Three-Dimensional Individual and Group Risk Approach of Buildings above Roads and Railways during Exploitation

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Abstract

This paper will propose an approach for the 3rd dimension for both individual and group risk analysis for buildings above roads and railways during exploitation stage.

1 Introduction

Lack of space leads to the design and construction of projects which make intensive and multiple use of the limited space. Buildings above roads and railways are examples of such projects. Usually, a large number of people and several multiple risk dimensions are involved. Due to the complexity and interrelationships, a small accident, like a fire in the building or the infrastructure, can easily lead to a big disaster. Therefore, safety is one of the critical issues in such projects for the construction phase as well as for the exploitation phase [1]. A research has been carried out for risk of buildings above roads and railways in the exploitation phase [2]. The level of safety is examined by a probabilistic risk analysis using Bayesian Networks and checked with the societal risk acceptance criteria. In order to perform a risk analysis for the exploitation phase three basic areas, can be distinguished [1]; 1. the building (above the infrastructure), 2. the infrastructure (beneath the building), 3. the vicinity (besides the infrastructure). The safety relations between these areas are determined by a risk analysis that is performed for five different situations (figure 1) [3]:
(1) External safety and risks from the building in relation to the infrastructure beneath (e.g. falling elements and fire);
(2) External safety and risks from the infrastructure towards the building (e.g. release of toxic gasses, fire, explosions and accidents);
(3) Internal safety and risks from the constructions enclosing the infrastructure (e.g. explosions, fire, explosions and accidents);
(4) External safety and risks from the infrastructure towards the vicinity (e.g. release of toxic gasses, fire, explosions and accidents);
The fundamental characteristic of the area of building above infrastructure is its dimensions, such as the height, the span *l* and the covering length of the building *L*. The ratio of passing vehicles and heavy traffic, in particular both quantity and type of the transport of hazardous goods are basic parameters for the area infrastructure.

The density of the buildings and thus the number of people present are important for modelling the vicinity.

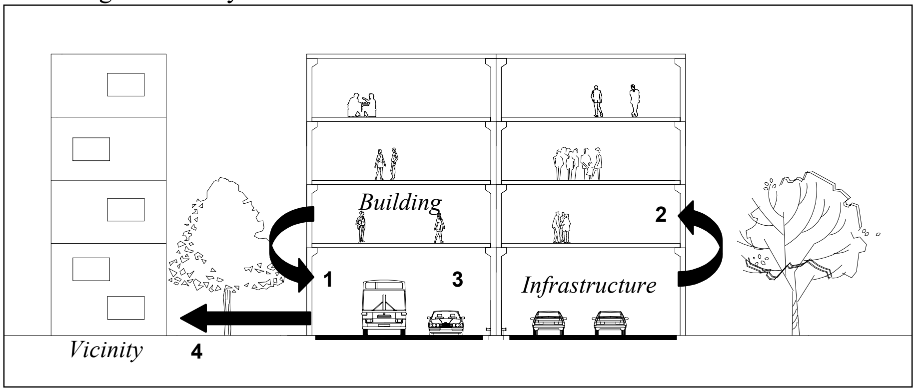

Figure 1: The four risk interactions in multiple use of space projects.

2 Qualitative Risk Analysis

Considering the four interrelations between the three areas as presented in figure 1, which are interrelated to safety aspects during the exploitation phase, these aspects and their risk are analysed. First of all, a qualitative risk analysis is performed for people in neighbour of multiple use of space projects using FMEA-techniques. This FMEA is transformed into a Bayesian Network (figure 2). It appears from the FMEA that the risk for people, either in the building above the infrastructure or at the infrastructure or in the vicinity during the exploitation phase largely depends on the hazards taking place on *the infrastructure* or the hazards taking place in *the building*. Although table 1 might indicate that the interrelation hazards on the infrastructure to the building (1) are the same as the interrelation hazards from the constructions enclosing the infrastructure (3), it should be noted that the risks are not of the same calibre because both have different consequences and probabilities on different areas. The hazards on infrastructure can be grouped into four dominant classes; *traffic accidents* (mechanical load on the structure of the building), *fires*, *leaks of toxic substances*, and *explosions* [4,5]. Furthermore, the risk of people present in the building above the road it is relevant if the building collapses due to hazards occurring on the infrastructure. Fire, explosions and mechanical accidents towards the building may cause the collapse of the building.

