An economic approach of treating external risks from the point of view of an independent infrastructure manager

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Abstract:

The vulnerability of modern transport infrastructure has been shown through devastating terror attacks and natural disasters, but also through minor events. The owner and / or manager of the infrastructure has to deal with the possible event of damage of infrastructure elements through force majeure, or reduction in network capacity through man made or natural threats. To minimize the risk of financial set backs a variety of measures can be taken into account, e g. personnel or constructional measures or insurances.

An increase of private ownership models for transport infrastructure entails a growing importance of dealing with risks in an economic surrounding. In the first part of the paper, the authors show detailed descriptions of different external risks and their impact on service quality and business performance. In the second part possible (economic) solutions for coping with the different risks are suggested. The findings are illustrated by an example of a specific railway link in Germany.

I Introduction

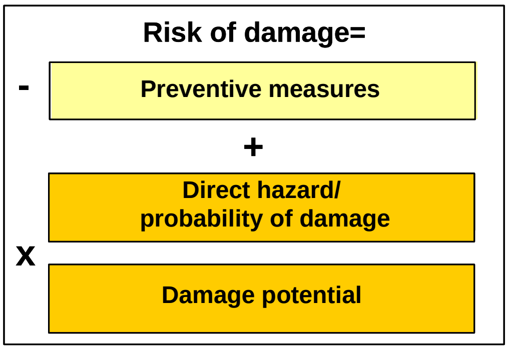
The reliability of transport infrastructures is of great importance to businesses, private mobility and society. Their significance made them however extremely vulnerable to interferences. Terror attacks and natural disasters have shown how strongly they can cause interruptions and damages to transport systems. When transport infrastructures were still owned by public authorities all losses due to force majeure were absorbed by public money. In recent years more and more infrastructure facilities like highways or airports have been privatised or are now managed under a private regime. In order to decide how to deal with risks most efficiently a closer analysis is necessary.

The following chapter II presents a common concept of risk and its components consisting of preventive measures, direct hazard and damage potential in respect to transport infrastructures. Afterwards the calculation of expected costs per year due to external risks is explained in detail. Chapter III concretizes the introduced concepts for the railway infrastructure. This is then followed in chapter IV by an example for risk calculation of a specific railway infrastructure part prone to flooding. The paper concludes by giving a summary of conclusions.

II Concept of risk

There are various definitions for risk. Here the risk of damage of a specific transport infrastructure part is defined by the direct hazard, expressed in a probability function of an event of certain intensity. This is multiplied with the damage potential dependant on the intensity of the event and the affected values. Measures taken to prevent damages by organizational or technical measures as well as risk transfer to insurances can reduce the own risk of damage. The costs and benefits for this measure have to be well-balanced. Figure 1 illustrates the components of the risk concept. The following paragraphs explain them in more detail.

Figure 1: Risk concept



Source: authors' own representation based on Münchner Rückversicherungs-Gesellschaft (2005), 62

Preventive measures - risk management

From an economic point of view, risk is concomitant with the wish to succeed and to earn money. To prepare oneself against damages, which affect the business or make it impossible to succeed, an infrastructure operator has several opportunities:

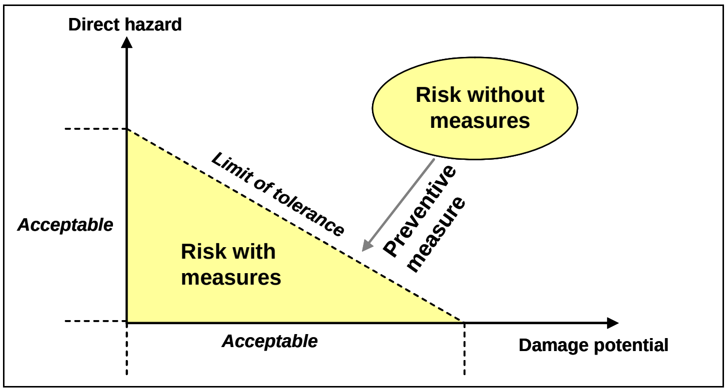
- Don't consider the risk, because the possibility of it occurring is too small.
- Try to minimize the risk by changes in personal or constructive structures.
- Sign an insurance that covers the financial aspects of possible damage.
- Keep reserves in the balance sheet, which can be dissolved in case of a damaging event.
- A combination of the measures above

