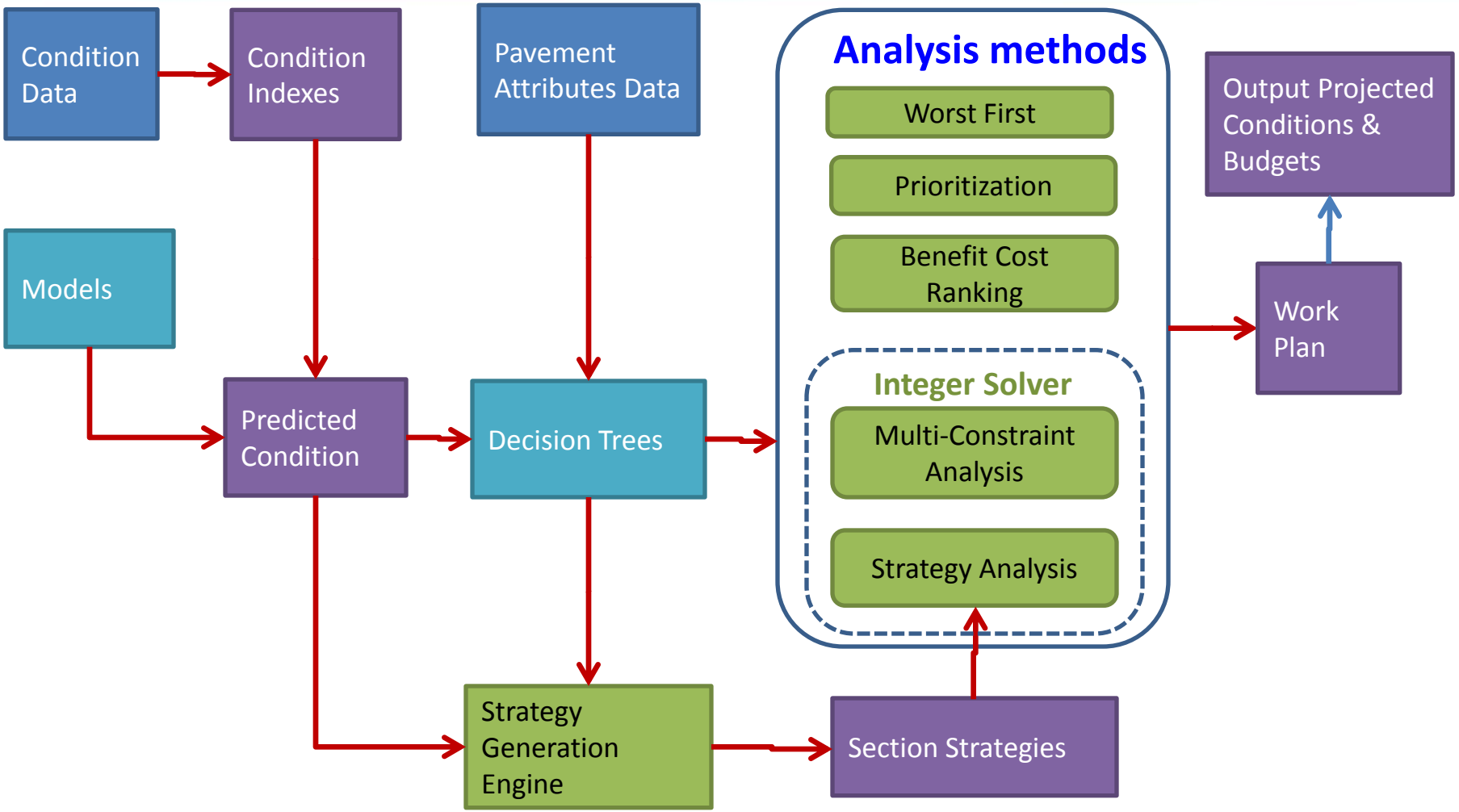
Use of PMS for Network Level Work Program Development

- Implementation of PMS provides a structured and rational approach towards creating maintenance & rehabilitation work programs based on the agency's Budget and Performance goals and constraints.
- PMS mitigates subjective bias and helps achieve objective work plans for the Agency.
- Literature Review suggests that Agencies have been successful in achieving cost savings using PMS.

Objectives of the Study

- To develop maintenance and rehabilitation work programs for a sample urban roadway network using AgileAssets Inc. Pavement Analyst™ tool.
- Comparison of selected network analysis methods and their respective approach in analyzing roadway network.

