The use of GIS for presenting the Group Risk for Land Use Planning

Shahid Suddle[a,b*], Robert Geerts[a,c], and Claudia Basta[a]
[a]Delft University of Technology, Delft, The Netherlands
[b]SSCM – Suddle Safety Consultancy & Management, Schiedam, The Netherlands
[c]AVIV, Enschede, The Netherlands

Abstract: In the Netherlands, regulations for land-use planning in the vicinity of major industrial hazards or transport routes of hazardous materials are explicitly risk-based, in which the risks are visualized in two ways: Individual Risk (IR) and Group Risk (GR). IR is visualized on a geographical map presenting iso-risk contours. This is an understandable way of communicating risk with (non-)experts. However, such a straightforward approach is not appropriate for presenting the GR, through which the communication between the (non-)experts and decision makers becomes rather hard. GR is usually represented as a graph in which the cumulative probability of more than n fatalities is given as a function of N, the number of people killed. This graph is called the fN curve, almost a non-communicable risk presentation for land use planners and decision makers. Land use planners are used to communicate in maps and drawings, while the risk analysts communicate the GR in fN-curves. Moreover, the risk acceptance criterion for the GR is difficult to apply as well. In this regard, a methodology to present the GR in a Geographical Information System (GIS) is proposed in this paper, through which the visualization and motivation of the GR becomes communicable for both land use planners and decision makers.

Keywords: Land Use Planning, Geographical Information System, Group Risk, Risk Maps.

1. INTRODUCTION

In the Netherlands, regulations for land-use planning in the vicinity of major industrial hazards or transport routes of hazardous materials are explicitly risk-based. This implies that potential adverse physical effects of incident scenarios are considered along with their probability of occurrence and their possible impacts. One of the main reasons for implementing the risk policy is simply the shortage of space, as a result of which the optimal space according to the effect distance of a worst case scenario between a risk generating activity and urban development cannot be achieved. In The Netherlands the calculated risk is visualized in two different ways. The first one is called the Individual Risk (IR). This is the probability that an unprotected person dies due to an accident with hazardous materials per year on a certain spot when this person resides here a full year. The IR depends on the geographical position and is displayed in the form of iso-risk contours on a geographical map, as presented in figure 1.

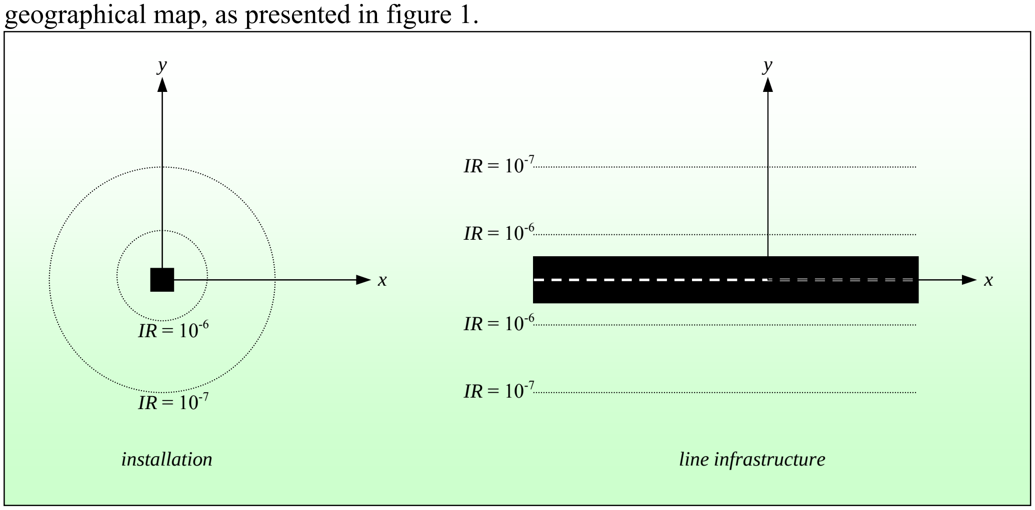


Figure 1: Schematic two -dimensional IR-contours for an installation and line infrastructure.

The second risk indicator generally applied is the Group Risk (GR). GR is defined as the probability per year that in an accident more than a certain number of people are killed. Group risk is usually represented as a graph in which the cumulative probability of more than n fatalities is given as a function of N, the number of people killed, also called the fN-curve (see figure 2).

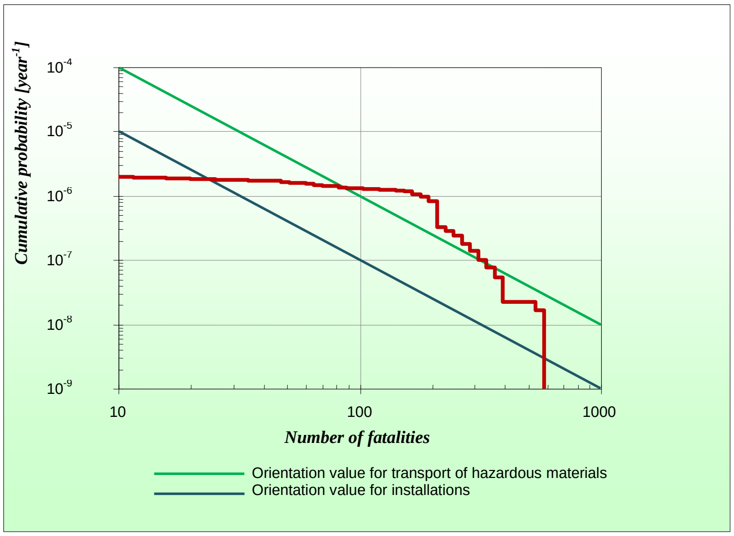


Figure 2: Schematic presentation of the Group Risk. The red line is the so-called fN-curve which is compared with the orientation value of a certain risk generating activity.