Before considering any measures the transport infrastructure manager has to be aware of the risk. In order to identify the appropriate risk measure the manager then has to find out how much risk the company is willing and able to tolerate. To reduce the risk to this limit the measures need to be evaluated by their cost effectiveness. Usually insurances are rather expensive[1] but are also very effective in covering financial losses. On the other hand changes in organizational procedures are relatively cheap but usually cannot reduce the vulnerability to a full extend. The tolerated risk is often taken care of by reserves in the balance sheet. The disadvantage is that the capital is

[1] A calculation method of the costs for an insurance rate can be found in Ott, A. (2006), 93f.

fixed for a long time. Another possibility is to find a bank to guarantee loans in case of the occurrence of an event. The costs for this service can however not be neglected. Figure 2 maps the mentioned aspects of risk management.

Figure 2: Risk Management



Source: authors' own representation based on Münchner Rückversicherungs-Gesellschaft (2005), 62

Direct hazard

Hazards can be divided into technical, man-made and natural hazards. Examples for each category in respect to the railway infrastructure are given in chapter III. Each hazard can be described with a probability function. The function sets the intensity of an event in relationship with it to happen in a certain amount of time, e.g. a year. A "century flood", for example, is an event of an intensity that can be expected once every one hundred years or with a probability of 1/100 per year. The probability functions are usually derived from historical data and current measurement data.

Damage potential

The damage potential of a network part is a function of the damage and the affected values. Vulnerability functions combine information on the intensity of an event with the expected structural damages. The capacity reductions due to certain damages and the duration of the changed conditions are captured in so called residual capacity functions. They are usually derived from historical data.

The affected values can be described with:

- The importance of the infrastructure (e.g. number of passengers affected, rerouting possibilities)
- Values of buildings and other constructions

The damage potential is expressed in monetary units. From the infrastructure operator's view, damages can be categorized as follows:

1. Damage or destruction of construction elements causing a limitation of service.
2. Damage or destruction of construction elements causing a (limited) cancellation of all services.
3. Temporary interruption of service not being caused by a material damage.
4. Damage of life, body or goods of third parties for whom the infrastructure operator is responsible.

Category 1 means that mainly physical damage on infrastructure occurs with hardly any interruption of service. Category 2 leads to heavy changes in the service structure. Train services have to be cancelled completely or to be rerouted. The results are higher expenditures for the continuation of service and less income due to less people using the service. The same occurs in damage category 3 however without any material damage. Category 4 does not mainly influence the infrastructure service but entails financial consequences. Even though, in most cases damages in category 4 happen in accordance to damages of category 1 or 2.
In many cases it is not only the direct damage to persons or infrastructure that lead to high costs, higher costs are usually caused by lost income from cancelled or poorly utilized train services.

Expected costs

An infrastructure manager has to take into account various costs for coping with risks:

- **Capital costs for additional and advanced infrastructure elements:** A differentiation between infrastructure elements can be made according their ability to withstand natural and man made hazards. (C 1)
- **Capital costs for the allocation of reserves:** In case of reserves, which are used to cover damages or losses of revenues, the capital costs have to be taken into account. The capital costs for the allocation of reserves can be calculated on an annual basis. (C 2)
- **Running costs for the insurance:** Annual premium of insurance for certain risk coverage. (R 1)
- **Running costs for personnel measures:** In case of keeping staff to reduce the risk (e. g. additional security staff in case of a terrorist threat) the costs have to be added. (R 2)
- **Costs of replacement:** In case of damaged or destroyed infrastructure elements costs for replacement have to be taken into account. The annual costs can be calculated by defining risk scenarios with certain costs for replacement. These costs have to be multiplied by the probability of certain risk scenarios. It has to be secured that only costs which are not covered by insurance have to be considered. (P 1)
- **Costs of rerouting:** If a rerouting is possible in case of an incident, the additional costs have to be considered. The annual costs can be calculated by defining risk scenarios with certain costs for rerouting. These costs have to be multiplied by the probability of certain risk scenarios. It has to be secured that only costs which are not covered by insurance have to be taken into account. (P 2)
- **Costs of reduction in revenue:** In case of major damage to the infrastructure, the infrastructure manager may face certain losses through the decline of demand. Some of the demand might shift to other modes of transport, some of the demand vanishes completely. In both cases the infrastructure manager faces a loss of revenue, which has to be taken into account. The annual costs

can be calculated by defining risk scenarios with certain costs for reduction in revenue. These costs have to be multiplied by the probability of certain risk scenarios. It has to be secured that only costs which are not covered by insurance have to be considered. (P 3)

