Evaluation of Bridge Functional Obsolescence Using Congestion Performance Measures Determined from Anonymous Probe Vehicle Data

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Moving Ahead for Progress in the 21st Century Act

- MAP 21
  - Seeks to implement Risk Based Asset Management of US Infrastructure

- Risk Based Asset Management involves identifying, assessing, and minimizing unacceptable risk
  - Loss of Life
  - Loss of Money

- Structural Failure:
  - Structurally Deficient

- Poor Function:
  - Functionally Obsolete
National Bridge Inventory

Database Maintained by FHWA
- Location data
- Geometric data
- Traffic data
- Conditional assessment data
Functional Obsolescence

- State where a bridge no longer meets the current standards for design and performance

<table>
<thead>
<tr>
<th>Categories</th>
<th>NBI Item Number</th>
<th>Deficiency Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Waterway Adequacy (W)</td>
<td>71</td>
<td>≤ 3</td>
</tr>
<tr>
<td>Deck Geometry (D)</td>
<td>68</td>
<td>≤ 3</td>
</tr>
<tr>
<td>Approach Roadway Alignment (A)</td>
<td>72</td>
<td>≤ 3</td>
</tr>
</tbody>
</table>

- Can’t carry enough load
- Floods
- Not wide enough for volume
- Not high enough
- Traffic must slow at approach
State that requires significant maintenance, rehabilitation, or replacement due to deterioration or damage of main load carrying elements

<table>
<thead>
<tr>
<th>Categories</th>
<th>NBI Item Number</th>
<th>Deficiency Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deck Condition</td>
<td>58</td>
<td>≤ 4</td>
</tr>
<tr>
<td>Superstructure</td>
<td>59</td>
<td>≤ 4</td>
</tr>
<tr>
<td>Substructure</td>
<td>60</td>
<td>≤ 4</td>
</tr>
<tr>
<td>Structural Evaluation</td>
<td>67</td>
<td>≤ 2</td>
</tr>
<tr>
<td>Waterway Adequacy</td>
<td>71</td>
<td>≤ 2</td>
</tr>
</tbody>
</table>
NBI Sufficiency Rating

- Structural Adequacy and Safety (55%)
- Serviceability and Functional Obsolescence (30%)
- Essentaility for Public Use (15%)
Objectives and Scope

- Use crowd sourced anonymous probe vehicle data to measure and evaluate congestion at bridges in Burlington County, New Jersey considered to be Functionally Obsolete
- Use the congestion analysis as a bridge management tool
Burlington County, NJ

- 7% Structurally Deficient
- 38% Functionally Obsolete
  - 21% Deck Geometry
  - 12% Under Clearance
  - 5% Other
Burlington County, NJ

- 37 bridges evaluated
  - Located adjacent to TMC (Traffic Message Channel)
  - Deficient due to Deck Geometry
  - Many located on county roads
<table>
<thead>
<tr>
<th>NBI Rank</th>
<th>Structure Number</th>
<th>Deficiency</th>
<th>Serviceability and Functional Obsolescence (Out of 30)</th>
</tr>
</thead>
<tbody>
<tr>
<td>#1</td>
<td>03C4004</td>
<td>SD/ FO-D</td>
<td>19</td>
</tr>
<tr>
<td>#2</td>
<td>03D3063</td>
<td>FO-D</td>
<td>20</td>
</tr>
<tr>
<td>#2</td>
<td>03D4560</td>
<td>FO-D</td>
<td>20</td>
</tr>
<tr>
<td>#4</td>
<td>M033940</td>
<td>FO-DU</td>
<td>21</td>
</tr>
<tr>
<td>#5</td>
<td>327153</td>
<td>FO-DU</td>
<td>22</td>
</tr>
<tr>
<td>#5</td>
<td>3000004</td>
<td>FO-DU</td>
<td>22</td>
</tr>
<tr>
<td>#5</td>
<td>03E4550</td>
<td>SD/ FO-D</td>
<td>22</td>
</tr>
<tr>
<td>#5</td>
<td>M055100</td>
<td>FO-DU</td>
<td>22</td>
</tr>
<tr>
<td>#9</td>
<td>327174</td>
<td>FO-D</td>
<td>24</td>
</tr>
<tr>
<td>#9</td>
<td>328157</td>
<td>FO-D</td>
<td>24</td>
</tr>
</tbody>
</table>
Data

- Speed data is calculated from GPS Locations
  - GPS is pinged entering and exiting a TMC
  - The time between pings is divided by the TMC length to produce space mean speed

- Time stamped speed data is reported
  - Approximately 35 million speed records for the 37 bridges studied (2013).
Data Processing

- Data is sorted into 15 min bins for each day of the year
  - The data points in each bin are averaged for that 15 min period

- Congestion is tied to a reduction in speed
  - Significant speed reduction was considered to be 70% of the free-flow speed
  - Free-flow speed was calculated for each TMC by finding the space mean speed for the year between 2AM and 6AM
Data Processing

• The data is evaluated using a binary indicator
  – If the average space mean speed drops below 70% of the free-flow speed, the 15 min period is assigned a value of 1
  – If the average space mean speed does not drop below 70% of the free-flow speed, the 15 min period is assigned a value of 0

• The binary indicators can then be summed and divided by 4 to calculate congestion hours
  – The hours can then be aggregated as desired (day, month, etc.)
- Approximately 258 work days a year
- Approximately 6 peak travel hours a work day (7AM-10AM, 4PM-7PM)
- For Bridge 314155 → \( \frac{224.75}{1548} = 15\% \)
Management Strategies

