



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

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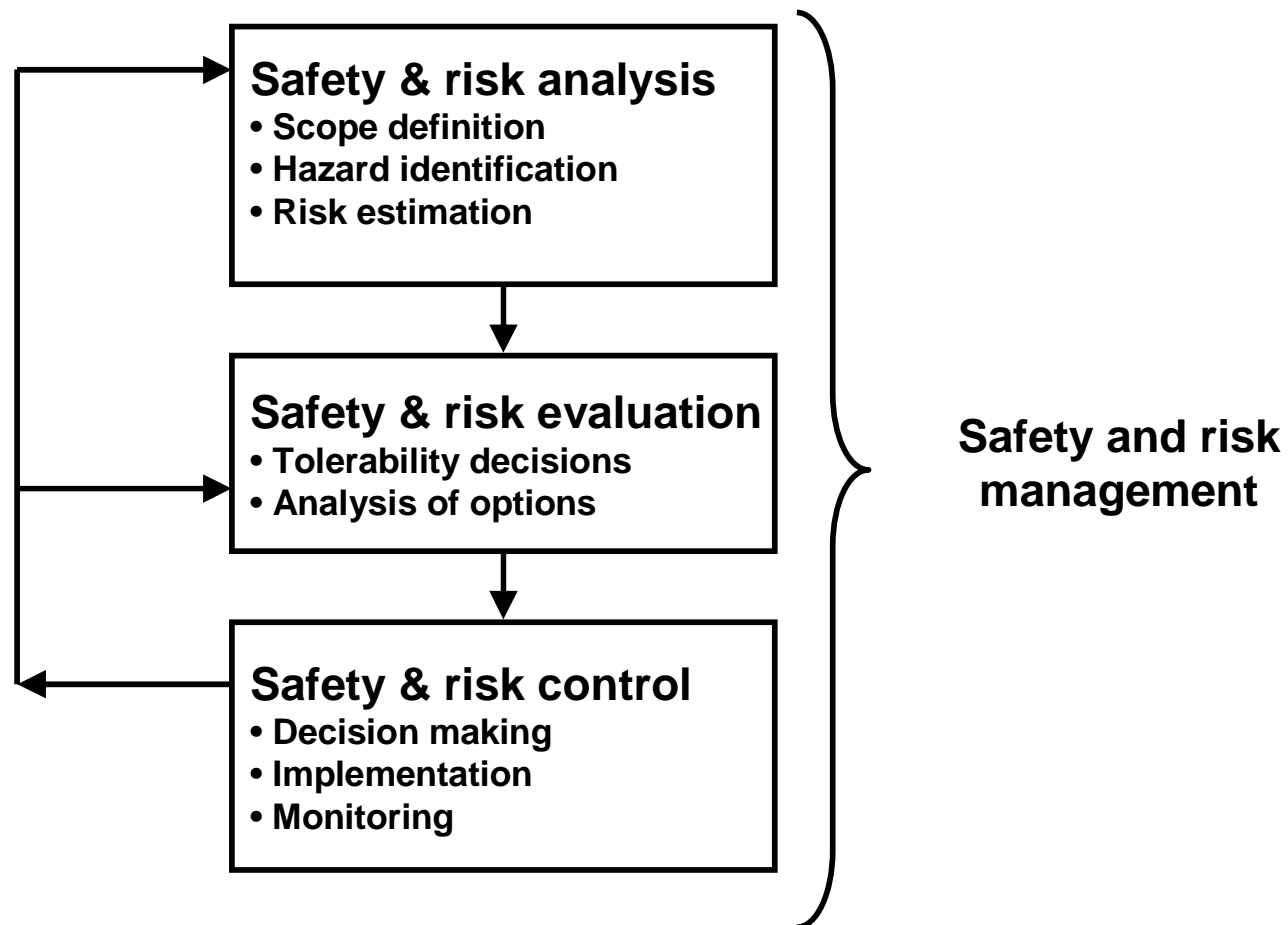