Pavement Management Network Analysis Process

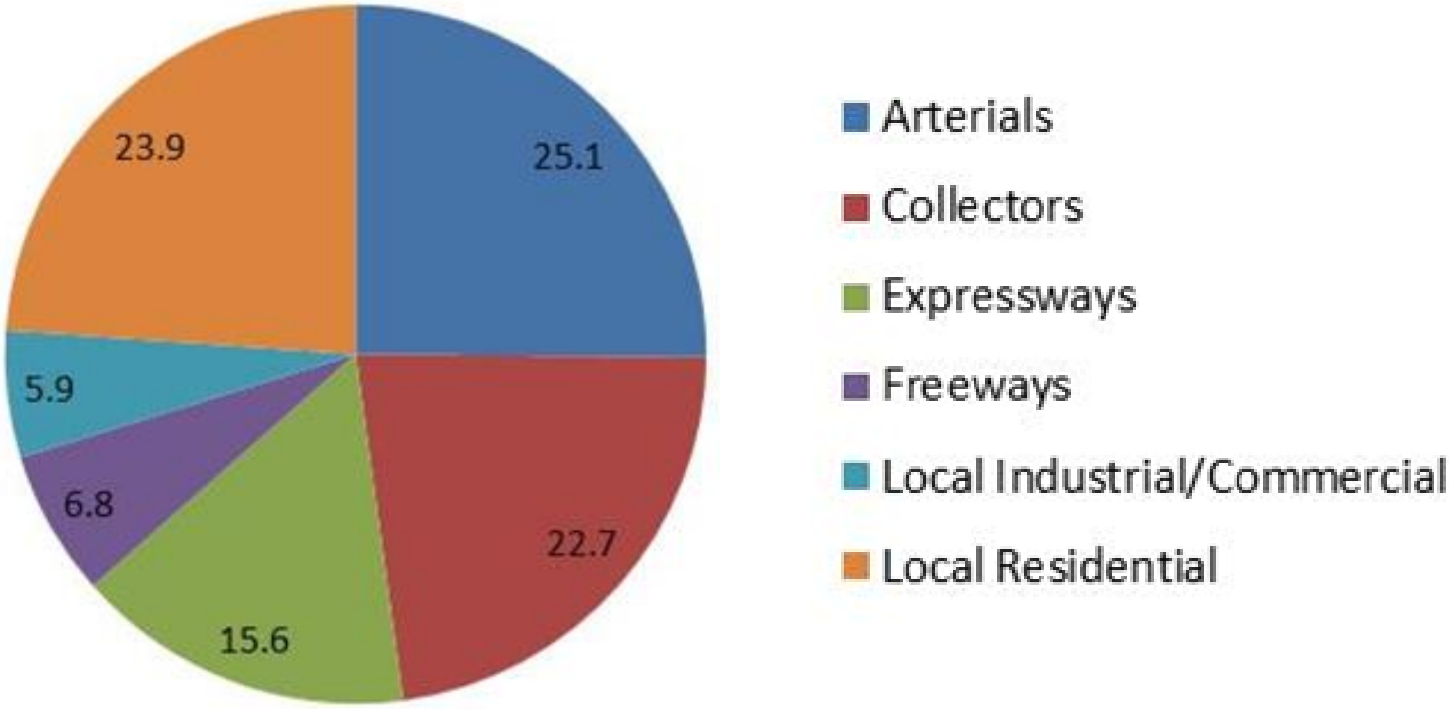


Pavement Management Network Analysis Outputs

- Best Set of Projects
  - Projects meet a set of constraints
  - Maximizes or minimizes an objective (Maximize condition, minimize budget, etc.)
- The desired OUTPUT of Analysis is a WORKPLAN, that tells:
  - What? - Which treatments to apply?
  - Where? - To which sections?
  - When? - In which year?

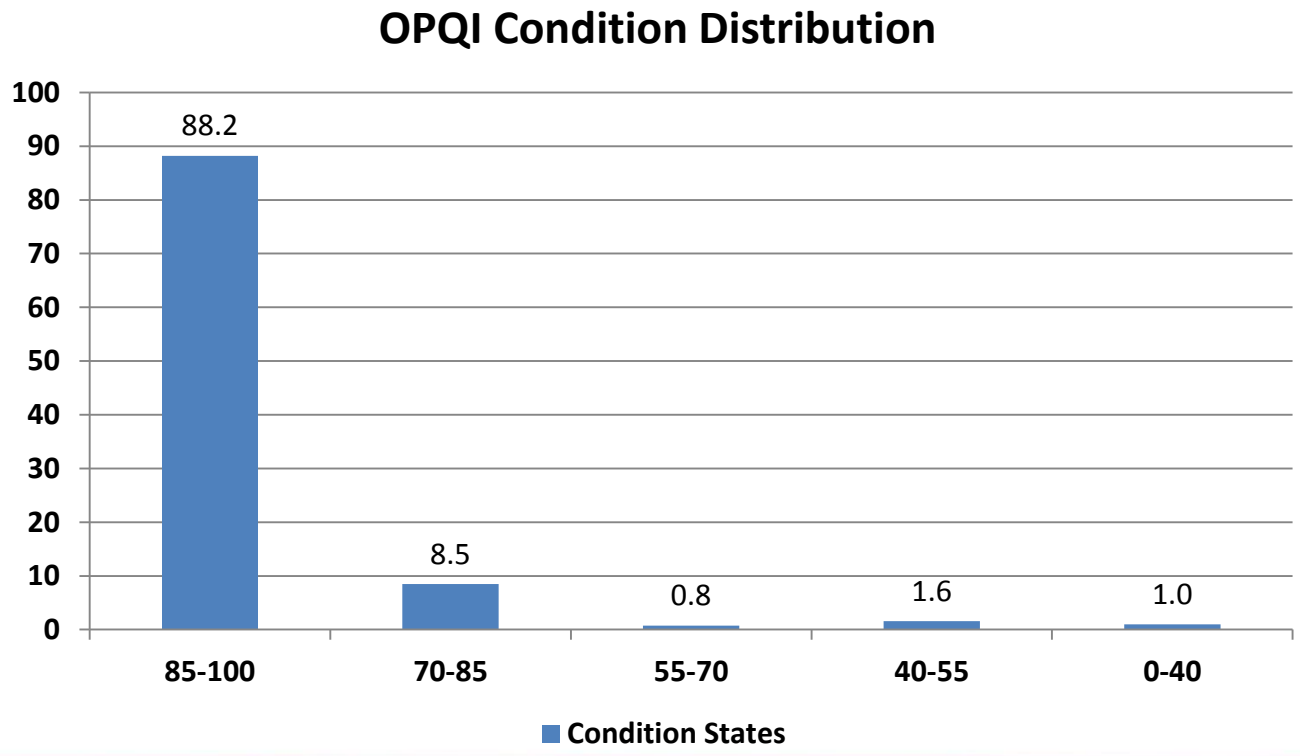
Urban Network Sample

- ~ 4900 lane mile
- Distribution by Functional Class:



Existing Network Condition

- Average Overall Index ~ 88% “Excellent”
- Structurally deficient ~ 4%



Study Methodology –Scenarios

- Scenario:
  - Maximize Performance (Average Overall PQI)
  - Budget Levels 5 Mil & 10 Mil per year (10 mil results are presented here)
  - Analysis Period = 10 years
- Alternate Scenario:
  - Minimize Treatment Cost (Budget) given fixed annual OPQI targets

Study Methodology – Network Analysis Methods

- Analysis Methods using Pavement Analyst™:
  - Worst First
  - Ranking - Benefit Cost
  - Optimization - Multi-Constraint Treatment Analysis
  - Optimization – Multi-Year Strategy Analysis

