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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 publics 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:

A	B	C
MAGLEV subground rail system, using "Swissmetro" technology	Aircraft system	Conventional railway system (e.g. TGV)

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 examinated systems can be easily compared, the risk map giving a graphical documentation of the "risk performance" of the system.

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

System:	MAGLEV HST	Element:	*Pilot (1)*	
State:		Element conditions:	Environment conditions:	Documentation
Moving. No extraordinary events				

Component		Failure			Effect			Assess-ment	
Nr.	Function	Scenario/ Cause	Mode	Recognition	Counter-measures	Remaining ef-fect	Necessary Reaction	L	D
1.1	*Motion con-trol*	*Heart attack or similar medical emergency*	*No human con-trol over unit*	*Dead man alert*	*Autopilot system Position identifi-cation system*	*Automatic stop at the next emer-gency exit station*	*Pilot change Delays on the timetable*	*0.5 / y*	*350 kCHF*
1.2	*Motion con-trol*	*Misinterpretation / non recognition of a signal*	*Missing pilot ac-tion (e.g. break-ing)*	*Dead man alert*	*Autopilot system Position identifi-cation system*	*Alert to Pilot* *If no reaction => 1.1*	-	*90 / y*	*1 kCHF*
1.3	*Motion con-trol*	*Hijacker attack*	*Forced miscon-trol of the unit*	*a) Terrorist alert b) Dead man alert*	*Autopilot system Position identifi-cation system*	*If severe miscon-trol => 1.1*	*Standstill of the unit. Negotiations etc. ==> Follow 5 (unit / security)*	*2E-4 / y*	*5 M CHF*
Etc.	....	....	....	....	....	....	....		

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

RISK = DAMAGE x 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 beeings — Nr of killed people
- damage to equipment or property — CHF
- damage to the environment — Ecopoints (ecological scarcity method)

The chosen risk map works on double logarithmical scale and with 4x4 classes

cflasses of likelihood		**risk classes**			
> 1 per year	frequent	4	5 C	6	7
1E-3 - 1 per year	seldom	3	4	5	6
1E-6 – 1E-3 per year	very rare	2	3	B 4	5
< 1E-6 per year	unlikely	1	2	3 A	4
	classes of damage	bagatelle	accident	major acci-dent	catastrophy

indicator	**units**	**chosen scale**			
money	million dollar	< 0.1	0.1 - 3	3 – 100	> 100
people	nr of killed	0	1	2 - 20	> 20
environ-ment	effect in million eco-points	< 100	100 - 3000	3000 - 100'000	> 100'000

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:

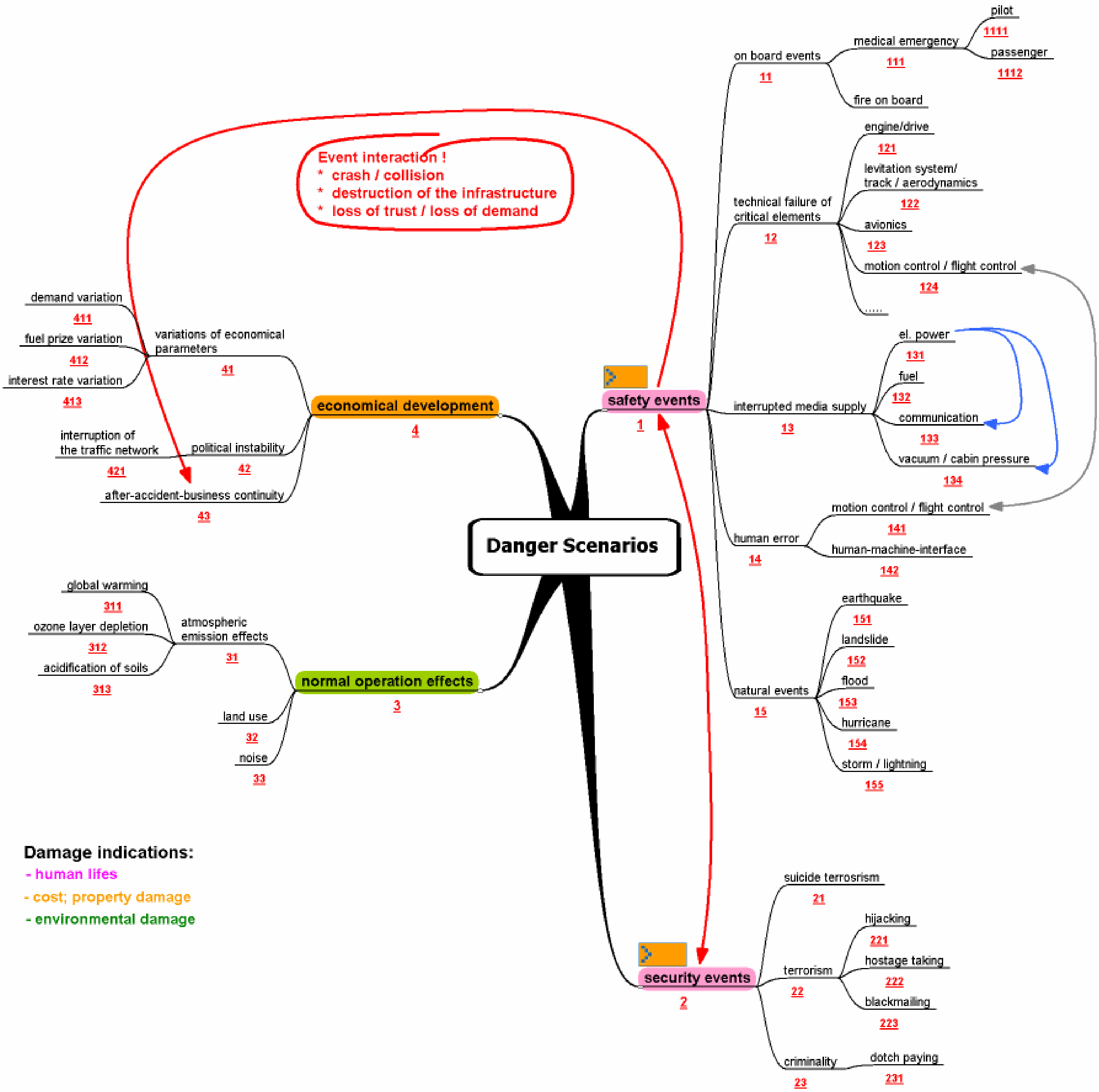
1 – safety events: Here all accidents caused by human or technical failure or by natural events can be found. The damage has mostly 2 dimensions: human life damage and financial damage

