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Environmental Risk Analysis for High-Rise Buildings In Belgium With The European Seveso Directives

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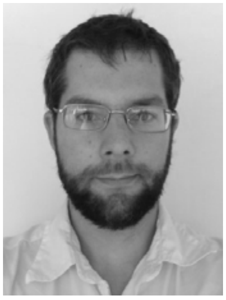

Yves Dechamps

Biography

Yves Dechamps is currently a Ph.D. student at the Department of Building, Architecture and Town planning, Faculty of Engineering and Applied Sciences, Université Libre de Bruxelles, Brussels, Belgium.
He graduated as an architectural engineer in 2008 at the Université Libre de Bruxelles and in 2009 he obtained a grant by the Brussels Institute for Research and Innovation (IRSIB).
His research areas include high-rise building risks and environmental analysis.

Abstract

The High-Rise Buildings (HRB) are currently the subject of many discussions about their architectural and sociological impact in the city but the situation regarding the safety w.r.t. to their environments and related risks? In the past, HRB were strongly criticized for their poor integration in the city but now the environmental safety aspects cannot be neglected. Indeed HRB design cannot be made without undertaking risk analysis on their environment and vice versa on their involvement in the future development of the city. The original contribution of this paper is to propose a risk analysis model of HRB environment adapted from the Seveso Directive about the control of major accident hazards and specifically HRB present in Brussels-Capital Region, Belgium. The model proposed integrates different steps of risk analysis related to the environment specific to HRB by both deterministic and probabilistic approaches.

Keywords: High-Rise Buildings, Risk Analysis, Seveso, Environment,

Introduction

Towers, which symbolize true innovation for some, represent urban nightmares for others. They are buildings which generate controversy, excitement or rejection. Moreover, since the events of the 11th September 2001 in New York, risk analysis of HRB has been brought to focus. This major event has raised many questions about the safety of these giants. What are the risks that such towers may face and how can we address them?

High-Rise Buildings

It is first necessary to define the concept of High-Rise Building (HRB) based on French standards, any housing building over 50 m high is considered as HRB. This limit is fixed at 28 m for non-residential buildings. However the definition of a HRB cannot be only limited to its height since other characteristics implying security notions come into play. The first characteristic of a HRB should not be just its intrinsic height. It should be measured in comparison to other nearby buildings, at least for a time.
A building substantially higher than its neighbors may be bar-shaped but in this case it is difficult to speak of HRB without considering the slenderness ratio, i.e. the ratio between height and width of the building. Some authors and referral sites for towers, like the Canadian website SkyscraperPage refer to a HRB when it reaches a minimum of 12 floors or 35 meters in height (Skyscraper Source Media, 2010).
Various sources refer to skyscrapers exceeding 500 feet (152 meters) but this definition will not be chosen. Indeed in Belgium there are currently no buildings exceeding this limit, and even the highest Belgian HRB located in Brussels, “Tour du Midi” (South Tower), is two meters below this threshold. However Council on Tall Building and Urban Habitat (CTBUH, 2010) proposes a set of characteristics that give a broader definition to a HRB based on the following criteria:

- height relative to the context,
- proportion,
- use of specific technologies such as elevators.

By taking these aspects into account, a new safety factor could be integrated for HRB design. Evacuating people from the outside façade is impossible because of constraints for emergency services due to height limitation for firefighter ladders; more stringent standards must be set in terms of resistance to fire, compartment and access to the fire (Ministère de l’Intérieur, 1997; Lataille, 2003). In fact HRB can be defined as any structure where the height will have a real impact on the evacuation due to the impossibility of any external intervention (Craighead, 2009). The presence in the building of a large number of people makes it impossible to evacuate an entire building rapidly except in case of extreme emergency.
Finally a HRB according to French standards is a building distinguished by height at the minimum 50 meters which will require specific protection measures due to hazards caused by the height factor, as resulting risks get higher and people evacuation is made more difficult only through the central core. The concept of proportion as well as the required presence of elevators in the building will be added to this definition.