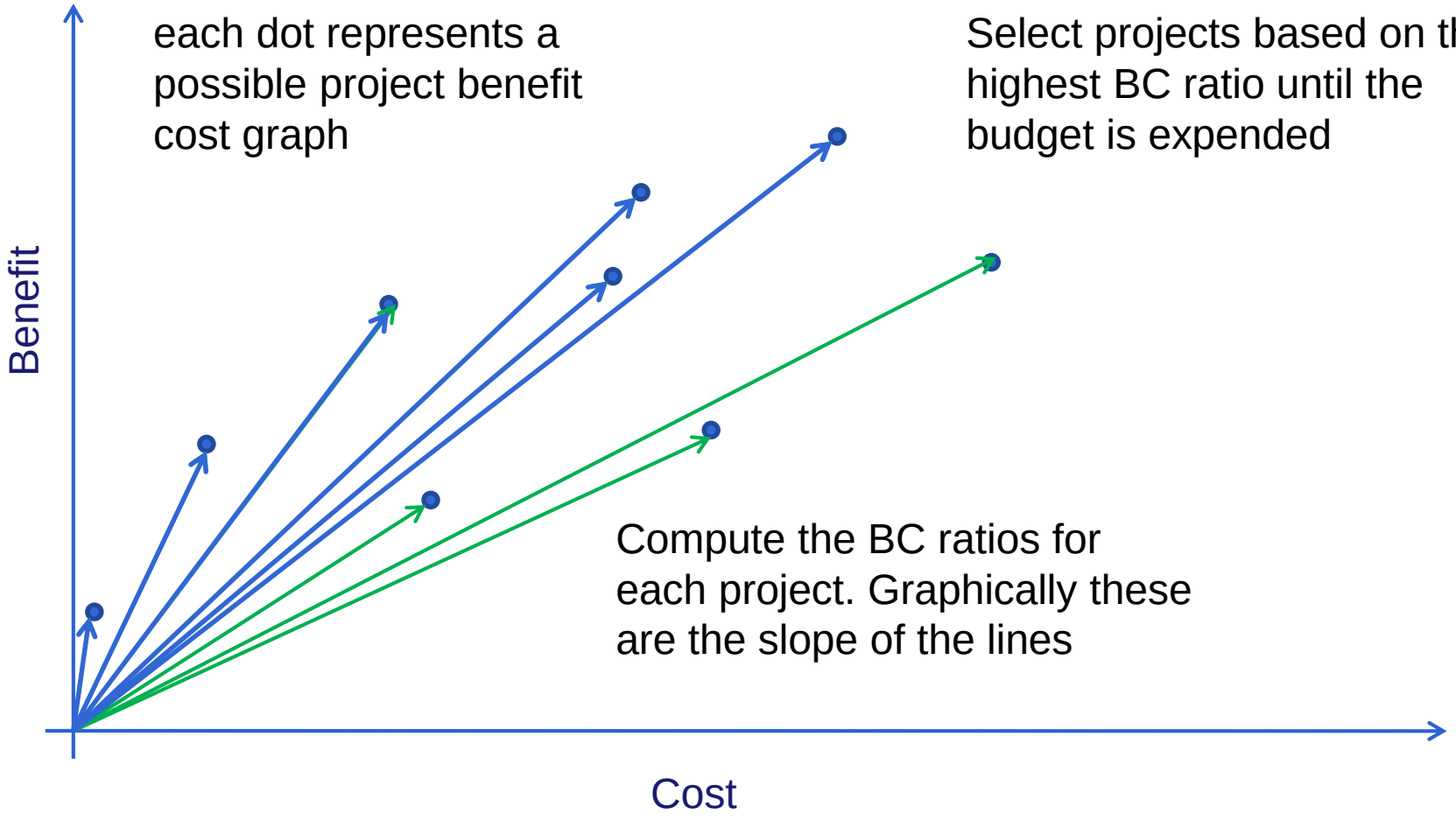
Analysis Scenarios Setup and Execution

- Worst First
  - Budget Constraint Per Year = 10 mil
  - Period = 10 years
  - Pick Lowest Overall PQI Index
- Ranking - Benefit Cost
  - Budget Constraint Per Year = 10 mil
  - Period = 10 years
  - Pick projects with highest BC Ratios

