The Analytic Hierarchy Process (AHP) for decision-making and expert judgement in railway infrastructure maintenance

Peter Söderholm\textsuperscript{1} and Birre Nyström\textsuperscript{2}

\textsuperscript{1}Banverket, Sweden, peter.soderholm@banverket.se

\textsuperscript{2}NSB, Norway, birren@nsb.no
Presentation outline

• **Introduction**
  – Safety and risk management process
  – Decision-making and expert judgment
  – Analytic Hierarchy Process (AHP)

• **Methodology**

• **Results**

• **Discussion**

• **Questions and comments**
Safety and risk management process

Safety & risk analysis
- Scope definition
- Hazard identification
- Risk estimation

Safety & risk evaluation
- Tolerability decisions
- Analysis of options

Safety & risk control
- Decision making
- Implementation
- Monitoring

Safety and risk management
Decision-making and expert judgment

- Risk perception theory and Multi-Criteria Decision Making (MCDM)
- Historical data
- Analytical or simulation methodologies
- Expert judgment
  - Delphi methodology, absolute probability judgements, category ranking and paired comparison, Analytic Network Process (ANP), Analytic Hierarchy Process (AHP)
Analytic Hierarchy Process (AHP)

- Developed during the 1970’s
- Book by Thomas L. Saaty (1980)
- Decision-support
- Mathematics and psychology
- Both qualitative and quantitative data
- Pair-wise comparison
- Consistency check

Goal

Criteria

Alternatives

Socio-economically efficient and sustainable railway system 1.00

Cost 0.25

Safety 0.25

Track work time 0.25

Punctuality and availability 0.25

Frost insulation 0.20

Rail renewal 0.20

Real estate measures 0.20

Tamping of turnout 0.20

Turnout adjustment 0.20
Methodology

- What characterises the usage of the Analytical Hierarchy Process (AHP) within rail applications?
  - Literature study

- How important do decision-makers consider different criteria affected by infrastructure maintenance to be?

- How consequent is the selection of maintenance actions?
  - Empirical study
Methodology – Literature study

- What characterises the usage of the Analytical Hierarchy Process (AHP) within rail applications?
  - Google Scholar
  - Search words: rail; analytic hierarchy process; safety; risk; maintenance; infrastructure maintenance
  - Time period: 1980-2009
Methodology – Empirical study 1(3)

- **Decision**
  - Infrastructure maintenance action (8 or 12)

- **Decision-maker**
  - Track manager (6)

- **Decision-support**
  - Analytic Hierarchy Process (AHP)
  - Software tool (Expert Choice)
# Methodology – Empirical study 2(3)

<table>
<thead>
<tr>
<th>Criterion</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Cost</td>
</tr>
<tr>
<td>2. Track work time</td>
</tr>
<tr>
<td>3. Safety</td>
</tr>
<tr>
<td>Definition of Safety: the absence of accidents and incidents, including level crossing accidents and suicides. This includes personnel at Banverket, other personnel within the railway sector and the general public.</td>
</tr>
<tr>
<td>3.1 Number of deaths and seriously injured</td>
</tr>
<tr>
<td>3.2 Number of accidents and incidents</td>
</tr>
<tr>
<td>4. Punctuality and availability</td>
</tr>
<tr>
<td>5. Condition</td>
</tr>
<tr>
<td>6. Environmental impact</td>
</tr>
<tr>
<td>7. Own abilities and development</td>
</tr>
<tr>
<td>8. Collaboration with stakeholders</td>
</tr>
</tbody>
</table>
Methodology – Empirical study 3(3)

Goal of empirical study

To compare different ways of ranking

1. Ranking of criteria
   - Cost
   - Track work time
   - Safety
   - Punctuality and availability

2. Ranking by criteria
   - Maintenance actions

3. Ranking by alternatives
   - Maintenance actions
Results – Literature study 1(2)

Scholar Publications related to the Analytic Hierarchy Process (AHP) within General Rail Applications
Results – Literature study 2(2)

Scholar Publications related to the Analytic Hierarchy Process (AHP) within Rail Safety and Risk Applications

<table>
<thead>
<tr>
<th>Time Periods</th>
<th>Number of References</th>
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<tbody>
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<td>1980-1984</td>
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<td>2000-2004</td>
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<tr>
<td>2005-2009</td>
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</table>

- Others
- Social Sciences, Arts, and Humanities
- Physics, Astronomy, and Planetary Science
- Medicine, Pharmacology, and Veterinary Science
- Engineering, Computer Science, and Mathematics
- Chemistry and Materials Science
- Business, Administration, Finance, and Economics
- Biology, Life Sciences, and Environmental Science
<table>
<thead>
<tr>
<th>Criterion</th>
<th>Track manager</th>
<th>Priority</th>
<th>Rank</th>
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<tbody>
<tr>
<td></td>
<td>S1</td>
<td>S2</td>
<td>S3</td>
</tr>
<tr>
<td>Safety</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Punctuality and availability</td>
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<td>3</td>
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</tr>
<tr>
<td>Track work time</td>
<td>3</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Cost</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Condition</td>
<td>5</td>
<td>8</td>
<td>5</td>
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<tr>
<td>Own abilities and development</td>
<td>8</td>
<td>7</td>
<td>7</td>
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<tr>
<td>Collaboration with stakeholders</td>
<td>7</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>Environmental impact</td>
<td>6</td>
<td>6</td>
<td>8</td>
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## Results - Empirical study 2(5)