IR and GR are considered as different risk aspects and are therefore used for different safety goals. IR is only used as a measure to acquire sufficient safety for the individual subject. This is realised in Dutch Legislation for land use planning in the near vicinity of risk sources. GR serves only as a measure to express the risk on societal disruption. Its goal and purpose is to force local authorities to consider explicitly possible safety measures and take responsibility for the acceptance of this type of risk.

The presentation of the IR is an understandable way of visualising risk and more over to translate its purpose particularly for land-use planners. The IR-contour maps give information on the risk of a location. Besides, the risk acceptance criterion for the IR is easy to use as well and includes in legally binding rules, e.g. vulnerable objects (such as hospitals and schools) cannot be built within the 10^{-6} contour. In this way local authorities can meet the over all basic safety for the individual residents.

It wil be clear however, such a straightforward approach is not appropriate for presenting the GR, through which the communication between the (non-)experts, land-use planners and decision makers becomes rather hard. Land use planners are used to communicate in maps and drawings, while the risk experts communicate the GR in fN-curves. Additionally, land-use planners experience the rules for taking explicitly responsibility for the risk acceptance standards for the GR difficult to apply as well. In The Netherlands the GR risk acceptance criterion is rather an indication criterion with a so-called orientation value (OV) as decision standard / advise. Figure 2 shows two diagonal (risk-averse) curves representing the OV of the GR for both installations and transportation risk. When a calculated GR for an urban plan near a hazardous activity increases or exceeds the orientation value, the acceptance of the GR must be motivated by local authorities. Economic aspects and repressive measures are widely considered in such a motivation. So, the OV is losely binded by law and acts more as a guideline for policy makers and planners to review their (urban) development plans including safety aspects and the measures taken to reduce the risks. After all societal risk is taken for the sake of achieving societal goals. They are the inherent negative side effect of economic grow and prosperity.

Both the visualization of the GR (in relation to the OV) and the motivation hereof require a progressive and an integral approach, enabling the communication between the (non-) experts, land-use planners and decision makers. In this regard, a methodology is proposed enabling the GR visible on geographical maps by means of Geographical Information Systems (GIS), through which the visualization and motivation of the GR can be made more efficient by a by a structuralised frame work. The advantage of such an approach is its tractability of the arguments for accepting GR by the safety measures which has been considered in the process of land use planning projects.

Recent studies [1,2] explored the suitability of using GIS technologies to support their elaboration and visual rendering, especially for the presentation of IR . Accordingly, the potential of GIS to represent major risks at national scale is widely executed in The Netherlands for the IR, especially on flood defence systems [3]. However, almost no studies analyzed the use of GIS for presenting the GR for land-use planning process. In this regard, a methodology is proposed in this paper presenting the height of the GR in relation to the OV on a map using Geographical Information System (GIS), through which the motivation of the GR can be standardized as well.

2. THE USE OF GIS FOR LAND USE PLANNING IN THE NETHERLANDS

2.1 Risk assessment method and risk tolerability definition

The definition of safety distances as required by Art 12 of the Seveso II Directive on dangerous substances (96/82/EC) is necessary to minimize the consequences of potential major accidents. As they affect the land-use destinations of involved areas, safety distances can be considered as risk tolerability criteria with a territorial reflection [1]. In this regard, The Seveso II Directive is implemented in the Dutch legislation by the Dutch Major Hazards Decree (Brzo) and the Dutch Public Safety Decree (BEVI). The Brzo focuses on the safety management system of hazardous installations. The BEVI instead regards the regulation of land-uses around hazardous installations, i.e. the external safety regulation. Spatial decisions related to the adaptations, elaborations, modifications, dispensations and revisions of land-use allocation plans within the sphere of influence of a hazardous establishment fall under the BEVI. The Dutch external safety's methodological approach is extensively described in literature [4,5]. Relevant aspects of the current risk prevention policy which have a direct reflection on the elaboration of geographical risk-information are [1]:

1. The adopted quantitative approach to risk assessment, resulting from the estimation of both magnitude and probability of accidental events.
2. The definition of IR as the probability, for an individual permanently located in the vicinity of a dangerous site (and assumed without any protection or behaviour of self security), to die as a direct consequence of an accident involving Seveso II substances. Legally binding endpoints apply (see figure 1).
3. The classification of vulnerable objects into two classes. The first groups accounts hospitals, schools, and residential areas; for these objects, a risk tolerability threshold of IR = 10^{-6} event/year applies. The second group accounts less vulnerable objects as industrial zones, office buildings or recreational facilities For these facilities, a tolerability threshold of IR = 10^{-5} event/year applies.
4. The definition of GR as the probability, for a number of people (more than 10) > N, to die as a direct consequence of their presence in the vicinity of a dangerous facility in which an accident occurs; non-binding tolerability endpoints apply (see figure 2).