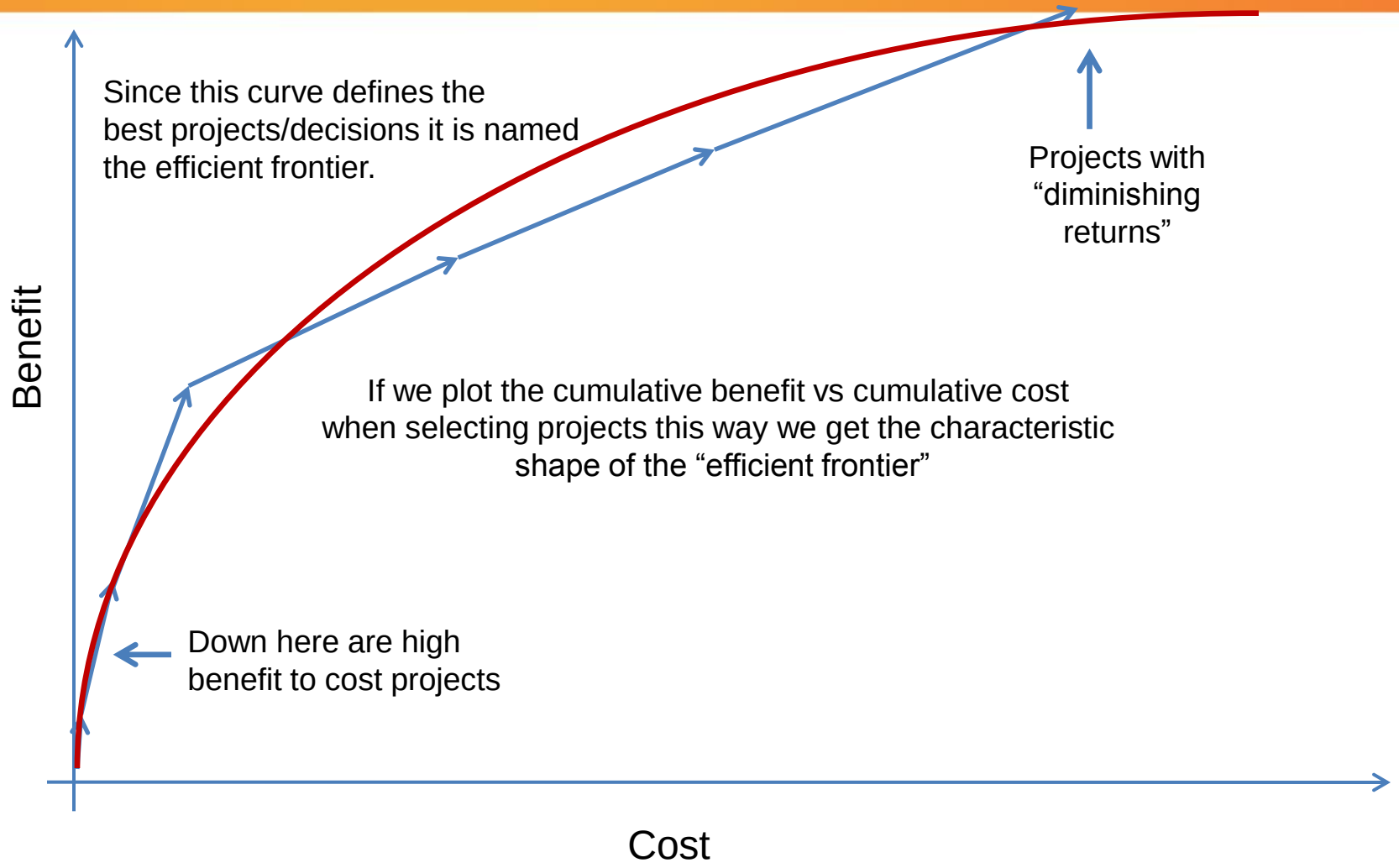
Analysis Scenarios Setup & Execution

- Optimization Methods:
  - Multi-Constraint Treatment Analysis &
    - Objective: Maximize Average “Overall PQI
    - Constraint: Budget = 10 mil per year
    - Additional Constraint: Proportion of Length (OPQI<70) less than10% of the Network
    - Period = 10 years
  - Multi-Year Strategy Analysis
    - Objective: Maximize Average “Overall PQI
    - Constraint: Budget = 10 mil per year
    - Period = 10 years

Projects Selection – Ranking Benefit Cost



Projects Selection – Ranking Benefit Cost - The Efficient Frontier



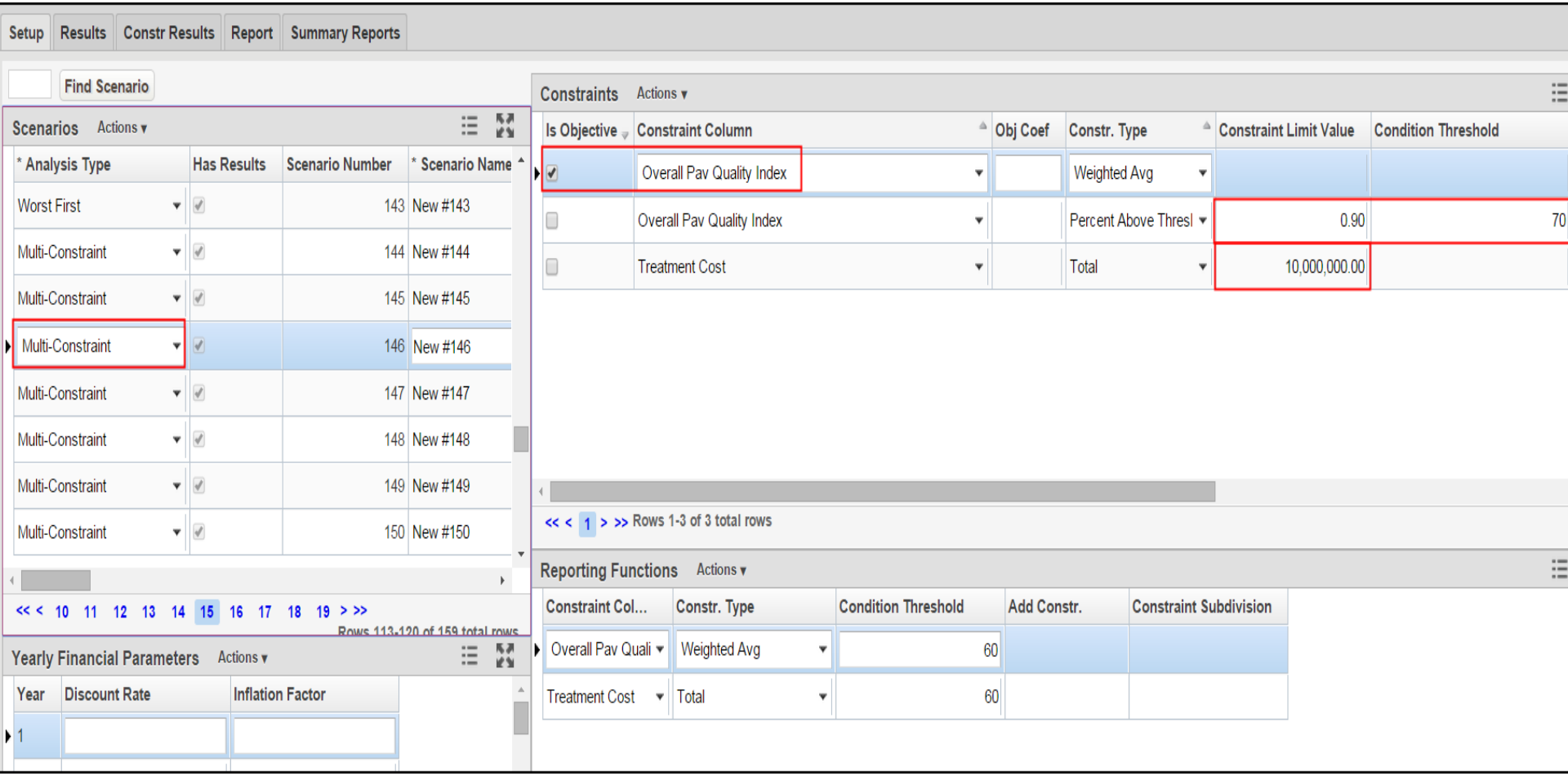
Projects Selection – Multi-Constraint Treatment Analysis

- Treatment Analysis (Multi-Constraint Analysis)
  - Period is broken into Y discrete stages (i.e. year). Optimizing over one year at a time.
  - Use decision trees to assign possible treatment(s). Compute benefits, costs and post treatment conditions
  - Pass Sections to integer-programming SOLVER
  - Optimal work plan passed back from solver
  - Sections selected for treatment are improved
  - The results of each year are used as a starting point for the next year.