Environmental Hazards

What risks does the presence of HRB cause to the environment? To this end, the Seveso Directive (Council of the European Union, 1997) sets out various risk notions for the environment. The objective of this work through these regulations is to assimilate the risk concepts for HRB.
The Seveso Directive refers to EU Directive 96/82/EC of the European Union dated on 9th December 1996 about the control of major accident hazards involving dangerous substances also known as Seveso Directive II. This Directive is a revision of the Seveso Directive I (82/501/EEC) by the Council of the European Union dated on 24th June 1982 about major accident hazards associated with certain industrial activities. It was then revised, producing the Directive 2003/105/EC of 16th December 2003. The obligations of the Directive become mandatory for industries as well as for the public authorities of the Member States as Belgium. This Directive is concerned with the prevention of major accidents which might result from certain industrial activities and with the limitation of their consequences for man and the environment. In the latest version of the Seveso Directive II, in terms of planning, it is expected that the objectives of preventing major accidents and limiting their consequences are taken into account. This policy of prevention will be complemented by drafting a document to the attention of public authorities about the safety report.
The concept of "major accident" is defined as "an uncontrolled event such as an “emission, fire or explosion resulting from uncontrolled developments in the course of the operation of any establishment covered by this Directive and leading to serious danger to human health and/or the environment immediate or delayed, inside or outside the establishment, and involving one or more hazardous substances" (Council of the

European Union, 1997). Directive 96/82/EC also defines the notion of "hazard" as "the intrinsic property of a dangerous substance or physical situation, with a potential for creating damage to human health and/or the environment" (Council of the European Union, 1997) and the concepts of “risks” as “the likelihood of a specific effect occurring within a specified period or in specified circumstances” (Council of the European Union, 1997).

Safety Report

The operator must demonstrate with the safety report that he manages its facilities safely for humans and the environment. To this end he should provide:

- a policy of preventing major accidents and a system of safety management were implemented,
- that the major-accident hazards have been identified and that all necessary measures have been taken to prevent such accidents and their limitations in terms of consequences for humans and the environment,
- the design, construction, operation and maintenance of facilities have adequate security and sufficient reliability,
- an internal emergency plan has been established and provides the necessary information to emergency services for establishing external emergency plan,
- that sufficient information was provided to the competent authorities so they can make informed decisions about their political planning around existing establishments.

Therefore to ensure a fast and efficient assessment, the safety report should follow the following structure:

- general information,
- presentation of the plant environment,
- description of the plant,
- identification and analysis of major hazards and prevention methods implemented,
- internal emergency plan.

Internal and external emergency plans

EU Directive requires that operators draw up an internal and external emergency plan. The objectives of these plans are to restrict consequences and damage and to introduce measures to protect humans and the environment against the repercussions of major accidents, to provide information to the people concerned and to the relevant authorities, and finally to ensure restoration of the environment following a major accident. The internal emergency plan takes into account various information such as description of measures to control and limit the consequences of foreseeable accidents, warning systems for authorities responsible to set off external emergency plan. Meanwhile the external emergency plan describes procedures for warnings, arrangements for coordination of all necessary means to implement the emergency plan and those for external intervention on the spot.

Domino effects

An important aspect in Directive 96/82/EC is to take into account the domino effects of the Seveso industries. This compels the authorities to identify establishments or groups of establishments where the hazards or potential consequences of major accidents are the greatest because of their location and their proximity. It is important to take into account the overall risk from the nearby site such as an explosion or fire that may have implications not only for the plant itself but can also initiate an accident in nearby plants! The overall risk of the neighboring plants may be considerably higher than the risk of each of them separately.

Land-Use Planning

Past accidents as in AZF Toulouse, France, in 2001 which caused thirty casualties, the release of a toxic gas cloud in Bhopal in 1984 killing 2000-2500 people or the explosion in a gas storage site in the crowded suburbs of Mexico City in 1984 leaving between 1500 and 2500 casualties (Lagadec, 1986), prompted the introduction of Land-Use Planning (LUP) in the Seveso Directive. The authorities cannot be unaware of the presence of existing and new plants in their LUP. This policy and its implementation must ensure that long-term adequate distances between Seveso plants and urban areas are maintained. If existing plants are already located near such urban areas, the Directive requires that LUP provides additional technical measures to avoid increasing hazards to the inhabitants.

Risks analysis for HRB

Following the previous points, the first study risk analysis related to the HRB environment and inspired by the Seveso Directive will be proposed. To this end the HRB Brusilia from Schaerbeek, Belgium, will be analyzed according to criteria and specific aspects of the Seveso Directive. It will be first conducted to identify risks and their analysis, followed by an assessment to end with the exploitation of results.
The Brusilia building is located 100-104 Avenue Louis Bertrand, 1030 Schaerbeek, on the site of a previous sports hall, Figure 15. Because of its height of 113 m and the fact that it is the tallest residential building in Belgium, this HRB is a good example for an initial risks analysis since about 640 people may be present simultaneously by night.