Presentation outline

- **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



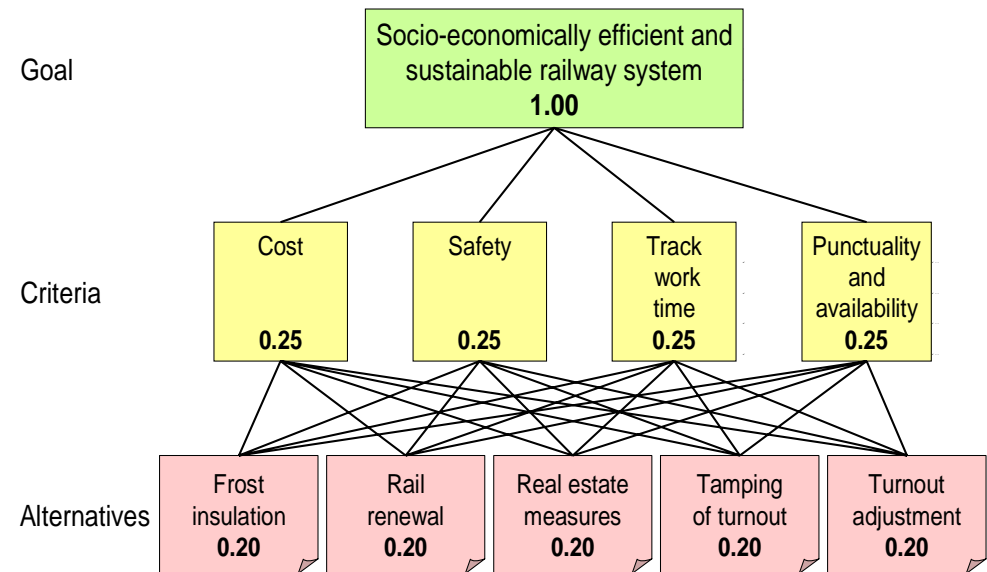


Decision-making and expert judgment

- **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**





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)

Criterion

1. Cost

2. Track work time

3. Safety

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.

