Optimization Model for Highway Work Zones (HWZs) Considering Safety, Mobility, and Work costs

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33rd ICTCT Conference, online, October 2021
Outline

• Background & Motivation

• Research Objective

• Optimization Model

• Conclusions
Background & Motivation

- Significant adverse impacts
  - 19B dollar per year
  - 10% of overall congestion delay
  - Increased crash risk: 40,000 injuries, 800 fatalities
### HWZ cost components

<table>
<thead>
<tr>
<th>Work</th>
<th>Agency</th>
<th>Material, equipment, labor, site overheads</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>TTC</td>
<td>Temporary traffic control</td>
</tr>
<tr>
<td>Mobility</td>
<td>Lost time</td>
<td>Extra traveled time</td>
</tr>
<tr>
<td></td>
<td>VOC</td>
<td>Vehicle operation costs</td>
</tr>
<tr>
<td></td>
<td>Emissions</td>
<td>Change in emission cost</td>
</tr>
<tr>
<td>Safety</td>
<td>Crash</td>
<td>Change in crash cost</td>
</tr>
</tbody>
</table>

- **Safety**
  - Crash: Change in crash cost

- **Mobility**
  - Lost time: Extra traveled time
  - VOC: Vehicle operation costs
  - Emissions: Change in emission cost

- **Work**
  - Agency: Material, equipment, labor, site overheads
  - TTC: Temporary traffic control

- **Total**
  - Work: Agency (Material, equipment, labor, site overheads) + TTC (Temporary traffic control)
  - Mobility: Lost time (Extra traveled time) + VOC (Vehicle operation costs) + Emissions (Change in emission cost)
  - Safety: Crash (Change in crash cost)
Background & Motivation

- A tool is needed to plan HWZ operations
  - Mitigate its adverse impacts
  - Optimization to minimize total cost
  - Consider all cost components
HWZ optimization models

• Current models (e.g., Chen and Schonfeld, 2004; Yang et al., 2009; Du and Chien, 2014)
  • Simplified agency costs and schedule
  • Crash costs and VOC as fraction of lost time
  • Traffic diversion model is missing
  • None considered emission cost
This research

• Develop HWZ optimization model
  • Consider safety, mobility, and work costs

• Incorporate
  • Location-based schedule
  • Crash cost model
  • Traffic flow model with alternative route choice
Objective function

\[ \text{Min}(TPC) = \text{Min}(AGC + TCC + LTS + VOC + EMC + CRC) \]

s.t.

\[ LB_i \leq X_i \leq UB_i \quad i = 1,2, ..., n \]

\[ AGC + TCC \leq B^{max} \]

\[ D \leq D^{max} \]

\[ TCMF \leq TCMF^{max} \]

\[ LT \leq LT^{max} \]

\[ G(X) \leq 0 \]

TPC - Total project cost
AGC - Agency cost
TCC - Temporary traffic control cost
LTC - Lost time cost
VOC - Vehicle operating cost
EMC - Emission cost
CRC - Crash cost
Decision variables

• Work schedule
  • Work days, hours, and start time/Crew formation

• TTC (Temporary Traffic Control)
  • Variable message signs/Speed display/Attenuator/Photo enforcement/flagger and police presence/Posted speed limit

• Site geometry
  • Workspace length/Lateral clearance, lane and shoulder width
Objective function calculation

1. Candidate solution
2. Location-based scheduling
3. Project details
4. Project schedule
5. Traffic flow model
6. Travel speed
7. Lost time
8. Converge?
9. Route choice model
10. Flows
11. No
12. Crash record
13. Crash cost model
14. Crash
15. Lost time
16. VOC
17. Emission
18. Yes
19. Agency TTC
20. TTC
21. Total project cost
22. Yes
23. Crash
24. No
25. Crash
26. Lost time
27. VOC
28. Emission
29. Total project cost
Case study