- **Costs payable to third parties:** The infrastructure manager may be forced to pay third parties (e.g. train operating companies) for neglecting risk prevention. The annual costs can be calculated by defining risk scenarios with certain costs payable to third parties. These costs have to be multiplied by the probability of certain risk scenarios. It has to be secured that only costs which are not covered by insurance have to be considered. (P 4)

The infrastructure manager can optimize the costs by doing a net present value analysis of different scenarios of risk coverage. Furthermore the legislation has to be taken into account, which is often very strict e.g. concerning risk prevention in the construction of certain infrastructure elements.

III Hazards and their possible impact on railway infrastructure

In this chapter, possible hazards are classified in three categories. In Central Europe the class of natural hazards is most common. Especially flooding is a widespread risk for many railway lines. Man-made hazards gained an increasing importance in the last years. Especially prestigious high-speed lines as well as heavily used commuter lines are targets of terrorists. In addition, there is still a certain possibility of technical failures, which have to be covered.

Natural Hazards – Force Majeure

Service interruptions and damages due to force majeure have happened since the beginning of services. The most present natural hazards are all more or less connected to weather conditions. Although weather forecasts may alarm the responsible operators to take appropriate actions, the exact conditions and the duration of the conditions are still not predictable. The following list gives and overview of the relevant natural hazards in Germany and their possible outcomes.

- **Earthquakes:** Engineering works are in the focus of earthquake endangered infrastructures in Germany. Earthquakes happen rather seldom in most of Germany’s states. There are some areas, however, which are under higher risk and need to pay attention to earthquake-proof measures. The constructional reinforcement results in higher infrastructure costs. These are (in most cases) marginal considering the total construction costs. Earthquakes can also trigger landslides.
- **Landslides:** Rail tracks often run through valleys and pass by slopes and therefore face the risk of landslides and subsidence. A slope failure can be the result of certain weather conditions or an earthquake. Usually an event like this entails temporary service interruptions. Depending on the accessibility and the residual danger of the failure’s location, the cleanup may take a very long time. There are regulations requiring the fixing of a slope above a certain incline.
- **Floods:** Floods can cause long service interruptions and damages of the infrastructure. Flood prone railway links and bridges are constructed to be able to withstand the water. So even a completely flooded railway infrastructure does not necessarily cause high structural damage. Extreme floods like in Saxony 2002 occurring once a century are not foreseen in the constructive measures. Seldom cases like this may therefore result in high infrastructure damages.
- **Storm:** Extremely severe storms can damage the railway infrastructure and interrupt train services. The main reason for this is the vegetation next to the railway tracks, especially high growing trees. These trees may break or fall during a storm and block the railway, so train service can only be resumed after clearance. Train services also have problems with wind coming from the sides. In the past, this problem was inherent in the freight transportation, where very light or bulky goods were in danger of being moved on the train. With the development of light and fast trains, the problem has also become interesting for the passenger transport.
- **Snowfall and ice:** In Central Europe there are often weather conditions, which lead to a blockade of lines or parts of the network. Heavy snowfall and ice can block tracks and switches or disrupt the energy supply. Snow ploughs and

heating at switches are common to deal with the problems. An infrastructure manager has to weigh up the capacities to cope with the seasonal risk and their redundancy in the summer season.

- **Lightning strike:** Lightning strikes are very unpredictable and a serious risk for the operating infrastructure. The electrical installations, like the control and communication system as well as the power supply, can be damaged or destroyed by over-voltage.

Man-Made Hazards

- **Terror:** The damages due to terrorist attacks can be divided in the reconstruction of the infrastructure, the short time loss of revenue and temporary stop of the train system and the long term deficiency in revenue due to the lower use of the transport system. Even the bare threat of an attack may result in high costs. All protection efforts focus on infrastructures with high vulnerability since they are common targets of terrorists.
- **Carelessness or acts of sabotage:** Risks through carelessness or acts of sabotage can occur if employees of the infrastructure manager or operators risk knowingly or unknowingly the operations of the transport system.