- Examine three bridges to evaluate congestion analysis as a bridge management tool

<table>
<thead>
<tr>
<th>Bridge</th>
<th>NBI Rank</th>
<th>Congestion Rank</th>
<th>Congestion Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>03C4004</td>
<td>#1</td>
<td>#26</td>
<td>1</td>
</tr>
<tr>
<td>03E4550</td>
<td>#5</td>
<td>#3</td>
<td>75.5</td>
</tr>
<tr>
<td>314155</td>
<td>-</td>
<td>#1</td>
<td>224.75</td>
</tr>
</tbody>
</table>
Bridge Management

• Bridge management is a complicated process involving a complex cost and benefit analysis, but ultimately it will result in the following recommendations:

  1) Do nothing
  2) Repair or Retrofit the Existing Structure
  3) Replace the Existing Structure

• Congestion analysis will be used to evaluate serviceability, and the structural condition will be evaluated using the NBI rating
Bridge 03C4004 (Worst NBI Ranking)

- Constructed in 1909, and improved in 2007
- Carries a city street across the Rancocus Creek
- NBI Rating Factors
  - Structural Evaluation: 2 out of 10
    - Structurally Deficient
  - Serviceability and Functional Obsolescence: 19 out of 30
    - Obsolete due to Deck Geometry
- Congestion Analysis
  - 1 Congestion Hour for 2013
Bridge 03C4004 (Worst NBI Ranking)
Bridge 03C4004 (Worst NBI Ranking)

• Conclusion
  – Serves residential area
  – Low number of Congestion Hours (1/year)
  – Close proximity to I-295 lessens need to carry heavy loads

• Recommendation: Do nothing
  – If structure becomes unsafe for the needs of the community, repair or retrofit
Bridge 03E4550 (Best Agreement)

- Constructed in 1932, and improved in 1977
- Carries Burlington County Route 616 across the Rancocus Creek
- NBI Rating Factors
  - Structural Evaluation: 2 out of 10
    - Structurally Deficient
  - Serviceability and Functional Obsolescence: 22 out of 30
    - Obsolete due to Deck Geometry
- Congestion Analysis
  - 75.5 Congestion Hour for 2013
Best Agreement

Northbound

Southbound

Time of Day

Month

Miles per Hour

January

February

March

April

May

June

July

August

September

October

November

December

Time of Day

Miles per Hour
Bridge 03E4550 (Best Agreement)

• Conclusion
  – Bridge is structurally deficient
  – Causes congestion in both directions (75.5 CH/year)

• Recommendation: Replace
Bridge 314155 (Worst Congestion)

• Carries NJ Route 73 South connecting Philadelphia to I-295
• Bridge 314154 carries 74 North (56.75 CH/year)
• NBI Rating Factors
  – Structural Evaluation: 6 out of 10
  – Serviceability and Functional Obsolescence: 25 out of 30
  • Obsolete due to Deck Geometry
• Congestion Analysis
  – 224.75 Congestion Hour for 2013
Bridge 314155 (Worst Congestion)
Bridge 314155 (Worst Congestion)

<table>
<thead>
<tr>
<th>Month</th>
<th>Time of Day</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>200-2400</td>
</tr>
<tr>
<td>February</td>
<td>200-2400</td>
</tr>
<tr>
<td>March</td>
<td>200-2400</td>
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<tr>
<td>April</td>
<td>200-2400</td>
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<tr>
<td>May</td>
<td>200-2400</td>
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<tr>
<td>June</td>
<td>200-2400</td>
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<tr>
<td>July</td>
<td>200-2400</td>
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<tr>
<td>August</td>
<td>200-2400</td>
</tr>
<tr>
<td>September</td>
<td>200-2400</td>
</tr>
<tr>
<td>October</td>
<td>200-2400</td>
</tr>
<tr>
<td>November</td>
<td>200-2400</td>
</tr>
<tr>
<td>December</td>
<td>200-2400</td>
</tr>
</tbody>
</table>
Bridge 314155 (Worst Congestion)

• Conclusion
  – Bridge is structurally adequate
  – Congestion is present at bridge
    • Signalized Intersections?
    • Proximity to I295?
    • Deck Geometry?

• Recommendation: Perform field evaluation of the bridge and adjacent roadways
  – If bridge is found to be source of congestion, widen the bridge
Conclusions

• 37 functionally obsolete bridges (due to deck geometry) were evaluated for congestion using anonymous crowd sourced vehicle data
  – FO was not necessarily an indicator of congestion
    • 7 bridges experienced no congestion hours
    • 28 experienced less than 100 hrs. (< 6% of peak hrs.)
    • 2 bridges experienced more than 100 hrs
  – Only 5 of the 10 bridges with the worst NBI ranking appeared in the 10 bridges with the worst congestion
Conclusions

• A bridge assessment methodology using the congestion analysis was demonstrated
  – The congestion analysis served to actually measure if the bridge was affecting traffic flow
  – Understanding if congestion actually existed made making a recommendation for a course of action clearer
Future Work

1) Accident data must be incorporated
   • If a structure is causing accidents it would warrant further investigation

2) An economic factor must be tied to congestion hours
   • Provide a basis for cost benefit analyses

3) The congestion analysis needs to be performed agency wide.
   • It must be used on Functionally Obsolete and Non-functionally Obsolete bridges
Future Work
Future Work
Future Work
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