Agenda

- Introduction
- Benefits of BaTMan & WebHypris for Bridge LCCA
- Bridge Life & the Possible LCCA Applications for Bridges
- Bridge Investment Case Studies & Large-Scale Feasibility
  - App. No. (1): The Optimal Road Corridor, Bridges
  - App. No. (2): The Optimal Bridge Design Proposal
  - App. No. (3): Repair or Replace a Bridge?
- BaTMan-LCC Program & BaTMan-LCC Course
- Questions & Discussion
Introduction

- **Bridge Life-Cycle Cost (LCC)**

- The time value of money, discount rate

- Life-Cycle Costing/Life-Cycle Cost Analysis (LCCA)

- Life-Cycle Assessment (LCA)

- The concept of the lowest proposal & the concept of least LCC proposal
The Swedish Bridge and Tunnel Management System "BaTMan"

https://batman.vv.se/batman/
BaTMan’s Navigation Tool (WebHybris)
The Swedish Bridge Stock 2011

<table>
<thead>
<tr>
<th>Bridge Function Type</th>
<th>Total No. Of Bridges</th>
<th>Bridge Total Area (m²)</th>
<th>Bridge Total Length (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roadway</td>
<td>Railway</td>
<td>Pedestrian &amp; Bicycle</td>
<td>Other</td>
</tr>
<tr>
<td>BaTMan's Bridges</td>
<td>23,848</td>
<td>4,411</td>
<td>1,619</td>
</tr>
<tr>
<td>Trafikverket's Bridges in BaTMan</td>
<td>20,050</td>
<td>3,179</td>
<td>207</td>
</tr>
</tbody>
</table>

![Bridge Construction Material and Bridge Types](chart)

- Slab Bridge
- Slab-Frame Bridge
- Beam Bridge
- Beam-Frame Bridge
- Culvert Bridge
- Open Spandrel Arch Bridge
- Cable Stayed Bridge
- Suspension Bridge
- Other Bridge types

- L < 5m
- 5m ≤ L < 10m
- 10m ≤ L < 20m
- 20m ≤ L < 30m
- 30m ≤ L < 50m
- 50m ≤ L < 100m
- 100m ≤ L < 200m
- 200m ≤ L < 500m
- 500m ≤ L < 1000m
- 1000m ≤ L
The average real initial costs of the Swedish bridges different types, based on cost data for 2,508 bridges constructed between 1980 and 2011.
Swedish Bridges Anticipated INV Cost

The inflation rate for the Swedish bridges initial costs

Y = 458.37X - 904726
R² = 0.9189
Structural-Members Life-Cycle Measures

Actual Service Life of the Swedish Bridge's Expansion Joints

\[ y = -4.779 \ln(x) + 84.151 \]

Based on 288 Replacement Actions performed between 1979 and 2010
Bridge Life and the possible LCCA App.

A decision on whether or not to undertake the project

- Whole-life costing, WLC
- Life-cycle costing, LCC

1. Get a preliminary bridge LCC & specify the most cost-effective road corridor

2. Propose an optimal conceptual design
   - Specify the optimal bridge's structural member
   - Specify the optimal repair strategy
   - Specify the optimal structural member's replacement alternative

3. Decide whether to repair or to renew a bridge
   - Specify the optimal bridge’s replacement alternative

LCC Saving Potential
App. No. (1): Specify the most life-cycle cost-effective road corridor
App. No. (2): Specify the most life-cycle cost-effective road corridor
App. No. (2): Specify the most life-cycle cost-effective road corridor
App. No. (2): Propose an optimal conceptual design during
App. No. (2): Analysis Steps

1. For the bridge location, find out the technically feasible proposals
   - Check out the feasible bridge types
   - For each feasible bridge type, check out the possible bridge configuration.
   - List down the technically feasible proposals

2. For each proposal, assess the target quantities and the initial investment cost
   - Assign the available bridge propitiates
   - Check the proposal associated target quantities
   - Get the anticipated bridge initial investment cost

3. For each proposal, specify the required life-cycle measures and their associated costs
   - Inspections (INS)
   - Operation and Maintenance (O&M)
   - Repair, Replacement and Rehabilitation (RRR)
   - BaTMan Standard Actions (BSA)
   - Recycling, Demolition and Landscaping (R,D&L)

