

A Quick Scan Method to Evaluate the Impact of Off-site Developments on the Societal Risk of a Seveso Establishment

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According to the European Seveso III Directive, Member States should ensure that their land-use policy aims at maintaining appropriate safety distances between Seveso establishments and areas with high population densities. In Flanders, the location specific and societal risk of (upper-tier) Seveso establishments are calculated and evaluated against strict criteria when changes to the activities and/or the installations with dangerous substances within the Seveso establishment are planned. However, when new land developments that increase the off-site population are planned, the societal risk is often not recalculated. As a result of this and because of the difficulty (if not impossibility) to assess the impact of an increase in population on the societal risk without additional calculations, such off-site developments could unknowingly result in an exceedance of the societal risk criteria.

In order to aid land-use planners and the authorities in the evaluation of new developments in the vicinity of a Seveso establishment, a quick scan method has been developed to assess the impact of an increased population on the societal risk posed by the Seveso establishment. Restrictions that apply to the increase of population in the surroundings of the establishment can also be visualised on a map. In this paper this method is described, together with some worked-out examples.

1. Introduction

In Flanders, the risk of upper-tier Seveso establishments is quantified both as a location specific risk and as a societal risk (Vlaamse Overheid, 2006). The location specific risk is defined as the probability (expressed per year) that a person in the vicinity of the establishment dies as the result of a major accident (involving a dangerous substance) on the establishment's site, assuming that this person is continuously present at that location and is not protected against the effects of the accident. The location specific risk is typically shown on a map by means of lines that connect locations of equal risk. These lines are called isorisk contours. The societal risk is the cumulative probability F that N or more persons in the vicinity of the establishment die as the result of a major accident on the establishment's site. For each accident scenario considered in the risk analysis the frequency f and the number of fatalities N are calculated. The scenarios are sorted to obtain the cumulative probability F and the societal risk is represented by the FN curve. Figure 1 shows an FN curve together with a limit curve to evaluate the societal risk: the risk is deemed tolerable if the FN curve is below the limit curve.

The Seveso III Directive prescribes that Member States of the European Union should ensure that their land-use policies include controls on new developments in the vicinity of Seveso establishments where these developments may increase the risk or consequence of a major accident (EU, 2012). This implies that whenever a community plans a development in the vicinity of a Seveso establishment, there is a need to assess whether the development leads to an increase of the risk and when it does whether the risk criteria are met. Since the location specific risk is (nearly) independent of the surroundings, a change in the surroundings does not increase (nor decrease) the risk, and since the location specific risk is easily plotted on a map, checking whether the risk criteria are met is straightforward. In contrast, the societal risk depends on the entire

population within the impact zone of the Seveso establishment and as such is highly influenced by changes in the surroundings. Moreover, the societal risk itself cannot be plotted on a map. It is based on the total number of fatalities of an accident scenario and not on the number of fatalities in one area.

The need to assess the impact of new developments in the vicinity of Seveso establishments on the risk of these establishments early in the planning process combined with the complex nature of the societal risk poses a problem to the responsible authorities in Flanders and other countries or regions, where the societal risk is evaluated.

Laheij et al. (2000) have addressed this problem and have developed a method that allows the calculation of the uniform population density at a certain distance from the establishment for which the risk criteria are met. This method, however, is not accurate enough to assess new land-use plans when the societal risk is critical (i.e. when the FN curve is near the limit curve) because of the conservatism that was built into the method.

Wiersma et al. (2007) have created two maps to visualise the societal risk: a 'societal risk map' and a 'hotspots map'. To create these maps the area surrounding the establishment was divided into smaller areas by means of a cartesian grid. For each of the scenarios that affect a specific grid cell, the frequency of occurrence was combined with either the total number of fatalities occurring in all grid cells (societal risk map) or the number of fatalities occurring in the given grid cell (hotspots map) to construct an FN curve for the grid cell. Next, the cells were given a colour based upon the resulting FN curve. These two maps provide further insight into the societal risk. The maps, however, do not give any information regarding the increase in population that could be allowed before the risk criteria would be exceeded.

The aim of this paper is to present a method that accurately answers the question what increase in population can be allowed before the risk criteria are exceeded. In Section 2 the method will be described, while in Section 3 its use will be illustrated by means of a few case studies.