3.1 Number of deaths and seriously injured

3.2 Number of accidents and incidents

4. Punctuality and availability

5. Condition

6. Environmental impact

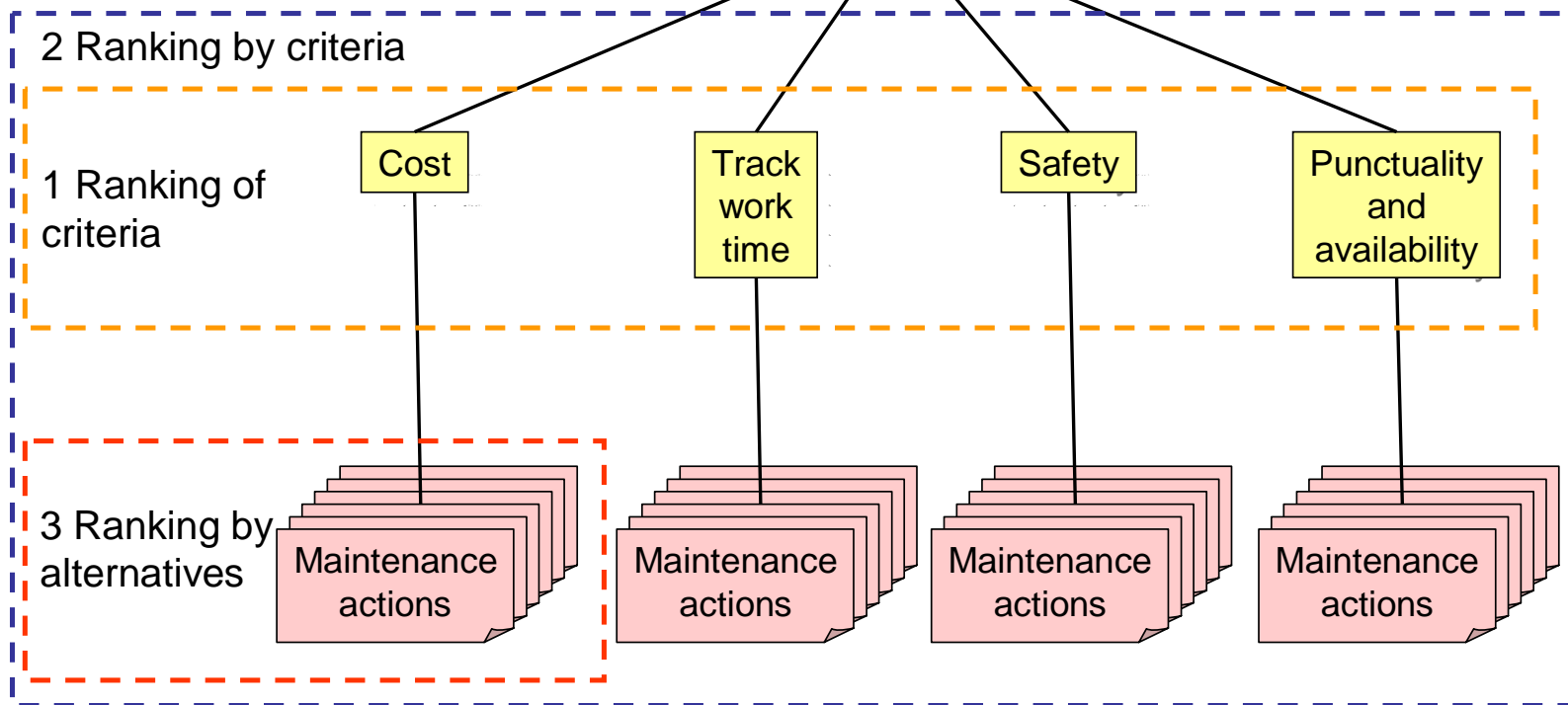
7. Own abilities and development

8. Collaboration with stakeholders

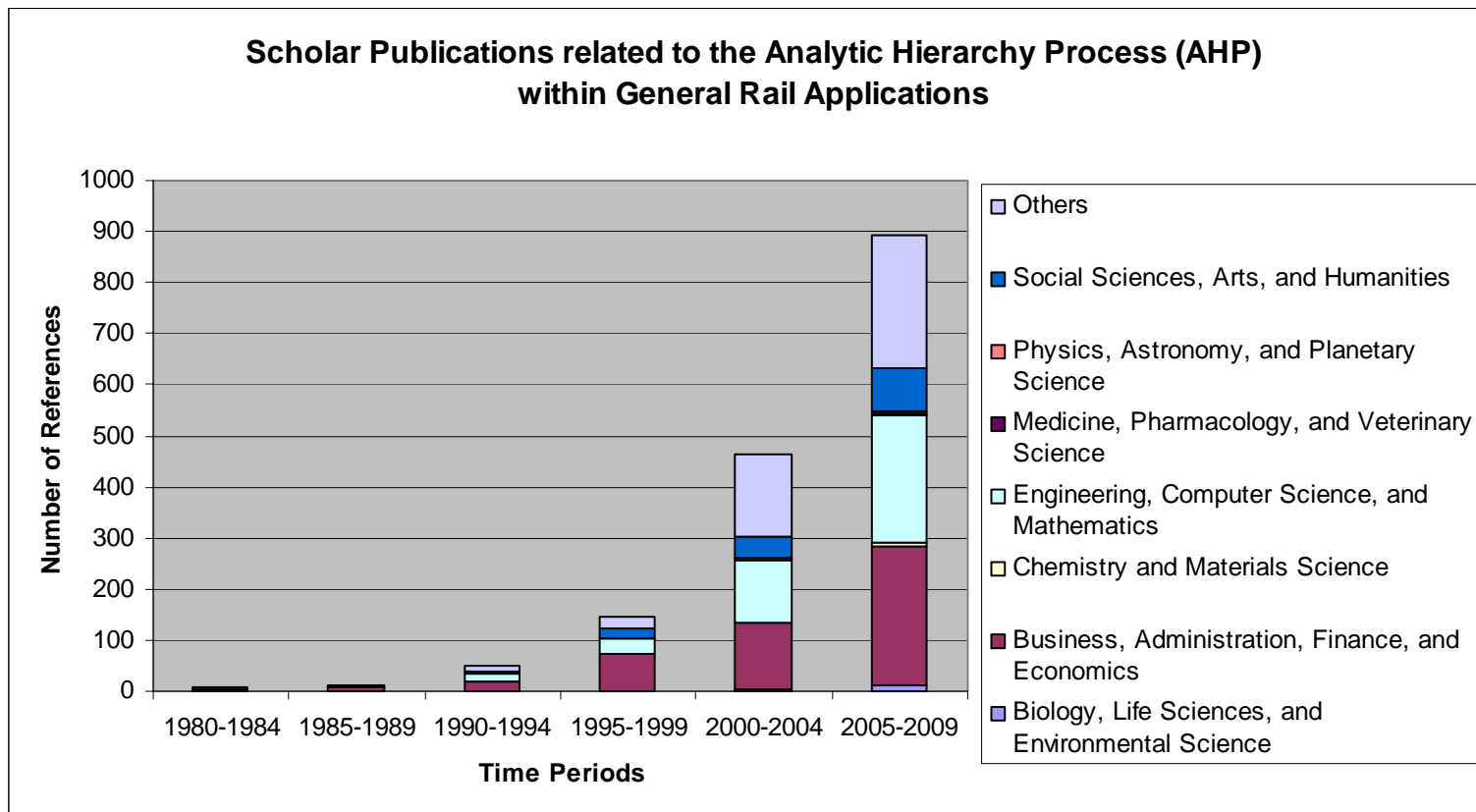
Methodology – Empirical study 3(3)