Projects Selection – Multi-Year Strategy Analysis

- Strategy Analysis (Multi-year Analysis)
  - Complex problem compared to the discrete year Multi-constraint Treatment Analysis.
  - Multiple feasible strategies for each section are analyzed together across full planning period.
  - Strategy is a work plan for a section. For example, reconstruction in the first year, DN in next 8 years and crack sealing in year 10.
  - Problem size is reduced by defining funding Strategy in terms of which years section can be treated and which years it cannot.

Example Multi-Constraint Analysis Scenario Setup



Typical Scenario Outputs Report

Setup | Results | Constr Results | Report | Summary Reports

Constraint Report Actions ▾

Constraint Column	Constr. Type	Scenario Year	Resulting Value
Overall Pav Quality Index	Weighted Avg	1	98.4081
Overall Pav Quality Index	Weighted Avg	2	98.1162
Overall Pav Quality Index	Weighted Avg	3	97.7493
Overall Pav Quality Index	Weighted Avg	4	97.3118
Overall Pav Quality Index	Weighted Avg	5	96.759
Overall Pav Quality Index	Weighted Avg	6	96.1164
Overall Pav Quality Index	Weighted Avg	7	95.3903
Overall Pav Quality Index	Weighted Avg	8	94.5945
Overall Pav Quality Index	Weighted Avg	9	93.7322
Overall Pav Quality Index	Weighted Avg	10	92.817
Treatment Cost	Total	1	9982626
Treatment Cost	Total	2	9967051
Treatment Cost	Total	3	9997748
Treatment Cost	Total	4	9875886

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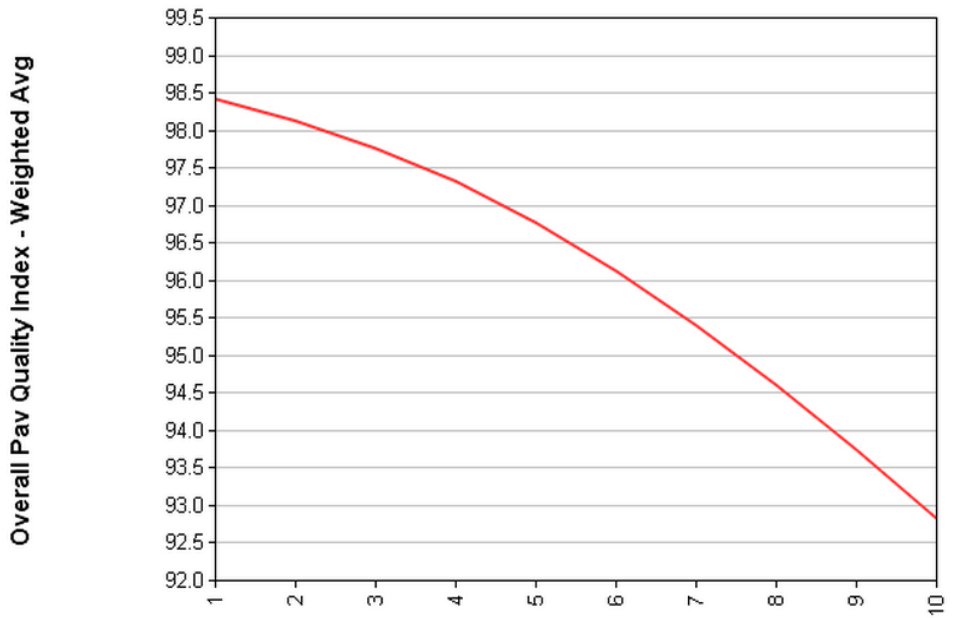
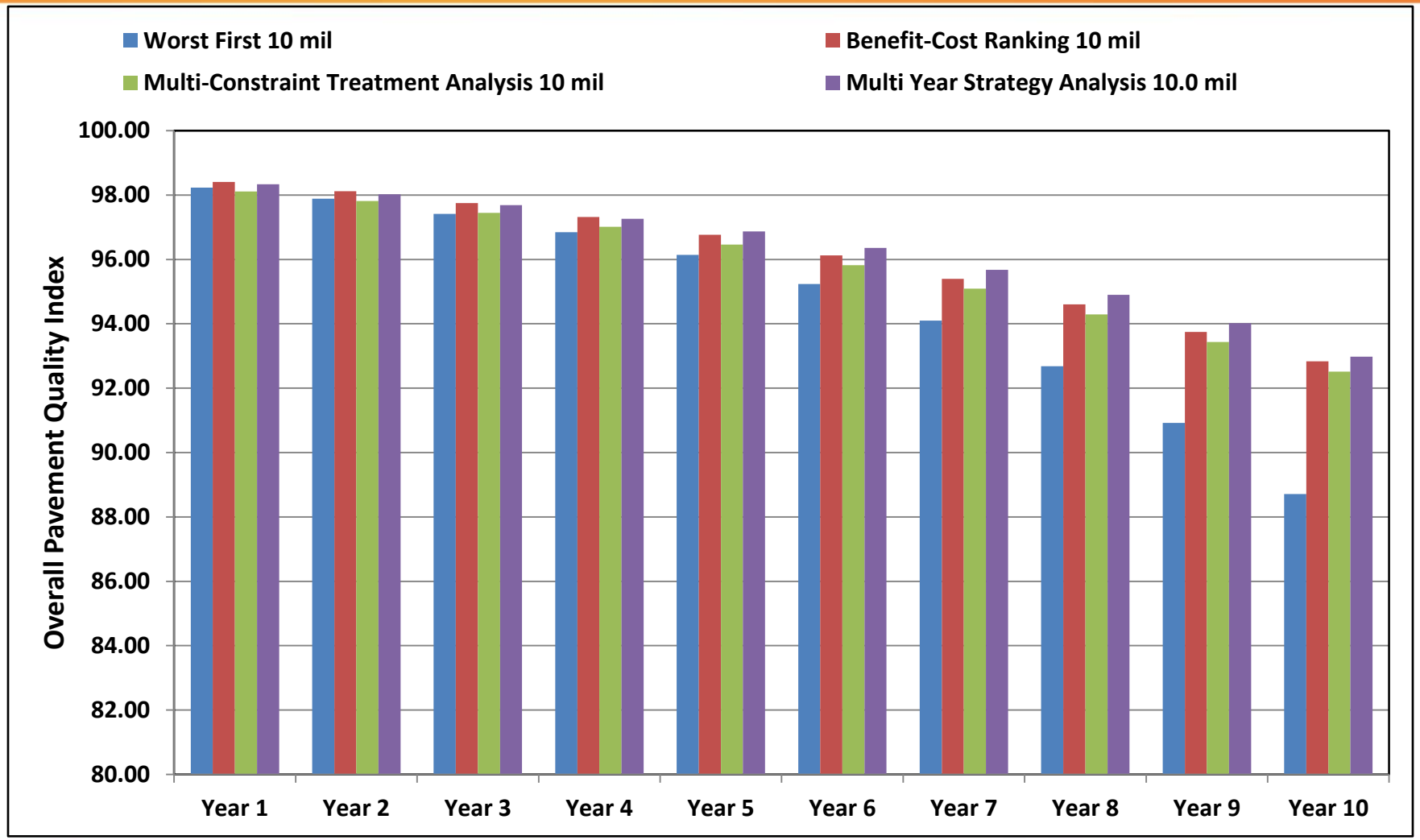
Constraint Column:Overall Pav Quality Index - Constr. Type:Weighted Avg