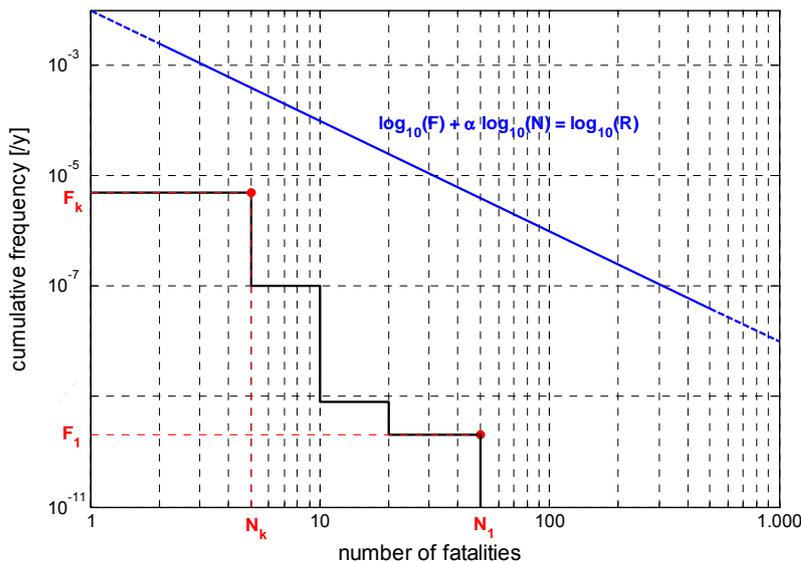


Figure 1: FN curve with limit curve

2. Description of the method

The societal risk criterion is assumed to be of the form

$$F \cdot N^\alpha = R \tag{1}$$

with N the number of fatalities of an accident scenario and F the cumulative frequency of all accident scenarios for which the outcome is N fatalities or more. R and α are constants representing the acceptable risk level (or anchor point) and the risk aversion factor (or slope of the criterion line), respectively. The societal risk criterion can also be written as

$$\log_{10}(F) + \alpha \cdot \log_{10}(N) - \log_{10}(R) = 0 \tag{2}$$

The necessary input to calculate the maximum allowable population increase consists of (1) an overview of all accident scenarios that contribute to the societal risk, together with the frequency of occurrence f and the numbers of fatalities N of these accident scenarios and (2) for each grid point, a list of accident scenarios that

result in relevant lethal consequences in that point, with the accompanying lethal responses for people indoors and outdoors. Furthermore, an assumption is made regarding the fraction of the additional population that is present indoors. The assumption is based on the planned development type (see Table 1). When more than one development type is possible, different sets of contours can be calculated for the different possibilities.

Table 1: Different types of development with corresponding assumptions for the indoor and outdoor fractions

Development type	Indoor and outdoor fractions			
	Daytime Indoor	Outdoor	Nighttime Indoor	Outdoor
Non-residential community facilities (e.g. schools, childcare, libraries, museums, community centres)	0.93	0.07	0	0
Residential community facilities (e.g. hospitals, nursing or retirement homes, boarding schools)	0.93	0.07	0.8	0
Assembly and leisure facilities (e.g. cinemas, dance and concert halls, indoor sport facilities)	0.93	0.07	0.93	0.07
Outdoor recreational areas (e.g. parks, golf courses or outdoor sport facilities)	0	1	0	0.5

A cartesian grid is defined with grid points (i,j) . The size of the grid is such that it encompasses the entire impact zone of the Seveso establishment. The resolution of the grid (e.g. 50 m x 50 m) is chosen taking into consideration the computing time and the desired accuracy of the result. The maximum allowable population increase in a grid point is determined iteratively as the root of the following vector-valued function, which is based on the societal risk criterion given in Eq(2) :

$$f_1(\Delta X_{i,j}) = \max \left(\log_{10} \begin{pmatrix} F_1 \\ F_2 \\ \dots \\ F_n \end{pmatrix} + \alpha \cdot \log_{10} \begin{pmatrix} N_1 \\ N_2 \\ \dots \\ N_n \end{pmatrix} + \log_{10}(R) \right) \quad (3)$$

where $\Delta X_{i,j}$ is the population increase in grid point (i,j) and n is the number of accident scenarios that contribute to the original FN curve or result in relevant lethal consequences in that grid point. The calculation starts by assuming a value for the population increase. Next, the expected number of fatalities N_k for each accident scenario k is calculated as

$$N_k = N_{k,org} + \Delta N_{k,i,j} = N_{k,org} + (L_{k,in,i,j} \cdot \chi_{in} + L_{k,out,i,j} \cdot \chi_{out}) \cdot \Delta X_{i,j} \quad (4)$$

with $N_{k,org}$ the original number of fatalities for accident scenario k , $L_{k,in,(i,j)}$ and $L_{k,out,(i,j)}$ the lethal responses for persons indoors and outdoors to accident scenario k in grid point (i,j) and χ_{in} and χ_{out} the fractions of the additional population that are assumed to be indoors and outdoors (see Table 1). Finally, the scenarios are sorted in decreasing order of number of fatalities and the cumulative frequencies of occurrence F_k are determined.