<table>
<thead>
<tr>
<th>Track manager</th>
<th>S1</th>
<th>S2</th>
<th>S3</th>
<th>S4</th>
<th>S5</th>
<th>S6</th>
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</thead>
<tbody>
<tr>
<td>Inconsistency of criteria prioritisation</td>
<td>0.01</td>
<td>0.24</td>
<td>0.28</td>
<td>0.03</td>
<td>0.11</td>
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</table>
### Results - Empirical study 3(5)

<table>
<thead>
<tr>
<th>Criterion</th>
<th>S1</th>
<th>S2</th>
<th>S3</th>
<th>S4</th>
<th>S5</th>
<th>S6</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Cost</td>
<td>0.11</td>
<td>0.34*</td>
<td>0.01</td>
<td>0.08</td>
<td>0.11</td>
<td>0.05</td>
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<tr>
<td>2. Track work time</td>
<td>0.26*</td>
<td>0.02</td>
<td>0.00</td>
<td>0.41*</td>
<td>0.19*</td>
<td>0.13*</td>
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<tr>
<td>3. Safety</td>
<td>0.22</td>
<td>0.16*</td>
<td>0.00</td>
<td>0.05</td>
<td>0.08</td>
<td>0.05</td>
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<tr>
<td>4. Punctuality and availability</td>
<td>0.71*</td>
<td>0.14</td>
<td>0.00</td>
<td>0.01</td>
<td>0.15*</td>
<td>0.05</td>
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<tr>
<td>5. Condition</td>
<td>0.08</td>
<td>0.04</td>
<td>0.00</td>
<td>0.04</td>
<td>0.04</td>
<td>0.01</td>
</tr>
<tr>
<td>6. Environmental impact</td>
<td>0.01</td>
<td>0.07</td>
<td>0.01</td>
<td>0.01</td>
<td>0.06</td>
<td>0.03</td>
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<tr>
<td>7. Own abilities and development</td>
<td>0.02</td>
<td>0.15</td>
<td>0.00</td>
<td>0.01</td>
<td>0.01</td>
<td>0.01</td>
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<tr>
<td>8. Collaboration with stakeholders</td>
<td>0.00</td>
<td>0.08</td>
<td>0.00</td>
<td>0.01</td>
<td>0.01</td>
<td>0.02</td>
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<td>Maintenance alternatives</td>
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<td>0.00</td>
<td>0.01</td>
<td>0.09</td>
<td>0.01</td>
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</tbody>
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Results - Empirical study 4(5)

<table>
<thead>
<tr>
<th>Track manager</th>
<th>S1</th>
<th>S2</th>
<th>S3</th>
<th>S4</th>
<th>S5</th>
<th>S6</th>
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<tbody>
<tr>
<td>$r_s$</td>
<td>0.69</td>
<td>0.69</td>
<td>0.41</td>
<td>-0.54</td>
<td>0.60</td>
<td>0.85</td>
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</tbody>
</table>
Results – Empirical study 5(5)

- When prioritising maintenance actions...

  - Safety correlates with (3 track managers):
    - Punctuality and availability
    - Condition

  - Safety correlates with (2 track managers):
    - Track work time
Discussion – Literature study

- Exponential increase of publications with rail and AHP
- Publications related to safety and/or risk about 70%
- Risk more common than safety
- Most common areas:
  - Economics
  - Engineering
  - Social sciences
- Environmental issues an emerging area?
- Transparency of search engine?
Discussion – Empirical study 1(2)

- Analytic Hierarchy Process (AHP)
  - Decision support
    - Methodology and software tool
  - Documentation
    - Transparency, inter-subjectivity and traceability
  - Time consuming
Discussion – Empirical study 2(2)

- **Prioritisation**
  - Rather high consistency in criteria prioritisation
  - Safety most important
  - Safety correlates with:
    - ‘punctuality and availability’ and ‘condition’
    - ‘track work time’
  - Low consistency between different ways of selecting maintenance actions
Discussion – Further work

- **Other decision-makers**
  - E.g. infrastructure managers and centralised train traffic control centres

- **Maintenance alternatives with the same aim**
  - E.g. increased level crossing safety or reduced risk of derailment

- **Analytic Network Process (ANP)**
  - Interaction and feedback

- **‘Good’ and ‘bad’ criteria**
  - E.g. quotients or negative numbers
Questions and comments
References