2.2 Risk and Land-Use-Planning: the Dutch decision-making process

In the Netherlands, the spatial planning system involves three levels: the national, the provincial and the municipal levels [1]. All three tiers of government have independent planning powers, although the consistency requirement stated in the Dutch Spatial Planning Act has to be respected. This multi-level governance system is reflected in the supervision of hazardous installations by the side of different authorities. The Ministry of Housing, Spatial Planning and the Environment (VROM) is competent for facilities of national interest, such as nuclear power plants (NPP) and nuclear waste disposal. Dangerous establishments falling under the Seveso II requirements are classified in accordance to threshold values considering the quantity of stored/treated dangerous substances. According to their classification, top-tier Seveso plants fall under the provincial competence and, in case of lower-tier plants and small LPG storages, under the municipal competence. Operators whose facility falls under the Seveso Directive are responsible of the elaboration of a quantitative risk assessment (QRA).

The supervising authority checks the validity of the analysis, and it is responsible for acquiring and updating all the information which are necessary to assess the compliance of the installation with the operational, spatial and environmental legal requirements.

The described organization in the acquisition and validation of risk-related information responds to a multi-level system, which reflects the institutional decentralization of the country. Because of this decentralization, until recent developments in the risk-information system, geographical and industrial data of plants were spread out over numerous authorities. As a reaction to the Commissie Onderzoek Vuurwerkramp's report (translation: Committee on investigation of the fire works disaster) [6], appointed after the accident of Enschede occurred in 2000, a national scale overview of the risk posed by Seveso establishments had to be created. Furthermore, the Seveso II Directive obligation of reporting major accident events to the European Commission Major Accidents Reporting System (MARS) [7] posed the problem of centralizing the information relative to accidents. Finally, the need of informing the public had to find a translation into a systematic elaboration and delivery of geographical risk-information. The most relevant initiatives in this respect were the development of the Installations Handling Dangerous Substances Database, managed by the Netherlands National Institute for Public Health and the Environment (RIVM), and the development of GIS-based riskmaps ('risicokaart'), which realization falls under the provincial responsibility. They are both described in the following section.

2.3 Elaboration and representation of major accident risk information

With the development of the Installations Handling Dangerous Substances Database the authority responsible for granting the environmental license to the operator of a given hazardous installations is obliged to forward all relevant information to the database. The authority responsible for granting the license is the owner of the data and it is responsible for their validity. Next to the development of the national database, the issue of delivering risk-information to different authorities and citizens in an easy-reading was addressed. As well known, the IR estimation is visualized as a set of more or less concentric areas, representing different effect levels, which origin stands at the emission point of the accident. Effects are experimentally deducted. For each scenario, the probability of its likelihood is calculated; a representative scenario is therefore selected for formulating the planning advice [4,5]. The vulnerability of the involved urban and environmental elements is classified accordingly to vulnerable categories (high, medium, low). Standing to this approach, the visualization of the risk connected to an accident results from the overlap between the selected accidental event, its iso-risk contours and the specific territorial context. Digital risk-maps reporting this overlap are therefore an obvious, although recent, operational development. For this purpose, risk-maps are developing under the provincial responsibility. The national Installations Handling Dangerous Substances Database is used as informative source together with the ISOR database. ISOR is the result of the cooperation between the 12 Dutch provinces, in which additional risk information such as flood risks and vulnerable objects are collected. Data in this database is owned by municipalities. Thanks to these developments, previously spread out risk information are converging towards national, multi-accessible d-bases. Provincial risk-maps are realized on a GIS platform. The variety and quantity of reported information is notable and comprise the localization of plants, the amount and nature of substances stored/treated, iso-risk contours for IR and the emergency planning in the area. At present, IR-contours are thus suitable to inform the development of spatial plans, building development plans and single planning permission.

A recent model plotting the relative contribution of societal risks to the over all societal risk (GR) on digital maps was developed by the Dutch Applied Research Institute TNO [8]. However, the approach used by TNO was either an appropriate methodology for presenting the height of the GR, through which the communication problems between the decision makers and land use planners and risk analysts still remained. Besides it doesn't meets the legal requirement of comparing the GR with the orientation value. Nonetheless, a foreseeable evolution of risk-maps is therefore the incorporation of the societal risk contours [1].

3. THE BACKGROUND OF THE GROUP RISK

3.1 The calculation of the Group Risk

The GR for a hazardous activity is defined as the probability that a group of more than N persons would get killed due to an accident at the hazardous activity. The group risk is in this sense not location-dependent, but rather is characteristic for the hazardous activity in combination with its populated surroundings and is displayed in the form of an fN curve where the probability (f) per year is plotted against the group size for the group of people killed (N) due to a major accident at the establishment. Thus, if no people are present around the hazardous activity, the GR is nil, whereas the IR may still has a value. The IR is calculated for a hypothetical person to secure the desired over all safety in case an individual will live at the nearby vicinity of the risk source. To enable a reliable calculation of the risks caused by a hazardous activity, several standards for the risk modeling and the parameters used in these models are defined in the Netherlands. This standardization comprises among others the following aspects [5]:

- Selection of accident scenarios that are representative for the risks involved;
- The physical modeling of outflow from the containment;
- Initial cloud formation and gas dispersion for given weather conditions;
- Consequence models for fire, explosion and release of toxic gasses (also called probit functions);
- Parameter values to be used in these models.

