Multi-Year, Multi-Constraint Strategy
to
Optimize Linear Assets Based on Life Cycle Costs

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Pavement Asset Management

- **Pavement management** is the process of planning the maintenance and rehabilitations of a network of roadways in order to **optimize** pavement condition and cost over the entire network.
NEED for PMS

• Transportation infrastructures represent a very large amount of investment.

• Preservation of these assets implies continuous investments to achieve serviceability, safety, life span.

• In the US, an estimated $91 billion is budgeted to maintain highway pavements, but there is still a shortfall of $89 billion annually — leading to a decline in condition and performance of pavements (*)

* ASCE, 2013 Report Card for America’s Infrastructure, American Society of Civil Engineers
PMS Outputs : What Where When

• Desired Output is a Work Plan

• Modern PMS assist decision makers in determining “what treatment, when, and where?” by optimizing pavement network work plans under budgetary and other agency constraints and objectives.
Common Analysis Methods

• Worst First Method
• Ranking (Benefit/Cost)
• Optimization Multi Constraint (Sequential Opt.)
• Optimization Multi Year (Holistic Opt.)
WORST FIRST

- Overly simplistic
- Spending the budget mostly on first years
- Ignoring Preventive Maintenance
- Not Optimized
Ranking

• Benefit Cost Analysis (BCA)
• Has been widely used by several transportation agencies
• Not too complex to implement and understand
• Cannot solve problems with multiple overlapping constraints
• It is not optimized
Need for Multiple Overlapping Constraints

– No budget in first year, X dollar in second year, Y dollar in third year

– PCI>75 for district A and PCI>80 for district B etc.

– Constrains that targets different roadway classes (Interstate, Primary Roads, Secondary Roads)

– PCI>75 for 80% or more of the network and not more than 10% of the network to have PCI<25
Ranking

- Available Budget is 250,000 $

<table>
<thead>
<tr>
<th>Sections</th>
<th>Treatment</th>
<th>Cost</th>
<th>Benefit</th>
<th>B/C (X100)</th>
<th>Selected</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>T1</td>
<td>$40,000</td>
<td>1400</td>
<td>3.50</td>
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<tr>
<td>5</td>
<td>T5</td>
<td>$15,000</td>
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<td>3.00</td>
<td>x</td>
</tr>
</tbody>
</table>

Total Spent : 135,000 $ (55%)
Sum of Benefit : 4550

* Benefit is defined as the area under the condition curve for each segment (Sum of condition score over service time)
Optimization

- Optimization checks different combo of Treatments in different years and solve for best sets of Projects
- Optimization can analyze problems that B/C ranking cannot tackle
- Optimization can handle Multiple overlapping constraints
- The solution is a real work plan with identified sections and treatments
Multi Constraint Optimization

- **Multi Constraint**: Year by year analysis. Start with recommending a treatment for each section for each year (Sequential)

- **Multi Constraint** analyzes each single year discretely.

- **Multi Constraint** solution is optimal in each year.
Multi - Constraint Analysis

Year No 1

Network (Management Sections)

Section 1
Section 2
Section 3
Section 4
Section 5

Decision Tree

Treatment (For S1)
Treatment (For S2)
Treatment (For S3)
Treatment (For S4)
Treatment (For S5)

Project Selection Based on Constraints

Project 1
Project 2
Project 3
Multi - Constraint Analysis

Year No 1

Network (Management Sections)

- Section 1
- Section 2
- Section 3
- Section 4
- Section 5

Decision Tree

- Treatment (For S1)
- Treatment (For S2)
- Treatment (For S3)
- Treatment (For S4)
- Treatment (For S5)

Project Selection Based on Constraints

- Project 1
- Project 2
- Project 3

Year No 2

Network (Management Sections)

- Section 1
- Section 2
- Section 3
- Section 4
- Section 5

Decision Tree

- Treatment (For S1)
- Treatment (For S2)
- Treatment (For S3)
- Treatment (For S4)
- Treatment (For S5)

Project Selection Based on Constraints

- Project 1
- Project 2
- Project 3

Year No 3

Network (Management Sections)

- Section 1
- Section 2
- Section 3
- Section 4
- Section 5

Decision Tree

- Treatment (For S1)
- Treatment (For S2)
- Treatment (For S3)
- Treatment (For S4)
- Treatment (For S5)

Project Selection Based on Constraints

- Project 1
- Project 2
- Project 3

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Multi Year Optimization

- Multi Year Multi Constraint: Checks the whole analysis Period for each section.

- More Complex, Bigger problem

- For short analysis period Multi Year results is marginally as optimal as Multi Constraint
## Multi Year

<table>
<thead>
<tr>
<th>Strategy</th>
<th>Year 1</th>
<th>Year 2</th>
<th>Year 3</th>
<th>Year 4</th>
<th>Year 5</th>
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<tbody>
<tr>
<td>Strategy 1</td>
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## Multi Year

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<td>Strategy 5</td>
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</table>

### Decision Tree

Section 1
- Strategy 1
- Strategy 2
- Strategy 3

Section 2
- Strategy 1
- Strategy 2

Section 3
- Strategy 2

Select Best for Each Section
- Section 1
- Strategy 5
- Section 2
- Strategy 3
- Section 3
- Strategy 1
- Section 4
- Strategy 2

Projects (WP)
- Project 1
- Project 2
- Project 3
- Project 4
Case Study for Analysis

- ~2000 Management Sections
- ~200000 lane miles
- 20 Treatment Alternatives
- Pavement Condition from Poor, to Good
- Average Condition Index = 70
Optimization

- Optimization method presented here have been used for many large scale networks ranging from the largest highway networks in the nation (e.g., Texas, North Carolina, Virginia) to smaller county/city networks.

<table>
<thead>
<tr>
<th>* SCENARIO NAME</th>
<th>* ANALYSIS TYPE</th>
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<tbody>
<tr>
<td>Need Analysis</td>
<td>Estimate MWP Influence</td>
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<td>Multi Year with Work Plan</td>
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<td>Multi-Constraint</td>
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<td>Prioritization</td>
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<tr>
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<td>Ranking</td>
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<tr>
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<table>
<thead>
<tr>
<th>* YEAR OF CONDITION DATA</th>
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<table>
<thead>
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<th>* DECISION TREE SET</th>
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<tbody>
<tr>
<td>test</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>MWP SCOPE</th>
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</table>
• Case Study Number 1
Need Analysis
5 years- Need Analysis

Total spending almost was the same for both optimization methods (Need Analysis) after running analysis.

<table>
<thead>
<tr>
<th>Number of Projects in the Work Plan</th>
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<tbody>
<tr>
<td>Multi-Constrain</td>
</tr>
<tr>
<td>1733</td>
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</table>

Objective: Maximize Benefit
Unlimited Budget ($$$$$$)
• Case Study Number 2
  Limited Budget Analysis
While benefits are maximized exactly the same way in both analyses, Multi Year analyses reached that benefit by spending less money which demonstrates better optimization.
Summary

- Pavement management project selection for a large network is a complex problem specially when having several overlapping constraints.
- Solving such complex problem need appropriate approach and powerful tools.
Summary

• Ranking method is not optimized.
• Ranking method can not handle multiple constraints

• **Optimization** is proven to be the best solution.

• Results from analysis on different networks have shown significant budget **savings** when using optimization methods.

• Particularly for longer analysis periods, Multi-Year optimization analysis leads to better results and can save more money compare to Multi-Constraint analysis.
Thank You!