Goal of empirical study

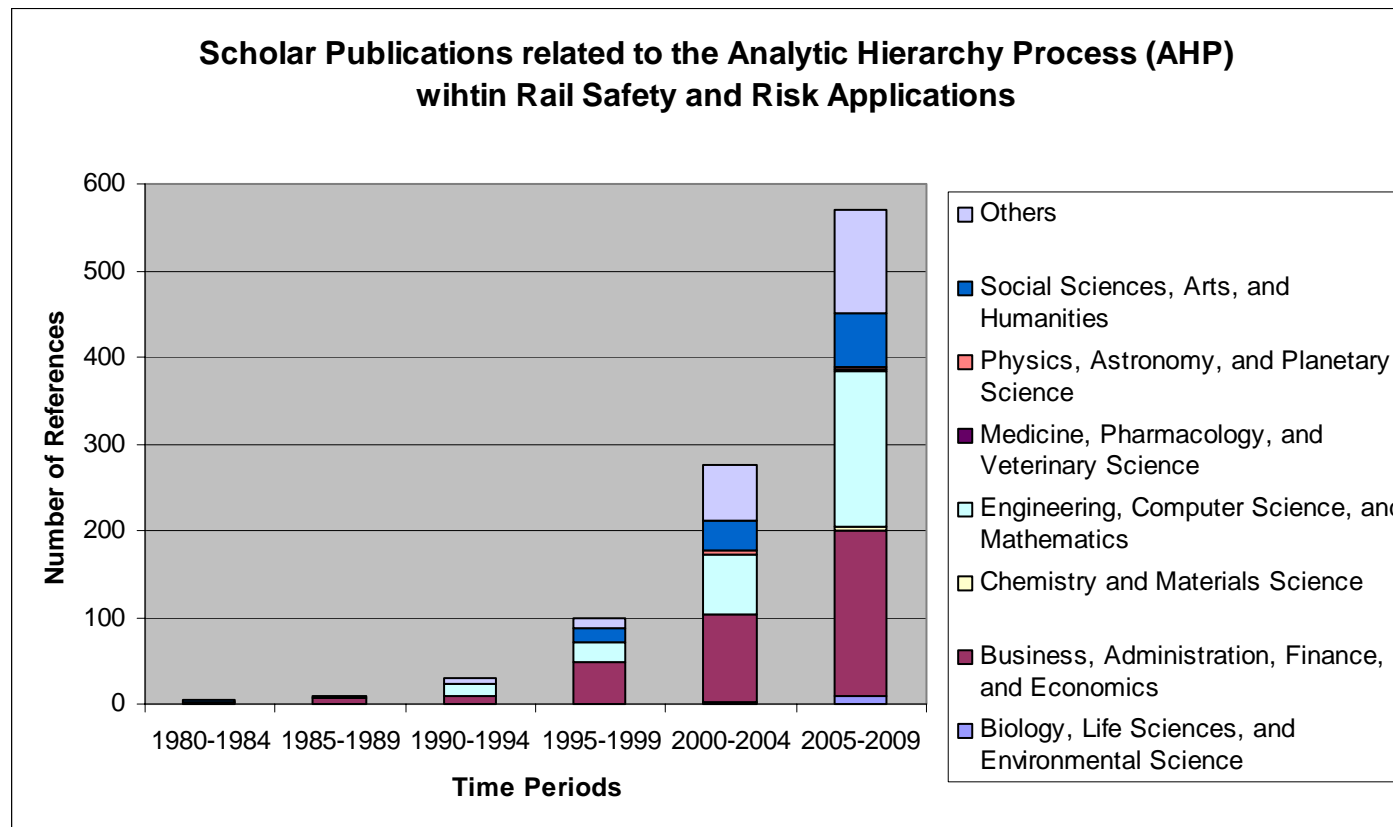
To compare different ways of ranking



Results – Literature study 1(2)