3.2 The Group Risk acceptance criteria

After the GR is calculated, the GR has to be evaluated for an activity to determine whether the risks are acceptable. In the Dutch external safety policy, risk acceptability criteria have been developed and were adopted by the Parliament to support decisions that are to be made on the acceptability of risks in the field of external safety. But the Ministry of Housing Spatial Planning and Environmental Affairs also stressed that decisions solely based on the quantitative magnitude of GR are not sufficient. The risk criteria are pertinent both for the IR and for the GR. Both types of criteria are of importance for decisions on Environment Protection Act licences. The GR is assessed taken into account the number of persons that are expected to be present in the objects classified as vulnerable or less vulnerable, even with a percentage of persons assumed to be present at the location of these objects, but being outside and therefore less protected. The distance range over which the calculation around the hazardous site is performed, is determined by the distance at which the conditional probability for lethalities meets a 1% fatality rate. The GR in the form of an fN plot is then evaluated against the reference criterion which is called, as mentioned before, OV (see fig.2). Risk reduction "at the source" should prevail according to ALARA. This is met by the international standard practices for designing and constructing activities with hazardous goods. Next, it should be decided on the basis of the GR criterion whether a license can be granted for a new activity and/or whether new housing, offices or other objects around the establishment can be tolerated under required circumstances, i.e. implementing safety measures. The authorities can accept a situation that does not fulfil the GR criterion, if it can be motivated that this is acceptable under the given circumstances and mitigating safety measures. It is considered the primary responsibility of the municipal authorities to establish the appropriate level of that motivation.

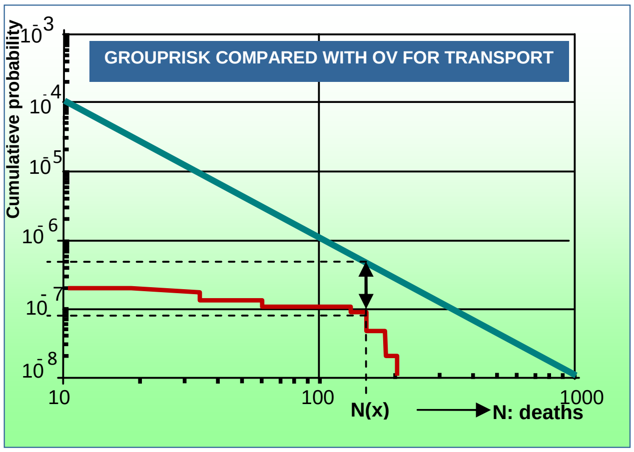
However, an additional problem may occur when motivating a spatial plan by using the criteria for GR, since the reference criterion OV is as such not legally fixed. Though it has worked well over the past period to a certain extent, still in the field of spatial planning, there are practical shortcomings. One of the major problems is that local authorities - i.e. municipalities - do not have their local external safety policy. As a consequence, the motivation of accepting or rejecting a spatial activity near a hazardous activity becomes ad hoc and not standardized. In such cases every spatial plan is handled entirely different from an external safety point of view, i.e. the required safety measures differ in each case. From an external safety / urban planning policy point of view, it is interesting to streamline the motivation of the GR depending on the particular height of the GR (in relation to the orientation value).

3.3 The Group Risk in relation to the orientation value

In The Netherlands, it is quite common to present the level of the GR in relation to the OV as a factor, through which the height of the GR-level can be defined. This results in a triple partition of the factor of the GR in relation to the orientation value:

- A factor smaller than 1 represents a GR lower than the OV.
- A factor exact 1 represents a GR meets the OV.
- A factor higher than 1 represents a GR above than the OV.

The factor of the GR in relation to the OV is calculated as follow:



Deviation F of grouprisk with OV

$F = P_{cum|Nx} / [10^{-2} / N(x)^2]$

In this example:

$F = 9.10^{-8} / [10^{-2}/150^2] = 0.2$

Formula for sites:

$F = P_{cum|Nx} / [10^{-3} / N(x)^2]$

It should be noticed that all three mentioned possibilities regarding the GR contain the order of magnitude of the GR-level, whereas the second mentioned (GR meets exact the OV) result is hardly found.

3.4 An example of different magnitude group risk levels

If an activity is evaluated, and it is concluded that the GR increases or even exceeds the OV, extra risk-reduction measures can be applied. In this regard, a first question of course might be whether there are possibilities for risk reduction. These possibilities can be determined by means of a study which quantifies and or qualifies the influence of possible safety measures, e.g. [9,10,11]. Such studies can analyze the total risk for the whole of the activity in order to determine wich cost-efficient risk-reducing measures should be applied. A differential scheme of risk-reduction possibilities vs. cost of safety measures can be helpful in selecting optimal risk-reduction strategies, which is not provided by the government [10,11]. Some of the risk-reduction measures can be set as a requirement in the license under the Environment Protection Act.