By connecting points of equal maximum allowable population increase contours are created, which can be plotted on a map (see Figure 2). On the basis of four sample projects with an expected population increase of 200, the use and limitations of the societal risk map are illustrated. The development of sample project A at a distance of 350 m northeast of the establishment will result in a societal risk that meets the risk criterion, as the entire project area is located outside the contour corresponding to a population increase of 200. The development of sample project B at a distance of 440 m to the west of the establishment, will result in a societal risk curve that exceeds the criterion, as the project area is rather small and situated entirely within the contour for a population increase of 200. For projects that cover a large area and are located within the relevant contour (e.g. project C) or projects that are partly situated within the relevant contour (e.g. project D), no conclusive answer can be given about the acceptability of the societal risk based on the map.

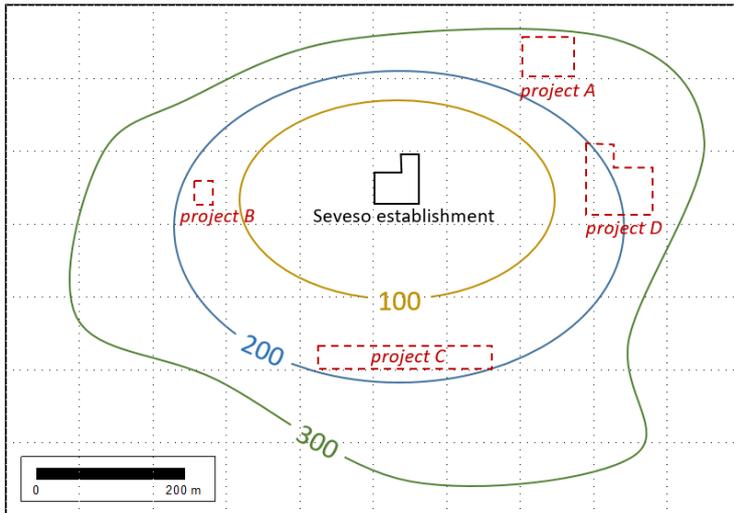


Figure 2: Example of a societal risk map

3. Testing of the quick scan method using case studies

The quick scan method was tested for different types of Seveso establishments and installations with dangerous substances. In this paper, the results are presented for an LPG storage facility. The facility considered has 8 aboveground cylindrical pressure tanks (2x 200 m³ and 6x 146 m³) with a total storage capacity of about 600 tons. LPG is supplied to the facility and distributed by road tanker and tank container. They are unloaded and loaded at six loading bays by means of a pump and a 3" flexible hose at a maximum transfer rate of 20 ton/h. The total annual throughput is about 30,000 tons.

The facility is located in an industrial area close to the centre of a village with about 2,400 inhabitants (see Figure 3). Between the industrial and the residential area there is a buffer zone and an unoccupied area intended for day recreation (e.g. playground or outdoor sports activities). Figure 4 shows the calculated location specific risk and societal risk posed by the facility for the existing population within the impact zone of the facility. The maximum effect distance (1% lethality) for the worst-case accident scenario is about 1,000 m and was calculated for a vapour cloud explosion after a catastrophic rupture of a 200 m³ storage tank. Figure 4 also shows the societal risk criterion used in Flanders, which consists of two limit lines: a descending line in the 10 – 1,000 range and a cut-off line at 1,000 fatalities.

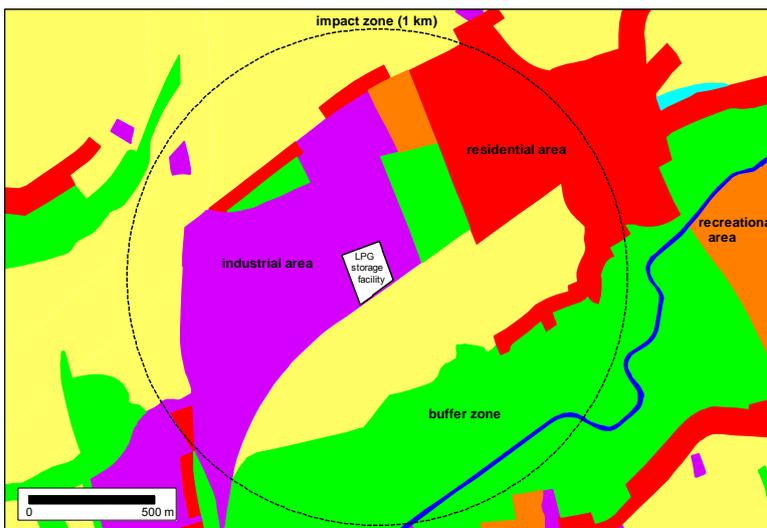


Figure 3: Location of the studied LPG storage facility on a regional land-use plan