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.



Damage indications:

- human lifes
- cost; property damage
- environmental damage

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

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

3.2 The comparative risk maps

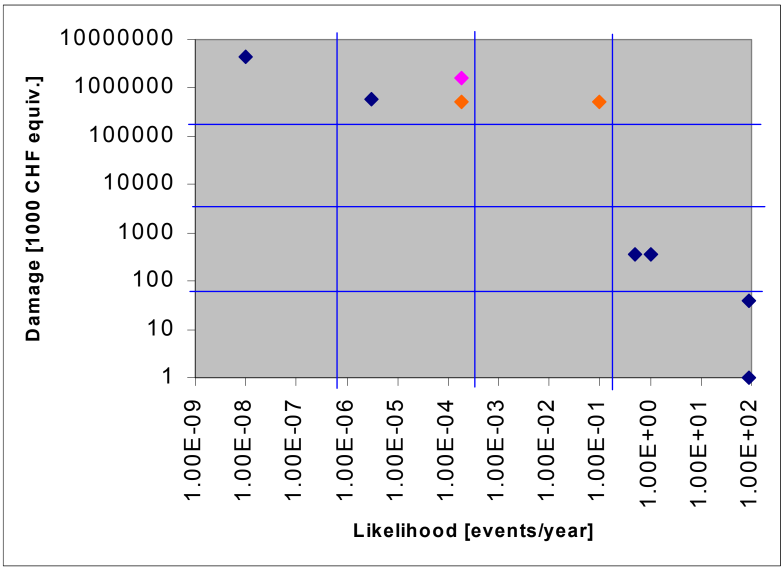
The following risk maps show an equally scaled Damage-Likelihood plot for a selection of the most interesting scenarios for each of the three HST systems. The represented scenarios are:

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 continuitiy

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

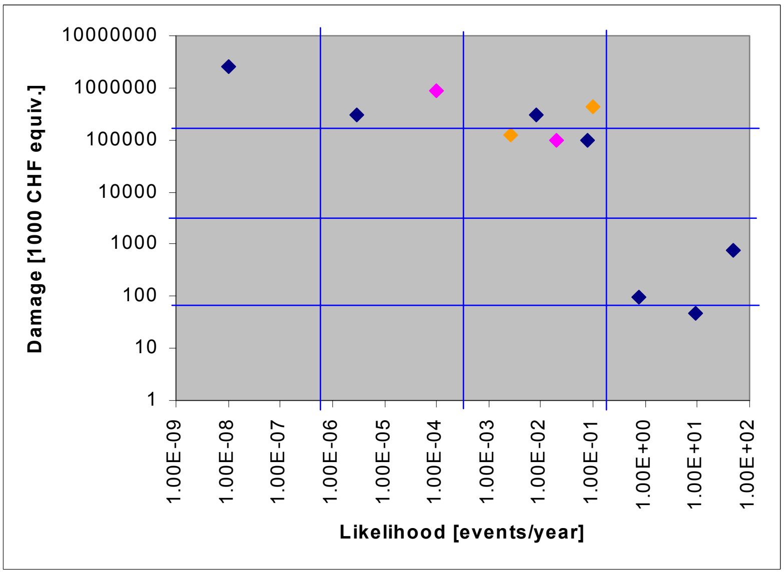


Comment

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

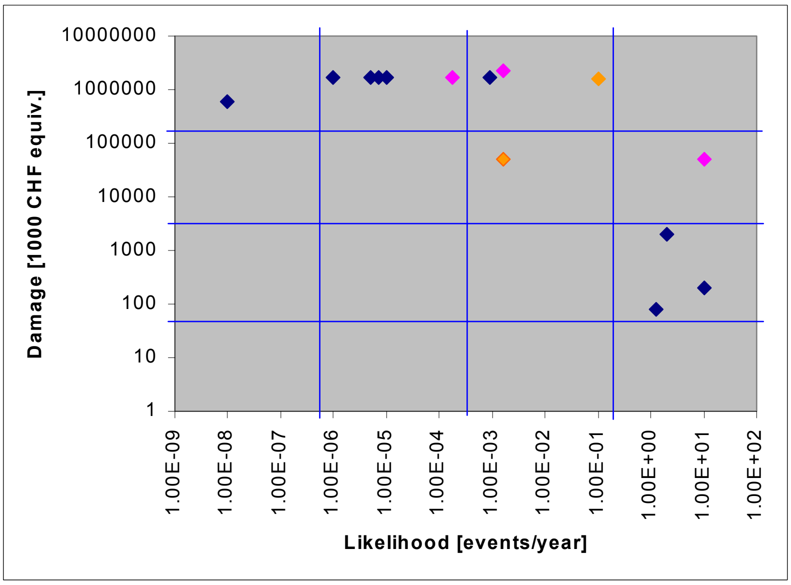


Comment

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



Comment

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 verifyed 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 exeed 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 hands 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.

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