4. Draw a conclusion and set-up LCCA guidelines to the contractors "SAFI & Sub-SAFI values"
Case-Study (1): The Karlsnäs Bridge

<table>
<thead>
<tr>
<th>Proposal No.</th>
<th>Description</th>
<th>Cross-Section Details</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>One bridge, two steel boxes</td>
<td><img src="image" alt="Cross-Section Diagram 1" /></td>
<td>5 Spans 4X60m + 2X40m Superstructure depth: 2.3m</td>
</tr>
<tr>
<td>2</td>
<td>Two Bridges, two steel I beams per bridge</td>
<td><img src="image" alt="Cross-Section Diagram 2" /></td>
<td>5 Spans 4X60m + 2X40m Superstructure depth: Haunch beam Max. 3.2m Min. 1.8m</td>
</tr>
<tr>
<td>3</td>
<td>Two bridges, one pre-stressed concrete box per bridge</td>
<td><img src="image" alt="Cross-Section Diagram 3" /></td>
<td>7 Spans 5X50m + 2X35m Superstructure depth: Haunch beam Max. 2.8m Min. 1.6m</td>
</tr>
<tr>
<td>4</td>
<td>One bridge, two pre-stressed concrete boxes</td>
<td><img src="image" alt="Cross-Section Diagram 4" /></td>
<td>7 Spans 5X50m + 2X35m Superstructure depth: Haunch beam Max. 2.8m Min. 1.6m</td>
</tr>
<tr>
<td>5</td>
<td>One bridge, one integral-cantilever concrete box</td>
<td><img src="image" alt="Cross-Section Diagram 5" /></td>
<td>4 Spans 2X100m + 2X60m Superstructure depth: Haunch beam Max. 6.5m Min. 2.3m</td>
</tr>
</tbody>
</table>
LCCA Results

• At discount rate equal to 4 %, the most cost-effective proposal is proposal (5) and the least cost-effective proposal is proposal (1).

• The Net Saving in case of implementing proposal (5) in comparison of implementing proposal (1) is equal to **56.7 Million SEK**.
Regardless of the discount rate, proposal (1) is the lease cost-effective proposal which is associated with the highest equivalent annual cost.
LCCA Guidelines in the Tender Documents
SAFI-Proposal Level

<table>
<thead>
<tr>
<th>Proposal No.</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anticipated INV Cost (M SEK)</td>
<td>169.94</td>
<td>110.13</td>
<td>116.96</td>
<td>124.20</td>
<td>115.55</td>
</tr>
<tr>
<td>LCM Cost NPV (M SEK)</td>
<td>15.86</td>
<td>19.33</td>
<td>14.79</td>
<td>13.61</td>
<td>13.58</td>
</tr>
<tr>
<td>Total LCC NPV (M SEK)</td>
<td>185.79</td>
<td>129.46</td>
<td>131.75</td>
<td>137.80</td>
<td>129.13</td>
</tr>
<tr>
<td>Cost-effectiveness Rank</td>
<td>Worst</td>
<td>Second best</td>
<td>Third best</td>
<td>Fourth best</td>
<td>Best</td>
</tr>
<tr>
<td>SAFI (K SEK), Bridge-Owner</td>
<td>2,272</td>
<td>5,750</td>
<td>1,210</td>
<td>22</td>
<td>0</td>
</tr>
</tbody>
</table>

During the Bid Evaluation Process

<table>
<thead>
<tr>
<th></th>
<th>163.6</th>
<th>124.8</th>
<th>121.6</th>
<th>145.6</th>
<th>--</th>
</tr>
</thead>
<tbody>
<tr>
<td>INV Cost (M SEK)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total LCC NPV (M SEK)</td>
<td>165.87</td>
<td>130.55</td>
<td>122.81</td>
<td>145.62</td>
<td>--</td>
</tr>
<tr>
<td>Cost-effectiveness Rank</td>
<td>Worst</td>
<td>Second best</td>
<td>Best</td>
<td>Third Best</td>
<td>--</td>
</tr>
</tbody>
</table>