Results – Literature study 2(2)



Results - Empirical study 1(5)

Criterion	Track manager						Priority	Rank
	S1	S2	S3	S4	S5	S6		
Safety	1	1	2	1	1	1	0.406	1
Punctuality and availability	2	3	1	3	5	2	0.154	2
Track work time	3	2	3	5	4	5	0.093	3
Cost	4	4	4	7	7	3	0.085	4
Condition	5	8	5	4	2	4	0.084	5
Own abilities and development	8	7	7	8	3	7	0.063	6
Collaboration with stakeholders	7	5	6	6	6	8	0.058	7
Environmental impact	6	6	8	2	8	6	0.057	8



Results - Empirical study 2(5)

Track manager	S1	S2	S3	S4	S5	S6
Inconsistency of criteria prioritisation	0.01	0.24	0.28	0.03	0.11	0.11

Results - Empirical study 3(5)

Criterion	S1	S2	S3	S4	S5	S6
1. Cost	0.11	0.34*	0.01	0.08	0.11	0.05
2. Track work time	0.26*	0.02	0.00	0.41*	0.19*	0.13*
3. Safety	0.22	0.16*	0.00	0.05	0.08	0.05
4. Punctuality and availability	0.71*	0.14	0.00	0.01	0.15*	0.05
5. Condition	0.08	0.04	0.00	0.04	0.04	0.01
6. Environmental impact	0.01	0.07	0.01	0.01	0.06	0.03
7. Own abilities and development	0.02	0.15	0.00	0.01	0.01	0.01
8. Collaboration with stakeholders	0.00	0.08	0.00	0.01	0.01	0.02
Maintenance alternatives	0.00	0.12	0.00	0.01	0.09	0.01

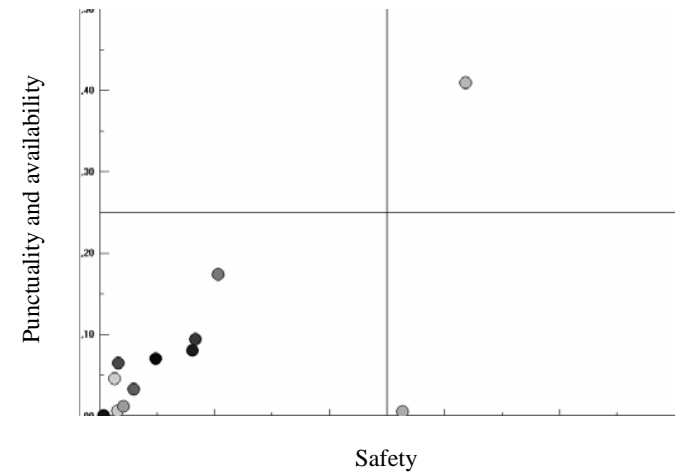


Results - Empirical study 4(5)

Track manager	S1	S2	S3	S4	S5	S6
r_s	0.69	0.69	0.41	-0.54	0.60	0.85

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

- **Söderholm, P. & Nyström, B. (2009). The Analytic Hierarchy Process (AHP) for decision-making and expert judgement in railway infrastructure maintenance. *International Railway Safety Conference (IRSC 2009)*, 27-30 September 2009, Båstad, Sweden.**
- **Nyström, B. (2008). *Aspects of improving punctuality: From data to decision in railway maintenance*. Doctoral thesis, Luleå: Division of Operation and Maintenance Engineering, Luleå University of Technology.**
- **Nyström, B. & Söderholm, P. (2008). Selection of maintenance actions using the analytic hierarchy process (AHP): decision-making in railway infrastructure. *Structure and Infrastructure Engineering: Maintenance, Management, Life-Cycle Design and Performance*, 1-13. iFirst article.**