Figure 15 HRB Brusilia implantation

The HRB environment is characterized by a high density with 10,496 inhabitants per km² whereas the average in Brussels-Capital Region is 6,312 per km². The HRB Brusilia is located on a land of about two acres with a park and two main avenues on the East side. On the west side there are mainly row houses of three to four levels. On the North there is a mall, a service station, a swimming pool and a car park in the basement. A partly underground railroad passes through Josaphat Park on the South.
Brusilia is a HRB of 36 levels and is 113 meters high. Originally it should have been twice as long but the second phase of construction never took place because of the crisis in the 70s. The HRB groundfloor leads to the apartments on the upper floors and is used by some offices and a store. Brusilia HRB consists of 204 apartments facing East-West spread over 34 floors with on each floor three apartments of two bedrooms (± 100 m²), two three-bedroom apartments (± 130 m²) and a single bedroom apartment (± 70 m). There are also two basements and a mezzanine. Brusilia HRB can be divided into three entities which have each a vertical circulation consisting of a lift, a freight elevator and a stairwell. Apartments accessibility requires a magnetic key giving access to the entrance hall on the ground floor. The main structure is composed of shear walls and reinforced concrete floors, all stiffened by the core of each three entities.

Risks files	Authority		Date
	Object of risk	Description	
	Brusilia	Residential HBR	
Adress		Complementary informations	
Av Louis Bertrand 100-104, Schaerbeek, 1030, Belgium			

Risks	Date	Target	Assessment
Riot		Mall	Low
Earthquake		Brusilia	Low
Train derailment		Railroads	Negligible
Car bomb		Carpark	Average
Fire		Nearby buildings	Average

Figure 16 Risks file and assessment

A first step in the identification and assessment of major-accident hazards is to check potential risks from pre-established lists (Direction générale de la Sécurité Civile, 2010). Preliminary identification of potential risks would be this: lightning and high winds are natural hazards N due to natural circumstances; a plane crash, malicious acts, attacks with explosives and fire risks are accidental or intentional hazards H due to human acts. The mall can be considered as subject of risk by the presence of a large number of people at the same time near the HRB. Objects to such risks as the two avenues and the railroad are a priori not to be considered as real threats because Brusilia is slightly elevated on a hill and should not fear a direct hit by a vehicle except in cases of voluntary acts. The presence of an underground carpark will require a thorough study of the impact on HRB by explosion or fire.