The problem is however does an insignificant increase of the GR demands a large scale of safety measures? Or should one just apply cost-effective safety measures in such cases? This is exactly one of the major issues through which the land-use planners practice the GR as non-contagious constraint. As a consequence, taking safety measures is on ad hoc basis. There is no proper structure for motivating the GR in which safety measures are risk-reducing or cost-effective. Besides, sometimes measures are put even forward in the motivation to the wrong problem owner [12]. As a result measures are considered sufficient even if they are hardly cost effective. This is because the measures aren't considered in relation to the (quantitative) risk reduction they achieve.

Figure 4 and 5 provide a schematic insight of this problem. Suppose a project developer initiates three different spatial plans adjacent to a transport of hazardous materials. Obviously, these three plans will result in different levels of GR (in relation to the OV). Figure 4 represents these three urban plans, in which the black spot is the present built area.

The green plan (A) of figure 4 is the realization of a small building near that built area. The orange plan (B) is a larger urban plan located on a large distance adjacent to the infrastructure. The red plan (C) is a large scale master plan with a high population density located on a small distance adjacent to the infrastructure. The three levels of the GR in relation to the OV for each plan are presented in figure 5. This figure shows that the master plan C (red) results in a large GR exceeding the orientation value. The urban plan B (orange) results in a significant increase of the GR, still quite below the OV. The individual plan A (green) leads to an insignificant and almost a negligible (increase) of the GR.

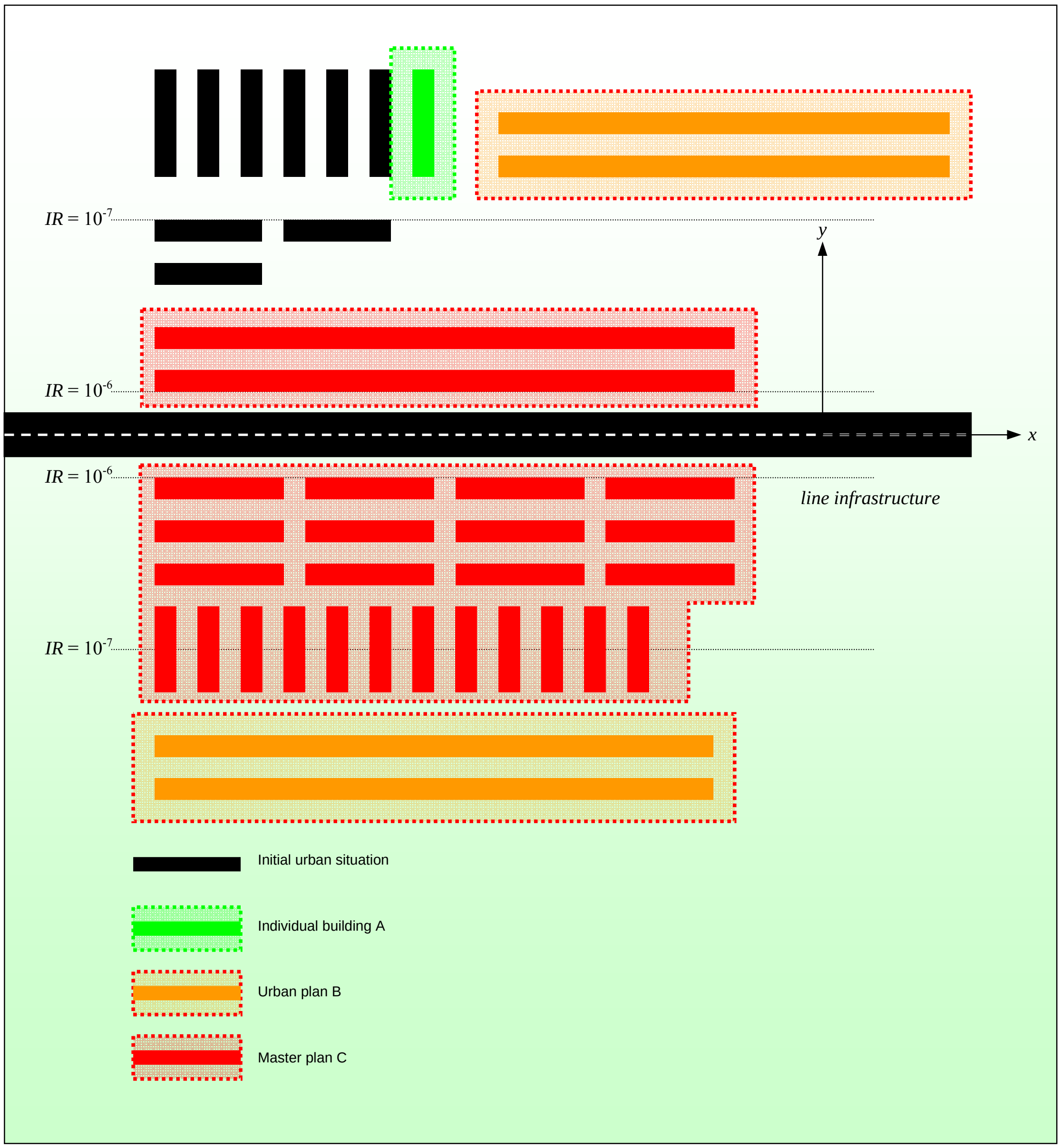


Figure 4: Schematic maps of three different urban plans.