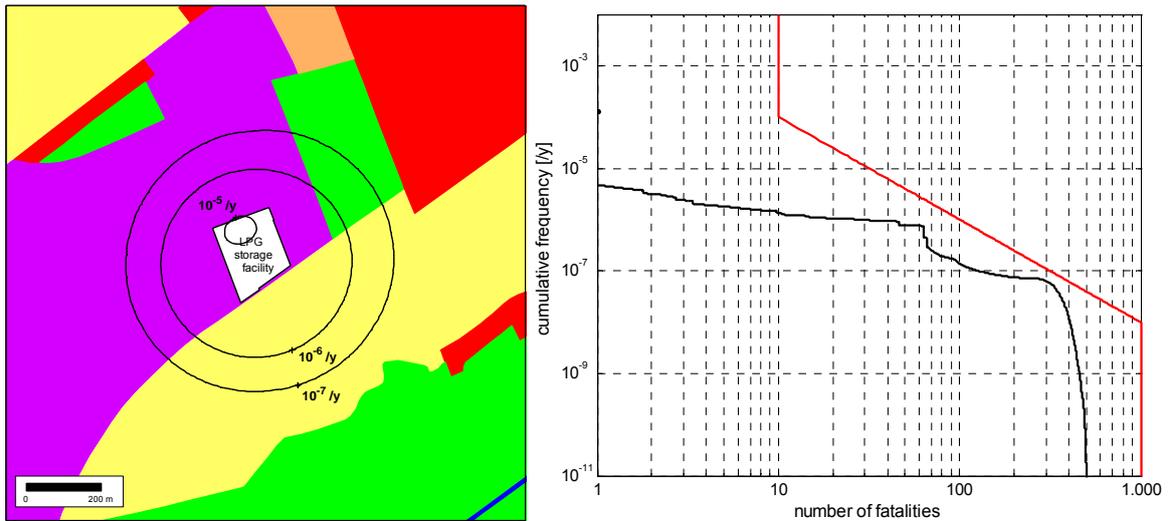


Figure 4: Calculated location-specific human risk (a) and societal risk (b) for the LPG storage facility with a storage capacity of about 600 tons and an annual throughput of 30,000 tons.

The impact of three sample projects on the societal risk of the facility is evaluated with the method. The first project is the construction of a public school with 900 students and 100 staff members at a minimum distance of 350 m east of the facility. The second project is the construction of a business centre with a capacity of 300 persons at two possible sites west of the facility, respectively at 100 m and 200 m from the facility. The third project is the development of the recreational area to the northeast of the facility, with a maximum capacity of 5,000 visitors per day. The map on the left side of Figure 5 is based on the indoor and outdoor fractions for the development of non-residential community facilities (see Table 1) and is used to assess the first and the second project. It is concluded that building the school at 350 m east of the facility will result in a societal risk that meets the criterion. Constructing the business centre at 100 m west of the facility will result in an exceedance of the criterion, whereas constructing it at 200 m west of the facility will not result in an exceedance. The map on the right side of Figure 5 is based on the indoor and outdoor fractions for the development of an outdoor recreational area and is used to assess the third project. It is concluded that the development of the recreational area to the northeast of the facility, will result in a societal risk that meets the criterion.