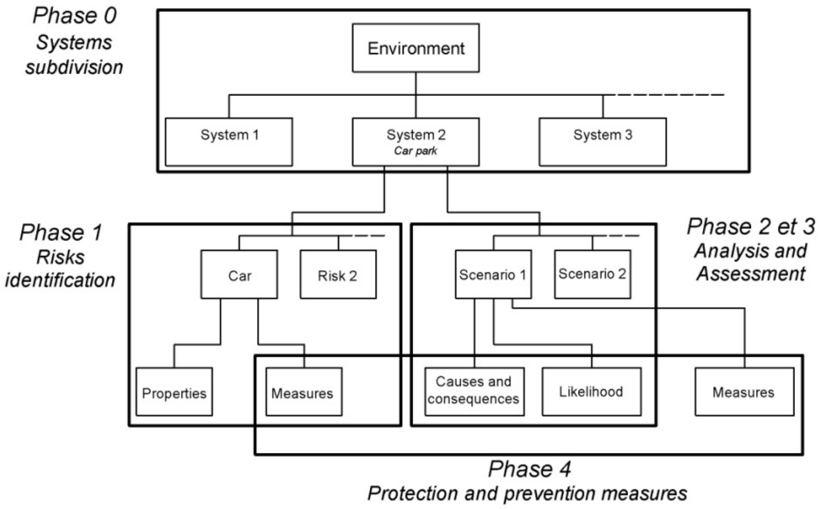

Figure 17 HRB and its environment - scenario study

What are the threats to the built environment in proximity to the HRB and conversely the risks to the HRB itself front its vicinity? To answer this question it is necessary to draw up a risks inventory that however may not be considered as exhaustive. This list, Figure 16, will take into account all objects of risks present near the HRB such as public and private buildings opened to public, public utility facilities, resources or transport infrastructure. After a preliminary investigation of accidents involving HRB, it appears that mainly accidents are due to fires and gas explosions. More recently HRB have faced bomb attacks, which cause the greatest damage (Craighead, 2009; Jeanroy, 2001; Bouillard and Rammer, 2001).
Determining causes and consequences, Figure 17, due to undesired events is necessary to assess the likelihood and the severity of such an event and to take the necessary protective measures. Knowing the causes allows determining preventive measures rendering undesired events less probable whereas knowing the consequences will enable decision making to limit possible damage (Boss and Day, 2009). This risk analysis consists of the following activities:

- definition of accident scenarios,
- identifying the causes and consequences of accident scenarios,
- estimating the likelihood and severity of these scenarios.

The definition of a single general accident scenario, Figure 18, has little meaning since this scenario will depend on various factors such as type of activity, occupation or environment. The consequences of a single scenario usually cannot be determined unambiguously. Determining the probability of the individual causes of accidents is therefore preferable.
The FRAME method (Kaiser, 1980; De Smet, 2010) was chosen because it currently integrates three different approaches under fire scenarios that are: protection of the building, people, and activity present in the building. The environment could be related to this method as a fourth point. By doing so, this method, initially developed for the fire safety of buildings, now integrates any of the other risks previously described. Subsequent researches will be developed to implement this fourth term inspired by what is done in safety studies for Seveso plants.