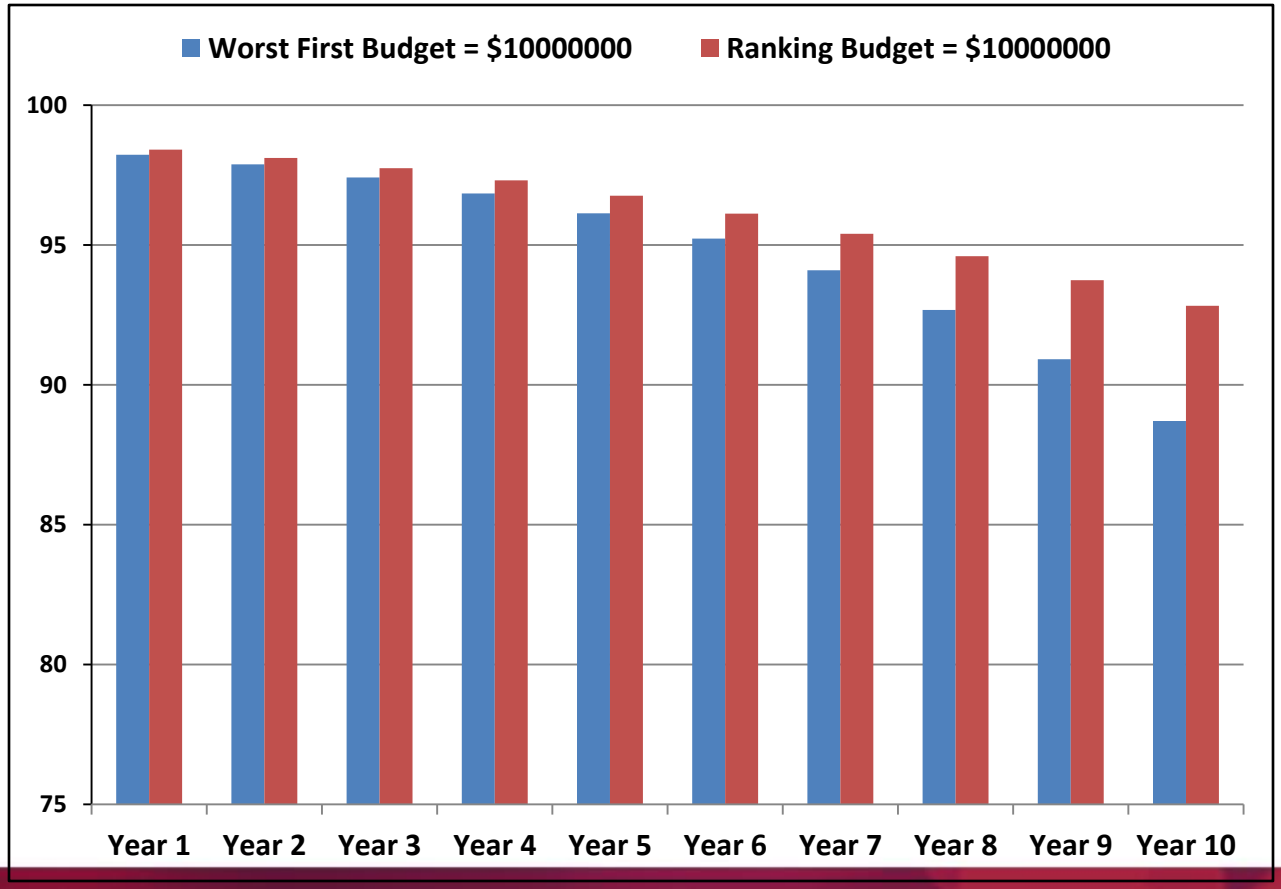
Comparing Overall Results – Scenario – Fixed Budget



