Risk Assessment of High Speed Transport

1 High Speed Transport systems and Risk aspects

Due to their special physical features, High Speed Transport (HST) systems using conventional or magnetic levitation technology as well as aircraft are affected with risks concerning their economical and ecological performance as well as the damage in case of accidents. Designers and operators of such systems are actively interested to recognize risks as soon as possible and to manage safety and security aspects in an holistic way. In the recent past, terrifying events have deteriorated a broad public’s trust in safety and security of conventional HST systems. It could be seen that such events (as e.g. September 11) not only lead to damages of thousands of fatalities and billions of dollars, but also to a severe economical crisis of the whole transportation branch. For a new HST system it is essential to analyse and compare risks in every phase of design and application. It is evident that success of a new HST system will not only depend on the achieved transportation comfort and prize, but basically on the trust of the customer and the investor in the safety of the system.

In this paper a comparative risk analysis is presented in which 3 HST systems have been compared:

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>MAGLEV subground rail system, using &quot;Swissmetro&quot; technology</td>
<td>Aircraft system</td>
<td>Conventional railway system (e.g. TGV)</td>
</tr>
</tbody>
</table>

The analysis uses no specialized risk modelling techniques but only well established and well known methodologies of risk assessment which are applied in a wide range all over industry.
2 Methodology of the comparative HST risk assessment

2.1 The FMEA approach

The Failure Mode and Effect Analysis (FMEA) is a well known and quite powerful tool to obtain an overview of the most important failure effects of a system. It is often used to optimize design in an early state of the designing process in order to avoid safety defects.

If FMEA is coupled with a damage-likelihood oriented risk map the examined systems can be easily compared, the risk map giving a graphical documentation of the "risk performance" of the system.

The table underneath shows an example of how the comparative assessment has been proceeded:

<table>
<thead>
<tr>
<th>Component</th>
<th>Failure</th>
<th>Effect</th>
<th>Assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nr.</td>
<td>Function</td>
<td>Scenario/ Cause</td>
<td>Mode</td>
</tr>
<tr>
<td>1.1</td>
<td>Motion control</td>
<td>Heart attack or similar medical emergency</td>
<td>No human control over unit</td>
</tr>
<tr>
<td>1.2</td>
<td>Motion control</td>
<td>Misinterpretation / non recognition of a signal</td>
<td>Missing pilot action (e.g. breaking)</td>
</tr>
<tr>
<td>1.3</td>
<td>Motion control</td>
<td>Hijacker attack</td>
<td>Forced miscontrol of the unit</td>
</tr>
<tr>
<td>Etc.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2.2 The risk portfolio

Scientifically speaking, risk is a measure for the magnitude of a danger. Mostly risk is defined as the product of the damage of a certain scenario and the likelihood of its happening

\[
\text{RISK} = \text{DAMAGE} \times \text{LIKELIHOOD}
\]

Since the FMEA analysis gives an indication for the damage and for the likelihood of every analysed scenario, these scenarios can be represented in a risk portfolio matrice. As shown underneath this is a 2-dimensional plot with the damage and the likelihood as dimensions.

One problem with such plots is the scaling of the damage axe since there are several damage indicators which are not obvious in comparison. For this analysis we used 3 damage indicators:

- damage to human beings
- damage to equipment or property
- damage to the environment

Nr of killed people
CHF
Ecopoints (ecological scarcity method)
The chosen risk map works on double logarithical scale and with 4x4 classes

<table>
<thead>
<tr>
<th>classes of likelihood</th>
<th>risk classes</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt; 1 per year</td>
<td>frequent</td>
</tr>
<tr>
<td>1E-3 - 1 per year</td>
<td>seldom</td>
</tr>
<tr>
<td>1E-6 – 1E-3 per year</td>
<td>very rare</td>
</tr>
<tr>
<td>&lt; 1E-6 per year</td>
<td>unlikely</td>
</tr>
</tbody>
</table>

| classes of damage     | bagatelle   | accident | major accident | catastrophe |

<table>
<thead>
<tr>
<th>indicator</th>
<th>units</th>
<th>chosen scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>money</td>
<td>million dollar</td>
<td>&lt; 0.1</td>
</tr>
<tr>
<td>people</td>
<td>nr of killed</td>
<td>0</td>
</tr>
<tr>
<td>environment</td>
<td>effect in million eco-points</td>
<td>&lt; 100</td>
</tr>
</tbody>
</table>

Scenarios like A, B, or C can be documented in the risk map as shown. The risk classes indicate an expectation value for the expected damage out of a certain scenario / failure. The risk maps of the different HST systems can be compared.