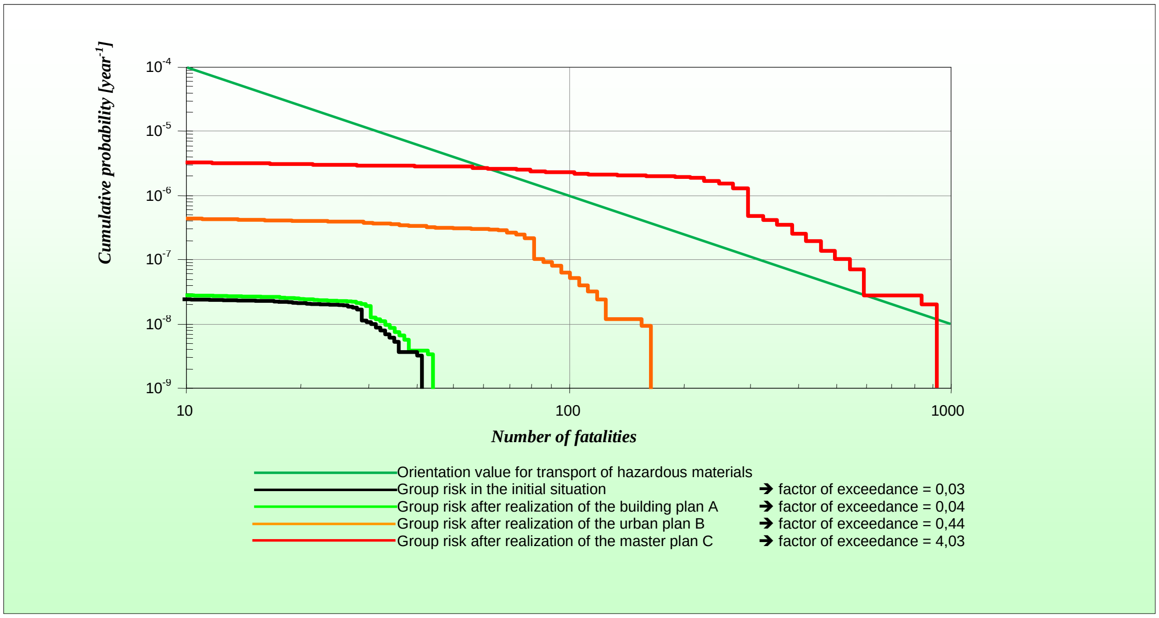


Figure 5: Schematic presentation of the Group Risk for different levels.

4. INTRODUCTION OF GIS APPLICATION FOR GROUP RISK

Considering the previous, two questions still remain: (1) is it possible to present the different GR levels in relation to the OV and (2) should the same safety measures be applied for different kind of GR levels? In this chapter we introduce a methodology which will examine both matters further.

4.1 The presentation of the order of magnitude GR-level in relation to the orientation value

Regarding the first question about the presentation of the GR in relation to the OV the following can be stated. In fact the height of the GR has more a magnitude character in stead of an exact calculated value. This magnitude character is associated with its logarithmic scale, because the GR of hazardous events are based upon the same order of magnitude severities of events. Moreover, fN-diagrams should be used to determine the effects of measures, rather than solely presenting risk results of urban plans near hazardous activities [9]. If the GR is limited to such an approach, the following three areas / zones in the fN-diagram of the GR can roughly be drawn:

- Area I: The area in which the GR < 0.1*OV (relatively small GR) ➔ green GR-colour;
- Area II: The area in which the 0.1*OV < GR < 1*OV (medium GR) ➔ orange GR-colour;
- Area III: The area in which the GR > 1*OV (relatively high GR) ➔ red GR-colour.

These areas are based on the logarithmic approach of the GR. Furthermore, the height of the 0.1*OV can be opposable, as well as the number of such areas in a fN-diagram. The boundary line of the 0.1*OV could also be taken as 0.01*OV. In the same manner more GR-levels can be combined with more number of GR-colours. Nevertheless, it is the mindset and the simplicity of this concept we would like to show, rather than the discussion whether such boundary lines for the OV or the number of GR-colours are appropriate.

If we plot now the calculated GR of the simplified plan of figure 4, the GR presentation becomes as shown in figure 6. The white and the black dot lines are representing respectively the OV and the 0.1*OV. It is remarkable that the presentation of the GR level becomes much easier to present by colours than a particular fN-diagram: a (GR-)colour is much accessible than a fN-diagram, through which the (GR) becomes communicable as well as the communication between the (non-)experts, risk analysts and decision makers.