Table 5.1: An example of the FMEA for safety of people during the exploitation.

Failure mode	**Failure cause**	**Effect of failure**
[1] External safety and risks from the building in relation to the infrastructure beneath		
fire in building	short circuit	costs, time loss, loss of quality, casualties
	cigarettes	
	cooking facilities	
	terrorism	

explosion in building	gas leak	costs, time loss, loss of quality, casualties
falling objects	montage failure	costs, casualties
	throwing out of window	
collapse building	explosion infrastructure	costs, time loss, loss of quality, casualties
.	.	.
[2] External safety and risks from the infrastructure towards the building		
traffic accident (towards structure)	unimportance	costs, casualties
	distraction	
	high speed	
	overtaking	
fire at infrastructure	traffic accident	costs, time loss, casualties
	leak of flammable materials	
	terrorism	
explosion at infrastructure	leak of flammable materials	costs, time loss, loss of quality, casualties
	terrorism	
release of toxic gasses	leak of toxic materials of vessels	
Electrocution	short circuit	costs, casualties
Derailment	defective track	costs, time loss, casualties
.	.	.
[3] Internal safety and risks from the constructions enclosing the infrastructure		
see [2]	see [2]	see [2]
.	.	.
[4] External safety and risks from the infrastructure towards the vicinity		
see [2]	see [2]	see [2]
.	.	.

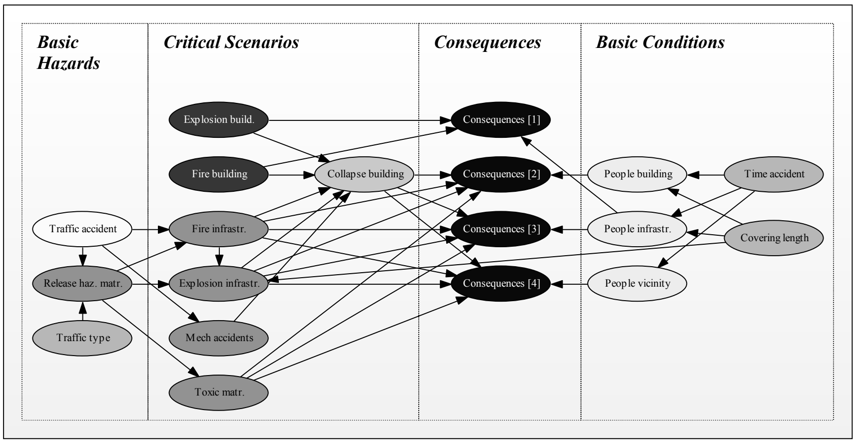

Figure 2: Bayesian Network for building above roads for construction stage.

The Bayesian Network represents the relations and conditional probabilities between events. Two consequences, loss of human life and economic loss, were considered in these networks.

3 Quantitative Risk Analysis

3.1 Three-dimensional individual risk contours

As dealing with the 3rd dimension safety system when doing risk analysis adds considerably to the complexity, this is not done in the traditional models for consequence analysis and frequency estimation. Therefore additional methods are needed for modelling the behaviour of risk in the 3rd dimension [4].