### 2.3 Risk aspects of HST systems

Possible danger scenarios have been found by a systematic search, covering different aspects or types of danger. For HST systems 4 general groups of dangers are evident:

1 – safety events: Here all accidents caused by human or technical failure or by natural events can be found. The damage has mostly 2 dimensions: human life damage and financial damage.

2 – security events: Here the criminal dangers are listed. These dangers as well have a human life and a financial damage component.

3 – danger effects of normal operation: Most of the environmental damage of HST systems is not due to accidents but to ordinary operation. This group is used to characterize and estimate environmental and environment-cost damage of HST operation.

4 – development effects: The long range risk of economical and political development must be taken into account as well. If the HST conception does not fit to the economical environment (transport demand, running cost of operation, ...) big financial damages may result.

In the following mind map the most obvious danger scenarios are represented.
3 Results of the first preliminary risk assessment

3.1 The basic system properties

In order to obtain a fair comparison of the systems also concerning economical and environmental effects it is necessary to normalize the three alternatives to a similar scale. The chosen base for comparison has the following properties:

- continental system (no sea crossings) Wien – Madrid X Rome - London
- nr of destinations: 25
- mean distance between destinations: 200 km
- overall transport capacity 76.8 million pers*km/day

<table>
<thead>
<tr>
<th></th>
<th>MAGLEV</th>
<th>TGV</th>
<th>Aircraft</th>
</tr>
</thead>
<tbody>
<tr>
<td>average speed</td>
<td>400 km/h</td>
<td>300 km/h</td>
<td>1000 km/h</td>
</tr>
<tr>
<td>levitation principle / environment</td>
<td>magnetic</td>
<td>conventional rail</td>
<td>aerodynamics</td>
</tr>
<tr>
<td>nr. of passengers per unit</td>
<td>800</td>
<td>800</td>
<td>300</td>
</tr>
<tr>
<td>investment (total)</td>
<td>380 billion CHF</td>
<td>300 billion CHF</td>
<td>97.7 billion CHF</td>
</tr>
<tr>
<td>running cost (total)</td>
<td>140 Mio CHF/y</td>
<td>100 Mio CHF/y</td>
<td>3500 Mio CHF/y</td>
</tr>
<tr>
<td>Mean primary energy consumption per pers-km</td>
<td>1 MJ</td>
<td>1 MJ</td>
<td>4 MJ</td>
</tr>
</tbody>
</table>

3.2 The comparative risk maps

The following risk maps show an equally scaled Damage-Likelihood plot for a selection of the most interesting scenarios for each of the three HST systems. The represented scenarios are:

1111 pilot medical emergency
121 driving engine failure
122 levitation system failure
141 motion / flight control failure (external)
151 earthquake (strong)
21 suicide terrorism
221 hijacking
411 unforeseen demand variation
43 after accident business continuity

Safety-type danger scenarios are indicated with blue symbols
Security-type danger scenarios are indicated with pink symbols
Economical danger scenarios are indicated with orange symbols

In the risk maps different damage types are aggregated, counting 1 killed person as 5 million CHF (in agreement with the Swiss ordinance on major hazard protection).
**A – MAGLEV-System**

Major risk scenario is economical type (demand variation) and of a magnitude of 50 million CHF/year.

Economical and security risk is predominant! Safety risk is of minor importance and smaller than for TGV or airplane!

**B – TGV-System**

Major risk scenario is economical type (demand variation) and of a magnitude of 40 million CHF/year.

There is a cluster of scenarios with risk values between 1 – 10 million CHF/y. There is safety, security and economical risk in this cluster.!

**C – Airplane System**

The major risk scenarios are of the economical and the security type and of a magnitude of 150 – 500 million CHF/year.

Economical and security risk is predominant! Safety risk is of minor importance but still bigger as for the Maglev system.
3.3 Conclusions

It is certainly too early to conclude that any of the compared HST systems have clear advantages over the other. It could be verified that the FMEA-method is a very powerful tool, not only to assess system safety, but also to support the development of new systems as e.g. a MAGLEV-HST system.

Within the selected frame of scenarios the MAGLEV system shows a good performance considering the safety risk. Safety risks do not exceed the risk class 5, whereas the airplane system as well as the TGV system has got safety risk scenarios that are placed in the risk class 6.

On the other hand side the big necessary investment makes the MAGLEV system risky on the economical scale and the big and vulnerable units make it a well suited target for terrorists.

It seems to be a general feature of HST systems, that economical and security risk is predominant over safety. This would be an interesting conclusion, showing that technology can better be handled, than the social and economical effects of the global society.

This analysis will be continued. We expect to have refined results until september.

References


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