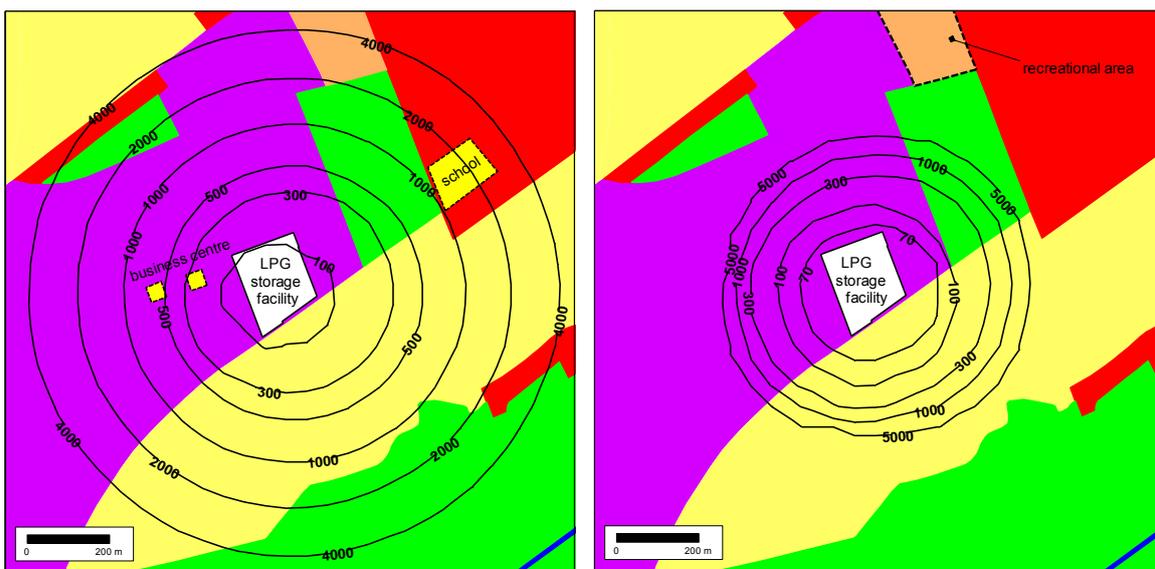


Figure 5: Calculated societal risk maps for the development of non-residential community facilities (a) and the development of an outdoor recreational area (b) within the impact zone of an LPG storage facility.

The conclusions based on the societal risk maps are tested against the results of risk calculations, taking into account the additional population of the development projects mentioned above. Figure 6 shows the recalculated FN curves for the LPG storage facility and the development projects considered. The risk calculations confirm the conclusions drawn on the basis of the societal risk maps. The only FN curve that exceeds the criterion is the one that was calculated for an additional population of 300 persons related to the construction of a new business centre at 100 m west of the LPG storage facility.

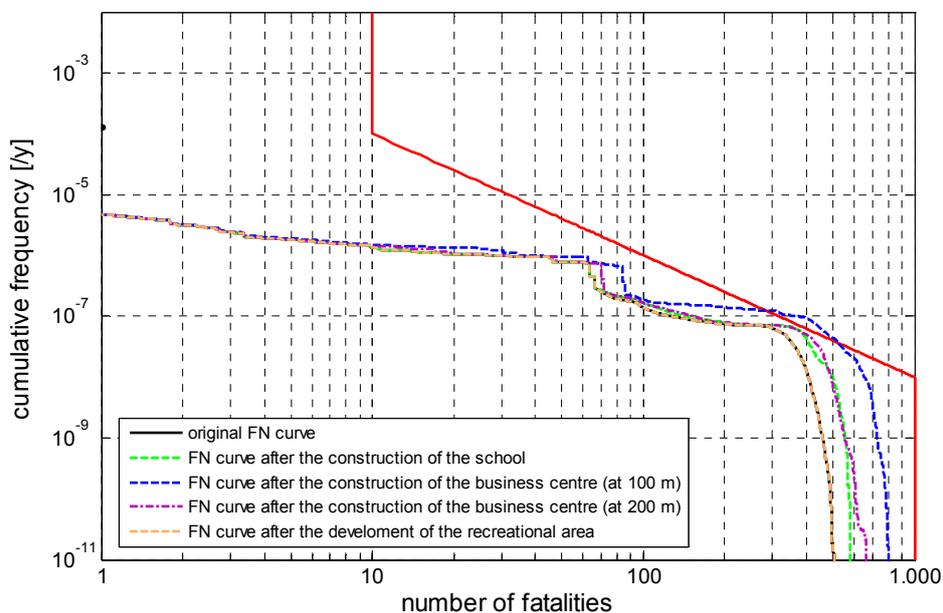


Figure 6: Recalculated FN curves for the LPG storage facility and the development projects considered.

4. Conclusions

It is concluded that the method described in this paper allows to accurately answer the question whether or not a development that increases the population in the vicinity of a Seveso establishment results in an exceedance of the societal risk criterion. As such, this method allows the assessment of the impact of new developments on the risk of Seveso establishments early in the planning process. It must be noted, however, that for some specific situations, which are also described in the paper, the method does not provide a conclusive answer and comprehensive risk calculations are required.

References

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