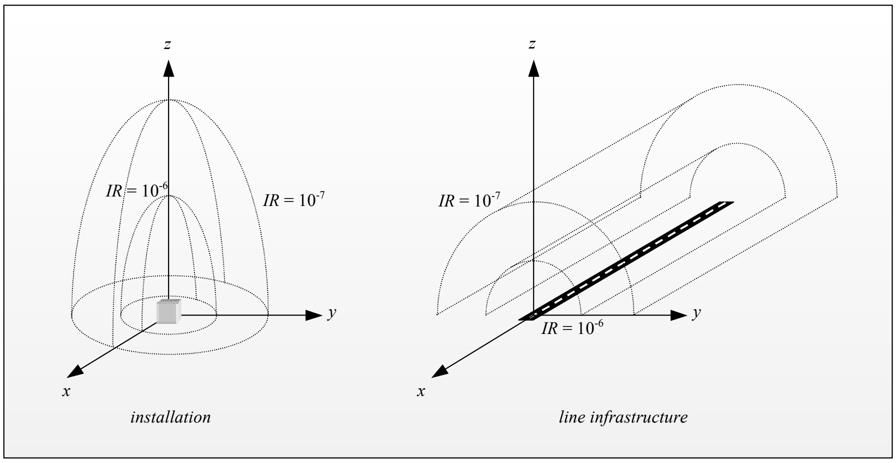

Figure 3: 3-D Individual risk contours for an installation and line infrastructure.

When realising buildings above roads or railway tracks these individual risk contours may look like the following:

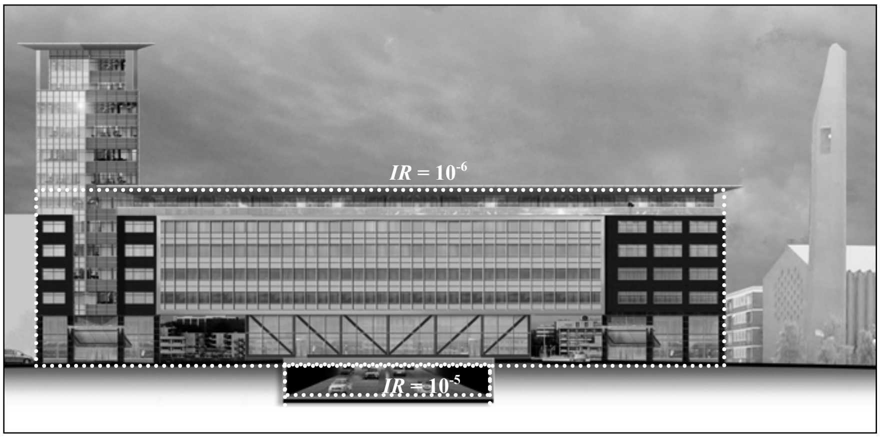

Figure 4: 3-D Individual risk contours for the case Bos en Lommer.

3.2 Three-dimensional group risk approach

Likewise, the group risk can be determined for Bos and Lommer. The FN-curve for this project - per risk dimension of figure 1 - is as follows:

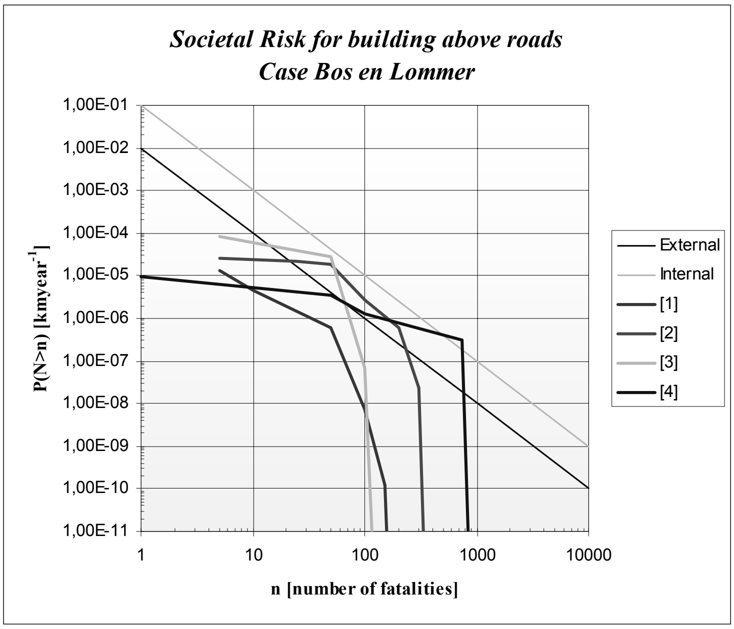

Figure 5: The group risk for Bos and Lommer building and vicinity.