Worst First & B/C Ranking Results Comparison – Fixed Budget

- BC Ranking produce Overall higher Network Conditions compared to Worst-First

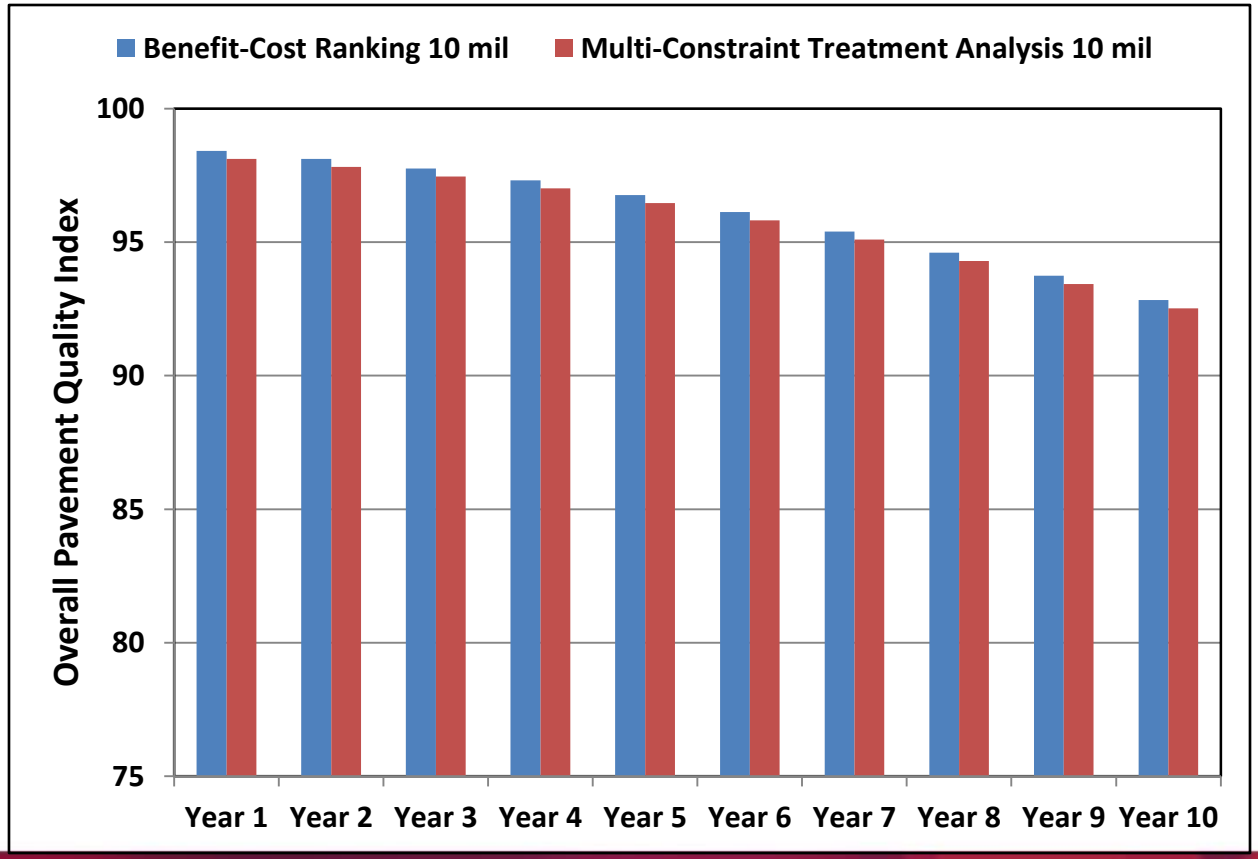
- Terminal Condition at the end of Analysis Period is "~5%" higher for BC Ranking compared to Worst First.



B/C Ranking & Multi-Constraint Results Comparison – Fixed Budget

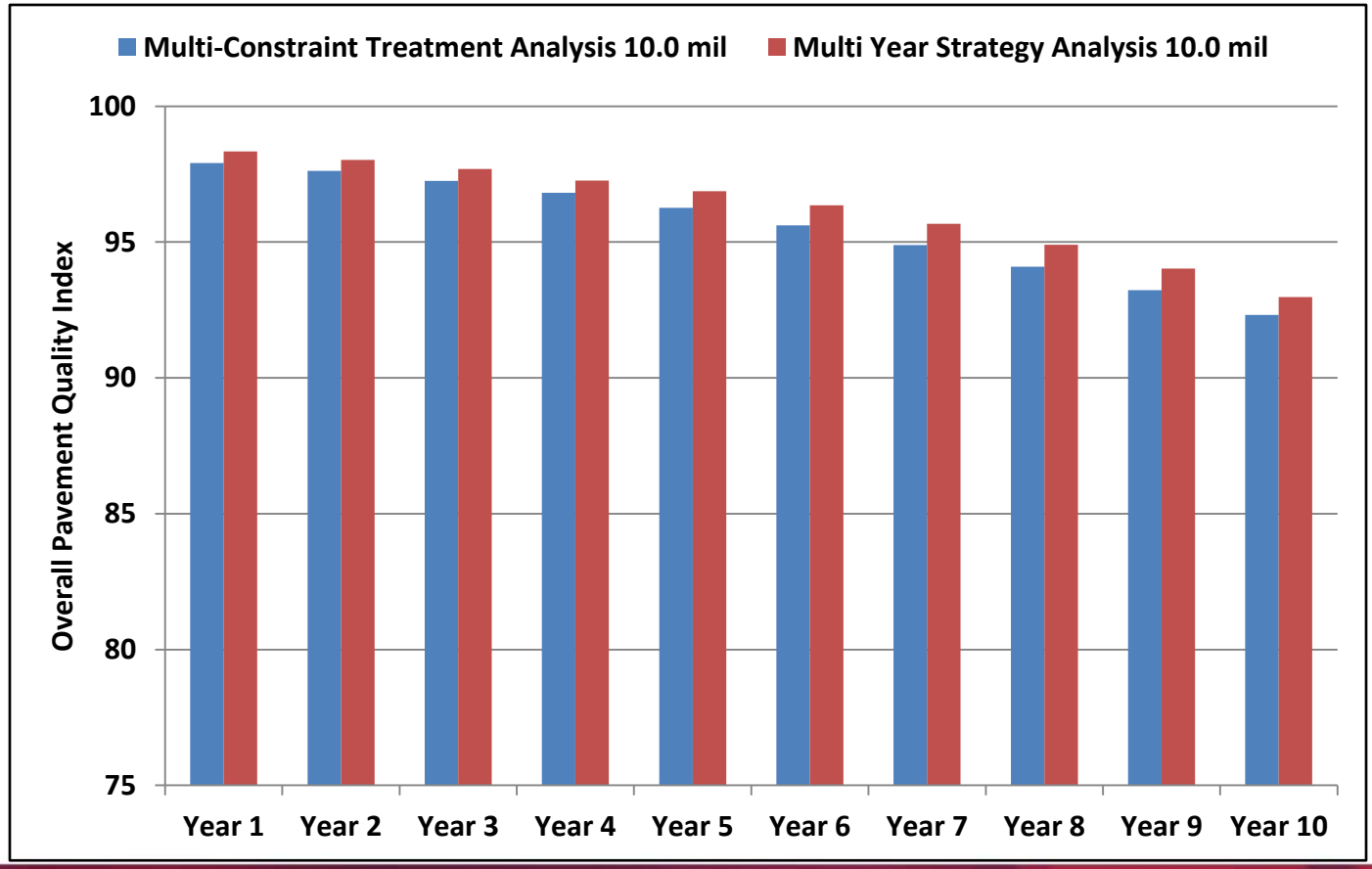
- Multi-Constraint optimization produces similar results as BC Ranking for scenarios that include single constraint (Budget).