Mohammed SAFI
# LCCA Guidelines in the Tender Documents

## SAFI-Structural Member Level

<table>
<thead>
<tr>
<th>Target Part</th>
<th>Unit</th>
<th>Free BQ</th>
<th>Sub-SAFI</th>
<th>Proposal (1)</th>
<th>Proposal (6)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Unit LCM cost (K SEK/Unit)</td>
<td>Fixed Cost (K SEK)</td>
<td>Variation</td>
</tr>
<tr>
<td>Bearings number</td>
<td>set</td>
<td>6</td>
<td>7.01</td>
<td>54.42</td>
<td>22</td>
</tr>
<tr>
<td>Drainage system points</td>
<td>set</td>
<td>5</td>
<td>32.67</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Edge beam length</td>
<td>m</td>
<td>676</td>
<td>1.62</td>
<td>108.30</td>
<td>0</td>
</tr>
<tr>
<td>Expansion joint length</td>
<td>m</td>
<td>89</td>
<td>5.78</td>
<td>156.37</td>
<td>-45</td>
</tr>
<tr>
<td>Painted area</td>
<td>m²</td>
<td>0</td>
<td>0.35</td>
<td>85.29</td>
<td>6,315</td>
</tr>
<tr>
<td>Parapets length</td>
<td>m</td>
<td>676</td>
<td>0.99</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Paved area</td>
<td>m²</td>
<td>7,267</td>
<td>0.53</td>
<td>462</td>
<td>0</td>
</tr>
<tr>
<td>Slops and cons area</td>
<td>m²</td>
<td>2,141</td>
<td>0.38</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Superstructure area</td>
<td>m²</td>
<td>7,176</td>
<td>0.14</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total bridge area</td>
<td>m²</td>
<td>7,537</td>
<td>0.62</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

**SAFI ( K SEK), Contractor**

<p>| | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>2,272</td>
<td></td>
<td></td>
<td>2,174</td>
</tr>
</tbody>
</table>
Case-Study (2): The Kolbäcksån Bridge

Comparing proposal No. 1 with 4, Trafikverket can save 10.6 Million SEK.
Large-Scale Feasibility

• Based on both case studies: The average net saving is equal to 8384 SEK/m$^2$.

• It can roughly be said that Trafikverket is expected in the coming ten years to annually build an average bridge total area of 55000 m$^2$ that are equivalent to of 200 bridges.

• Consider that 50 % of the Trafikverket's new bridges might be subjected to a wrong decision.

• This means that Trafikverket can annually save 230 million SEK. This annual loss is 220 million SEK as initial investment cost and 10 million SEK as LCM cost.
App. No. (3): Repair or Replace a Bridge?

Construction Year: 1934

Construction Year: 1929

(Residual service life is not more than three years, if no action is taken CC2)
Large-Scale Feasibility

- The bridges should not be repaired and should be replaced after utilizing their residual service life.
- The analysis shows that, the opportunity loss is equal to 241 SEK/year/m²
- Trafikverket is responsible for:
  - 23,948 bridges with a total bridge area of 5,516,590 m²
  - 6,268 bridges older than 70 years, total bridge area of 619,944 m².
- Consider that 50% of the Trafikverket’s old bridges might be subjected to wrong decision, This means:
  - Trafikverket can save 74.7 million SEK each year
- This loss will stand for 20 year, this also means:
  - Trafikverket can save 1.49 billion SEK during the coming 20 years
BaTMan-LCC Program

BaTMan-LCC
Bridge Life-Cycle Cost Optimization

Version 1 [2012-07-10]

Developer:
Mohammed SAFI, PhD Student, KTH
mohammed.safi@byv.kth.se

Supervisors:
Prof. Håkan SUNDQUIST, KTH
Prof. Raid KAROUMI, KTH
Dr. George RACUTANU, Trafikverket
BaTMan-LCC relation with BaTMan

1. Detailed Info., price etc. (N/A in BaTMan)
2. BaTMan-LCC (KTH)
3. WebHybris
4.  
5.  

NVDB
NATIONELL VÄGDATABASES

DOKUMENTER OCH LANDSTING-LANTMÄTERIET
SKOGSNÄRINGEN
TRANSPORTSTYRELSEN
TRAFIKVERKET
BaTMan-LCC Course

**Course Coordinators:**
- Peter Simonsson
- Mohammed Safi
- George Racutanu

**7 Super-Users**

**Course Outlines**

- **First Session:**
  - November 12, 2012
  - November 13, 2012
  - November 14, 2012

- **Second Session:**
  - December 4, 2012
  - December 5, 2012
  - December 6, 2012

- **Summing Up day 2013**
Thank You

Questions?