So, if a GR-colour is assigned to a certain hazardous activity, i.e. a transport route of hazardous materials or a stationary installation, the height of the GR-level in a specific situation can be understood by a wide range of people. Subsequently, different scale of urban plans will provide different GR-levels, and thus mostly non-similar GR-colours. The uniqueness of this method is particularly the simplicity of a multi-dimensional constrain of the GR. This concept is explained with some cases in chapter 5

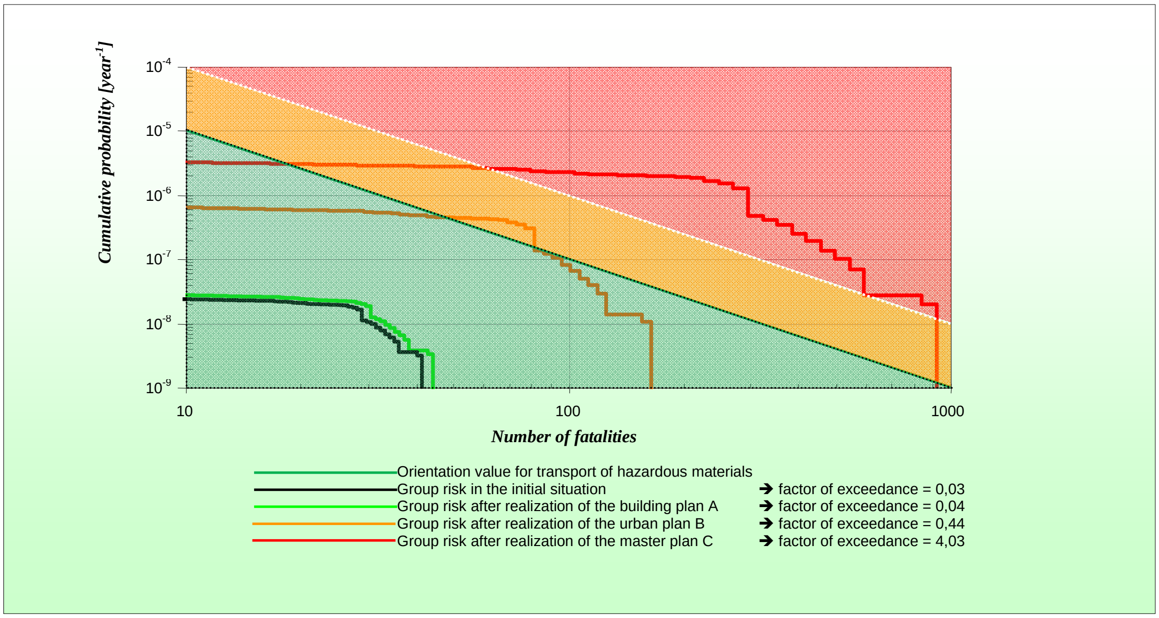


Figure 6: Schematic presentation of the Group Risk in different GR-levels.

4.2 The required safety measures per GR level

This straightforward approach can be applied to define the required safety measures per GR-level as well. This might be at least a solution in local policy documents. In our opinion, the implementation of safety measures depends on the level of GR caused by the urban plans. A high GR means that safety measures should be implemented at a large scale, while a small GR can be met by simple and cheap safety measures. For this to occur, we propose the following methodology, which is based on the order of magnitude level of the GR as presented in figure 7. This method is the extension of concept the previous paragraph. With respect to the content of this method, it means that different safety levels per GR-colour can be summed up as follows:

Green area The area in which GR < 0.1*OV (GR is at least a factor 10 smaller than the OV)

- Generic safety measures are required;
- No new urban objects with vulnerable persons near hazardous activities.

Orange area The area in which 0,1*OV < GR < OV (GR near, but below the OV)

- Measures of the green area are applicable;
- Risk reduction is explicitly considered;
- The governing institution is informed about the development;
- A large number of safety measures are implemented to reduce the GR;
- Spatial configurations and measures are considered to reduce the GR;
- Risk communication to civilians is executed in case of emergency.

Red area The area in which GR > OV (GR exceeds the OV)

- Measures of the orange area are applicable;
- Risk reduction is explicitly adopted;

- The governing institution is involved in the development;
- All possible safety measures are implemented to reduce the GR;
- Both fatalities and wounded should be considered in the motivation of the GR;
- The economic consequences of a disaster should be investigated;
- The cost-effectiveness of safety measures should be analysed.

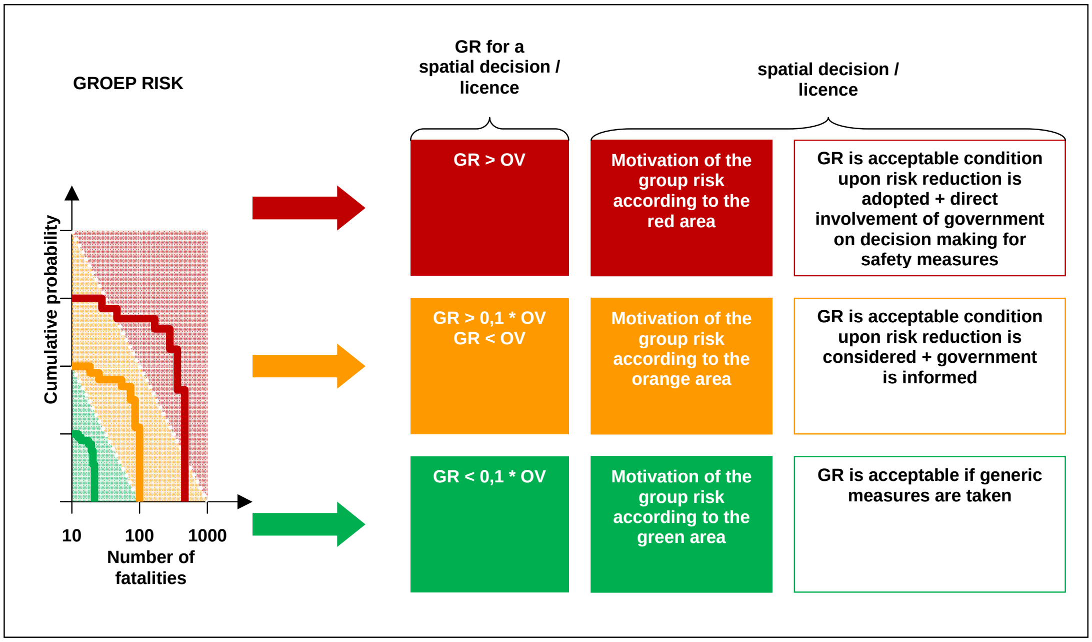


Figure 7: Schematic safety measures to different GR-levels.