- Ranking is showing slightly better results (less than 1%) most likely due to the additional Constraint used in Multi-Constraint.



Multi-Constraint & Multi-Year Results Comparison – Fixed Budget

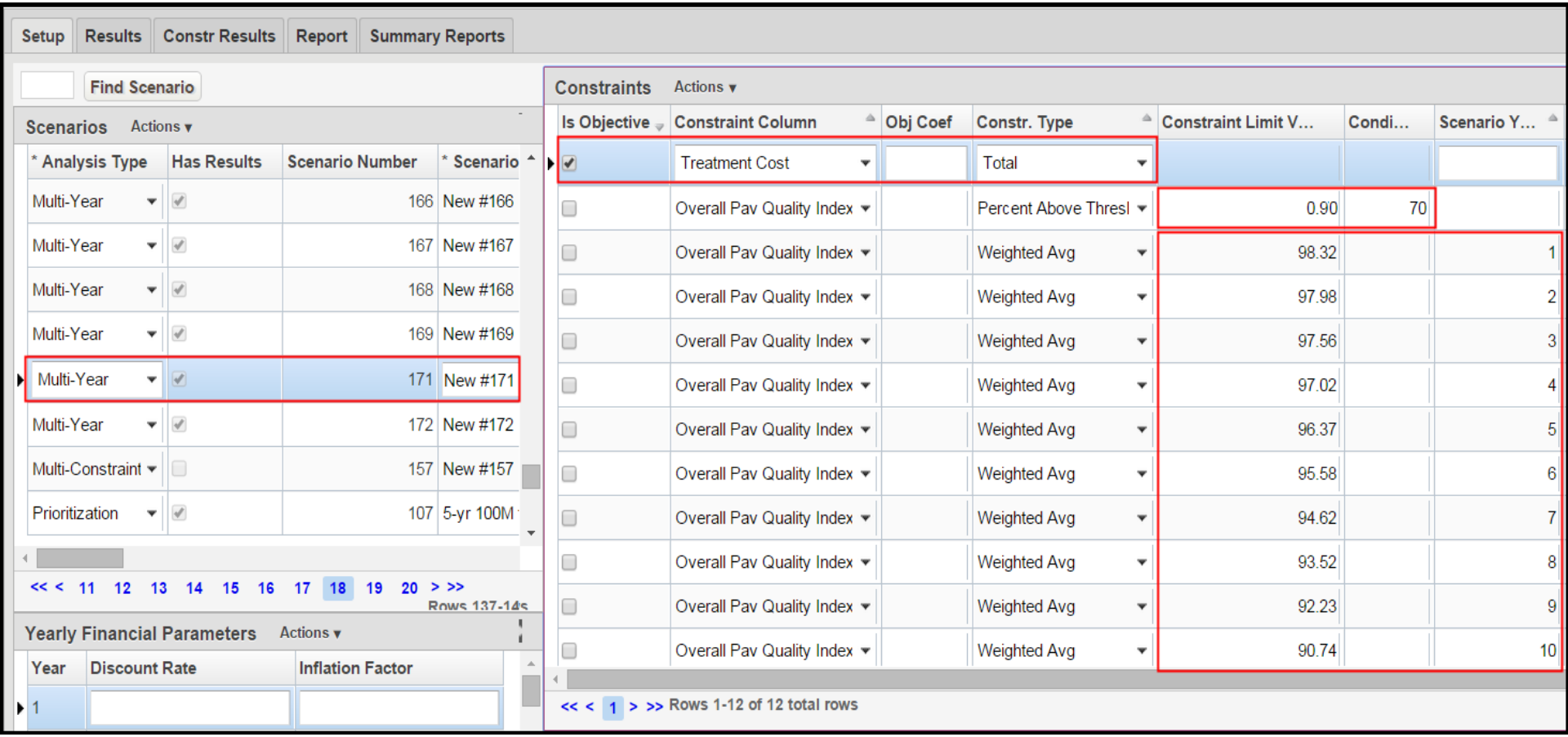
- Systematic improvement in network condition in Strategy Analysis results compared to Multi-Constraint Analysis.
- Condition increase is (~1%) in the sample network used.



Multi-Constraint & Multi-Year Results Comparison – Fixed Condition

- Alternate – Reverse Scenario
  - Objective: Minimize Budget
  - Constraint: OPQI annual limits
    - Using Terminal Annual Conditions generated by Multi-Constraint Analysis as “Constraints” in Multi-Year Analysis.
  - Additional Constraint: Proportion of Length (OPQI<70) less than10% of the Network
  - Period = 10 years

Example Multi-Year Scenario Setup



Multi-Constraint & Multi-Year Results Comparison – Fixed Condition

- Average Budget Per Year for Strategy Analysis is 6% (10 yr.) to 9% (5 year) less compared to Treatment Analysis achieving same Average Annual OPQI Condition score

Multi-Constraint Treatment Analysis (mil)	Multi Year Strategy Analysis (mil)	Strategy Analysis Budget Savings
4.98	4.51	9% Savings
9.98	9.34	6% savings

Conclusions

- “Worst-First” approach generates work plans that are not cost-effective compared to other analysis methods.
- “BC Ranking” method can produce good results but it handles one constraint which can be a significant limitation.
- “Multi-Constraint” analysis handles multiple constraints. However, additional constraints reduce the solution space and may provide some what sub-optimal results.
- “Multi-Year Strategy Analysis” represents a paradigm shift in network optimization methods. Other Analysis methods solve single year plans and the solution is carried forward to the next year. “Multi-Year Strategy” method determines potential candidates across the entire planning horizon and chooses the optimal treatment strategy for the individual sections.

Conclusions

- Overall network condition was not significantly different (0.5-1.0%) among, “BC Ranking” “Multi-Year”, or “Multi-Constraint” under fixed Budget scenario.
- Alternative scenario minimizing budget given the target annual condition constraints using the “Multi-Year Strategy” analysis shows cost savings between 6% (10 yr) and 10% (5 yr) which are significant cost savings.
- The results presented show that the use of PMS Analytics can yield reliable knowledge based objective decisions.
- Continue Study with additional scenarios and conducting sensitivity analysis of variables and their impact in different analysis methods used in this study.

Thank You

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