Technical Hazards

- **Defects of deficiencies in construction:** Damages, happening through use of wrong construction material or wrong construction calculations and execution are called defects or deficiencies in construction. They may occur in buildings, rail tracks, switches, as well as in electrification and telecommunication installations. The infrastructure manager is not responsible for these kinds of hazards.

Especially in case of natural hazards, there can be an interaction between risk categories. (For further information see Meyer (2002).)

IV Case Study

To demonstrate the developed model a part of the (left) Rhine Valley line was examined. The section is 29 kilometres long, starts in Gau-Algesheim and ends in Oberwesel. The line is one of the most important corridors for the North-South freight transport in Central Europe and plays a crucial role in regional passenger transport as well as in long distance passenger transport. At the moment approximately 220 scheduled trains run on the line. In addition there are many additional (not scheduled) freight trains, which make the line to one of the most crowded lines in Germany.

A major risk on this section is flooding.[2] The critical element of the infrastructure is the main station of Bingen. There, the tracks are built at a very low level compared to the river of Rhine. In case of a water level of the Rhine River above five metres the situation can be critical. In 1970, 1988 and 1995 the train operations stopped completely, because of flooding in this section. But even with a lower level of flooding, measures have to be taken into account and train operations have to be reduced or redirected.

In this paper, four steps of measures depending on the level of flooding are considered:

1. Secure all electrical devices and rolling stock. Trains are able to operate on main line tracks only. Rerouting of 40 % of freight trains. (Scenario 1)
2. Major reducing of the speed. 60 % of freight trains and all long distance passenger trains are rerouted. (Scenario 2)
3. Cancellations of all regional trains, all other trains are redirected. Repair of 1,000 metres of track has to be done. (Scenario 3)
4. No regional trains, all other trains are redirected. Major repair of about 5,000 metres of track has to be done. (Scenario 4)

After the identification of necessary countermeasures in case of flooding, the costs (per train and day) have to be calculated. Following measures are taken into account:

[2] General information of the risk and insurance of flooding can be found in Kron (2001).

- Additional manpower to make the line waterproof (removal of electrical devices and rolling stock) (R2)
- Creating new timetables for redirected trains (P2)
- Additional track access charges of redirected trains (P2)
- Cancelled trains (P3)
- Track restoration and renewal after flooding (P1)

For each mentioned scenario the probabilities of occurrence are calculated and multiplied with the costs of each measure. Probabilities of occurrence are derived from historical data of the water level of the Rhine River between 1970 and 2005. We do not assume any capital costs for reserves, etc. or any insurance, because the current infrastructure manager is able to incorporate damages and losses within his budget.[3]

Table 1: Cost of different scenarios of flooding[4]

	Scenario 0	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Probability	0.588	0.176	0.147	0.029	0.059
R 2 (EUR)	2,000	6,500	6,500	6,500	6,500
P 1 (EUR)	0	0	0	29,000	1,750,000
P 2 & 3 (EUR)	0	24,000	59,200	108,320	255,680
Total (EUR p.a.)	1,176	5,368	9,657	4,170	118,718

The total costs of the risk of flooding average out at about 140,000 EUR per year. In relation to the total costs of the infrastructure this kind of risk seems bearable. The total costs of risk prevention and insurance can be assumed at around 200,000 EUR per year for this segment of the network. These costs account for 2 % of the total costs in this section of the line.

[3] In reality, a major flooding of the river of Rhine can lead to problems at other segments of the rail network as well, so the infrastructure manager is not any longer able to incorporate all damages and losses within its cash flow.

[4] All figures are estimated. The basis of the estimation can be found in Ott (2006).

V Conclusions

The paper presented an economic approach of treating external risks from the point of view of an independent infrastructure manager. After defining some relevant terms, possible hazards, damages and ways to deal with external risks were explained. The paper then listed the relevant factors in calculating the expected yearly costs faced by an infrastructure manager due to external hazards. A formula captured the factors for calculation purposes. Finally the approach was illustrated by an example of a railway section in Germany prone to flooding and the calculation of its yearly costs.

It was shown that there are a number of external risks to infrastructures in Central Europe. Although they are usually relatively manageable, the risks cannot be neglected. For railways, on average the costs due to external risks amount to 2-10 % of the total annual infrastructure costs.

An infrastructure manager or operator should be aware of the relevant risks, their probabilities and possible damages. It is then to decide which measures need to be taken in order to reduce the risk to a bearable level.

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