4 Expected number of people killed

An important parameter for the overall risk interaction is covering length of the infrastructure. Other approaches to present the influence of the covering length of infrastructure and the risk is to make use of the expected number of people killed per kilometre per year, also called the PLL or the $E(N_d)$, due to scenarios which can take place in the described system of figure 1. If we correlate the $E(N_d)$ with the covering length, remarkable results can be obtained (figure 6).

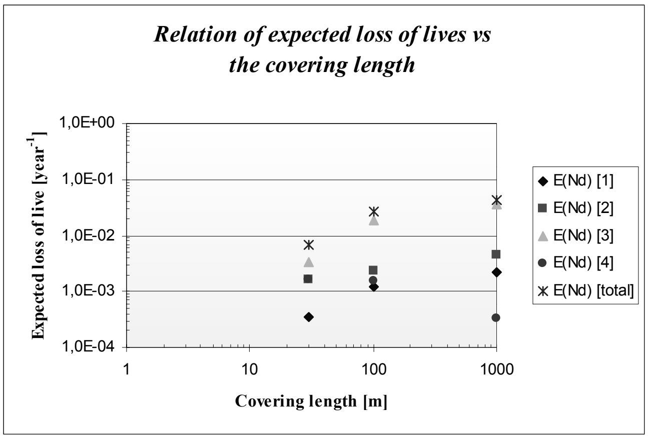

Figure 6: Relation of expected loss of lives vs the covering length.

Although the relation is not of a linear type, it can be observed that the $E(N_d)$ for the vicinity (4) decreases, in case the covering length of the infrastructure increases. In contrast, the $E(N_d)$ for the people at the infrastructure (3) increases rapidly with an increase of the covering length of the infrastructure. Both the $E(N_d)$ of (2) and (1) increases slowly with an increase of the covering length of the infrastructure. Figure 6 can be schematised as following:

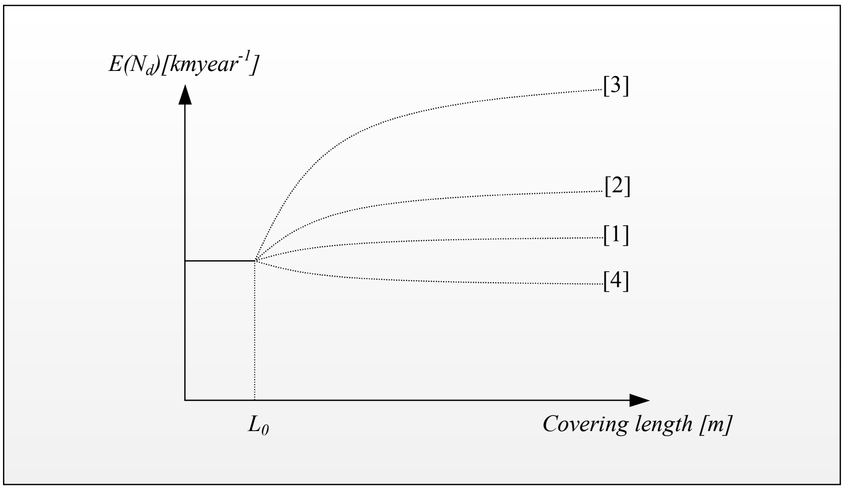

Figure 6: A schematised relation of expected loss of lives vs the covering length.

Figure 6 is applicable both to realising building above roads and above railways. This figure shows that from a minimum covering length (L_0) of the infrastructure, the expected loss of human lives per kilometre per year ($E(N_d)$) splits up in three additional risk dimensions ((1,2,3)). In fact, the risk towards the vicinity (4) already existed. It is clear that safety measures can influence the overall risks. For further information about the three-dimensional risk approach see [4].

References

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