- 20 km resurfacing project

- Scenarios:
  - Unrestricted time of day vs daytime only
  - Use of optional TTC
  - Proposed vs simplified models
## Proposed model

<table>
<thead>
<tr>
<th>Optional TTC</th>
<th>Unrestricted time of day</th>
<th>Daytime only</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scenario</td>
<td>Available</td>
<td>Not Available</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>

### Costs

<table>
<thead>
<tr>
<th>Costs</th>
<th>Unrestricted time of day</th>
<th>Daytime only</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total project cost ($)</td>
<td>668,690</td>
<td>709,540</td>
</tr>
<tr>
<td>Agency</td>
<td>91.92%</td>
<td>89.06%</td>
</tr>
<tr>
<td>TTC</td>
<td>7.62%</td>
<td>6.42%</td>
</tr>
<tr>
<td>Lost time</td>
<td>3.59%</td>
<td>0.59%</td>
</tr>
<tr>
<td>Vehicle operation</td>
<td>0.67%</td>
<td>0.29%</td>
</tr>
<tr>
<td>Emission</td>
<td>-0.03%</td>
<td>-0.03%</td>
</tr>
<tr>
<td>Crash</td>
<td>-3.76%</td>
<td>3.67%</td>
</tr>
</tbody>
</table>

### Project impacts

<table>
<thead>
<tr>
<th>Project impacts</th>
<th>Unrestricted time of day</th>
<th>Daytime only</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total delay (veh-hr)</td>
<td>1,094</td>
<td>192</td>
</tr>
<tr>
<td>TCMF</td>
<td>0.27</td>
<td>2.04</td>
</tr>
<tr>
<td>Workspace length (m/day)</td>
<td>1,418</td>
<td>1,103</td>
</tr>
<tr>
<td>Project duration (days)</td>
<td>14</td>
<td>18</td>
</tr>
<tr>
<td>Work start time</td>
<td>10 PM</td>
<td>11 PM</td>
</tr>
</tbody>
</table>
## Models' comparison

<table>
<thead>
<tr>
<th>Model</th>
<th>Proposed</th>
<th>Simplified agency and schedule</th>
<th>Simplified crash cost</th>
</tr>
</thead>
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<tr>
<td><strong>Costs</strong></td>
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<td></td>
<td></td>
</tr>
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<td>Total project cost ($)</td>
<td>668,690</td>
<td>766,560</td>
<td>681,440</td>
</tr>
<tr>
<td>Agency</td>
<td>91.92%</td>
<td>93.93%</td>
<td>91.31%</td>
</tr>
<tr>
<td>TTC</td>
<td>7.62%</td>
<td>7.66%</td>
<td>6.50%</td>
</tr>
<tr>
<td>Lost time</td>
<td>3.59%</td>
<td>0.58%</td>
<td>1.78%</td>
</tr>
<tr>
<td>Vehicle operation</td>
<td>0.67%</td>
<td>0.30%</td>
<td>0.43%</td>
</tr>
<tr>
<td>Emission</td>
<td>-0.03%</td>
<td>-0.03%</td>
<td>0.03%</td>
</tr>
<tr>
<td>Crash</td>
<td>-3.76%</td>
<td>-2.44%</td>
<td>0.01%</td>
</tr>
<tr>
<td><strong>Project impacts</strong></td>
<td></td>
<td></td>
<td></td>
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<td>Total delay (veh-hr)</td>
<td>1,094</td>
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<td>-</td>
</tr>
<tr>
<td>Workspace length (m/day)</td>
<td>1,418</td>
<td>1,000</td>
<td>1,260</td>
</tr>
<tr>
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<td>14</td>
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Conclusions

• Developed HWZ optimization model
  • Account for all cost components
  • Incorporate location-based scheduling, crash cost model, and alternative route choice

• Case study
  • Crash costs are substantial, optional TTC are recommended
  • Location-based scheduling improves the cost estimates
  • Emission costs are relatively small
Thanks For Your Attention
Any Questions?