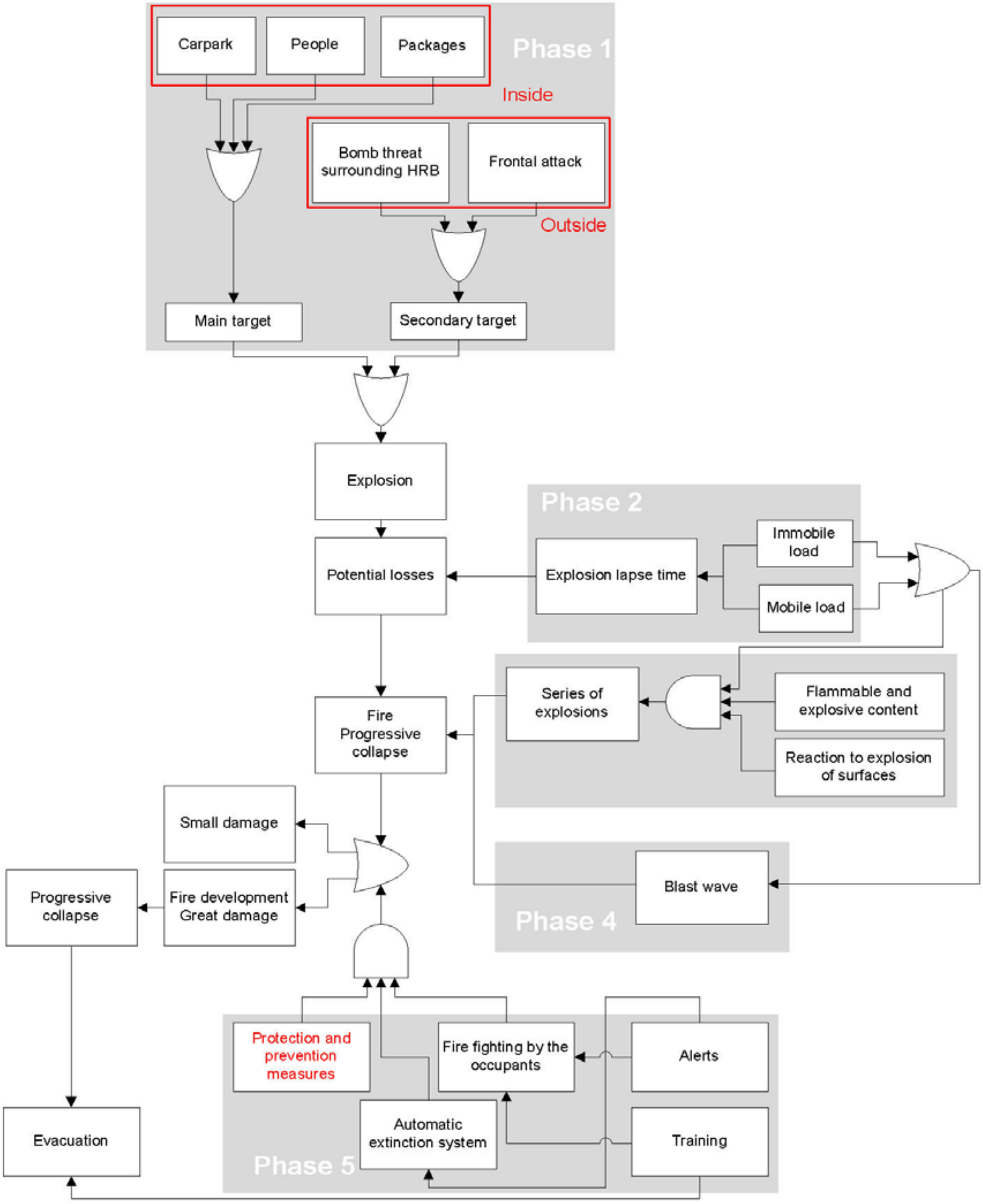

Figure 18 Bomb threat scenario

The next step is risk assessment that can be made by using factors or benchmarks. Without such criteria, the determination of prevention measures becomes totally subjective and uncontrolled. In practice, a number of discrete classes of these values can be proposed for this purpose. They will then be combined into risk classes (Direction des risques chimiques, 2001). The most visual method to represent these classes is to use the risk matrix, Figure 19, but it only concerns a qualitative approach. The results of this approach will be the specifications for preventive measures to be taken. The criteria for risk assessment will determine the relationship between the incoming and outgoing data. Two critical aspects come into account when defining evaluation criteria:

- the limits of the assed system and defining the type of measures that will have to meet requirements,
- specific requirements in respect of preventive measures based on the magnitude of risk.

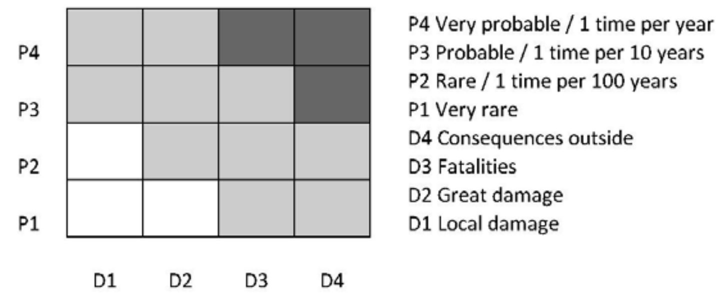

Figure 19 Risk matrix

The combination of the categories of severity and probability chart gives the risk matrix (Direction des risques chimiques, 2001; Kirchsteiger, 1999). The densely shaded squares as P4/D3 represent the most severe risks that require immediate action. Light areas like P2/D1 represent the least severe dangers and do not require any special measures.
The last step of the method of risk analysis is the operating results after identification of the risks, their analysis and assessment. What then are the measures to be taken to prevent or limit the consequences of an undesired event? Two types of action can be taken: at the level of prevention or protection. Three different strategies can then be followed when determining measures of prevention and risk reduction: reducing risks, avoiding damage and limiting damage.
Risk reduction means reducing the possibility of occurrence of scenarios in which undesired events occur or reduce the potential severity. It is therefore necessary to intervene on the sources of damage. Damage prevention means preventing undesired events from occurring by decreasing the probability of their occurrence. Limiting the damage is the last priority when determining preventive measures.

Conclusions

As seen earlier, the HRB is defined as a building distinguished by height at the minimum 50 meters and required specific protection measures caused by the height factor and the presence of a large number of people at the same time. Moreover the HRB can be seen as a Seveso plant due to the comparable impact to its environment in case of major accident. To this end it is possible to adopt the European Seveso Directive which aims to prevent major accidents involving dangerous substances. The concepts of protecting people and the environment, which form the basis of this research work, are integrated into the Directive. A HRB is not strictly speaking a Seveso plant but the occurrence of an undesired event can lead to catastrophic consequences similar to those of a major accident in a Seveso plant both from the human point of view and environmentally. A model of risk analysis has been proposed which allows us to integrate the safety report from the Seveso Directive and to develop scenarios involving the most serious consequences for environment and inhabitants. An application is shortly described.

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