Now the methodology to present the different GR levels in relation to the OV and the required safety measures for a GR-level is treated, it becomes rather a software issue to transform this information to a geographical environment. An example hereof is given in the next chapter.

5. CASE STUDY: GIS-APPLICATION FOR GR IN THE HAGUE REGION

5.1 The background of The Hague Region

In 2007 we started a project at the Regional Authorities of Haaglanden - also called The Hague Region - to provide the GR-information for spatial planners. The Hague Region is situated in the western part of the Netherlands [13]. This area comprises nine municipalities, including The Hague, and has a population of about 1 million. The Hague Region is a versatile region. It has four substantial economic divisions with international allure: government and corporate services, expertise and technology, tourism and agribusiness. It also has an extremely varied housing environment, as well as a wide selection of scenic areas and parklands. The Hague Region is administered by representatives of the nine town councils. The Hague Region comprises a cooperative entity made up of these nine municipalities. On the one hand, cooperation is essential because the region of Haaglanden is a cohesive area in many respects, with one labour market and one housing market closely interconnected by one complex road network and a host of green areas. In terms of actual facts and figures, this means that 78% of the Haaglanden working population finds a job within this city region, for instance, or that about 70% of all relocations take place in the city region and that one sole system is used for the allocation of housing in Haaglanden. On the other hand, legislation also demands collaboration between the municipalities. The Hague Region carries out tasks in six policy areas: Economic Affairs, Youth Care, Environment, Traffic and Transport, Spatial Planning, and Housing.

5.2 Data for GIS-application for The Hague Region

The main objective of the study was to develop a GIS-application (called GEOWEB) presenting the GR (data) for the transport of hazardous materials on road according to the methodology discussed in this paper. In this regard, the number and the type of transports of hazardous materials were counted on different locations in the region, as basic parameters for QRAs. Subsequently, address data along with the specific ZIP-code within the 1%lethal zone were collected as the other major parameter and integrated in the GIS-application. Finally, a large number of GR-calculations were made to present the GR-colour for the region using these parameters. The scope was initially to include all risk relevant data of transport of hazardous materials on roads in GEOWEB. This application was so users friendly that the risk relevant data of pipelines and installations were included as well in GEOWEB. The application was only accessible for professional users and not for the inhabitants.

The interesting of this concept is that more geo-information based issues, such as traffic information, (large scale) urban developments, air pollution, noise, and other environmental related aspects, can also be included in that same GIS-application. As a consequence, it is easy for users to perceive different environmental aspects if an urban plan is being developed. Especially, the external safety risks, i.e. GR level in relation to the OV, in the vicinity of a certain urban development are visualized to give a first idea to spatial planners and decision makers. It should be noted that both the risk data and the data for urban plans should be up to date for a continuously good working information portal. The range of the data can be extended in the GEOWEB GIS-application. The following (main) risk data per hazardous activity are included in the GEOWEB:

Table 1: GR-risk data per hazardous activity in GEOWEB.

GIS-risk data / **Hazardous activity**	Address points within the 1%-lethal zone	Distance of the 1%-lethal zone	Distance of the 100%-lethal zone	Colour code of the GR (according to 4.2)	The transport route of haz.mat.	The network of pipelines	The users of the pipelines	Propane tanks	LPG Stations	The IR 10^{-6}-contour
Transport of hazardous material (roads)	√	√	√	√	√					
Pipelines	√	√	√	√		√	√			√
Installations	√	√	√	√				√	√	√

This led to the GEOWEB GIS-application environment as presented in figure 8, in which a selection of the risk data has been visualized to provide the spatial planners a basic check if hazardous activities are taking place within neighbour of urban development plans.

If we plot the GR-colour of e.g. transport routes of hazardous materials on road the presentation of The Hague Region becomes like figure 9. In that figure we see something remarkable, which is encircled: the GR-colour is red on the Utrechtsebaan, while that route is not appointed as a transport route of hazardous materials by the municipality. The reason of that high GR is that the transport of hazardous materials is taking place without permission of the government in a high densely populated. This means that the GEOWEB system is not only acting as a tool through which safety measures for urban development can be required, but it provides also current illegal situations. This means that more functions can be assigned to the GEOWEB.

Furthermore, the GEOWEB provides the GR-colour in the present situation. This means that an urban plan will almost lead to an increase of the GR along with the fN-curve for the considered track. So, at least the GR-colour will be the same. If the GR-colour changes to a higher level, the requirements for safety measures will change as well. This method has proven itself as an understandable working method in practice.

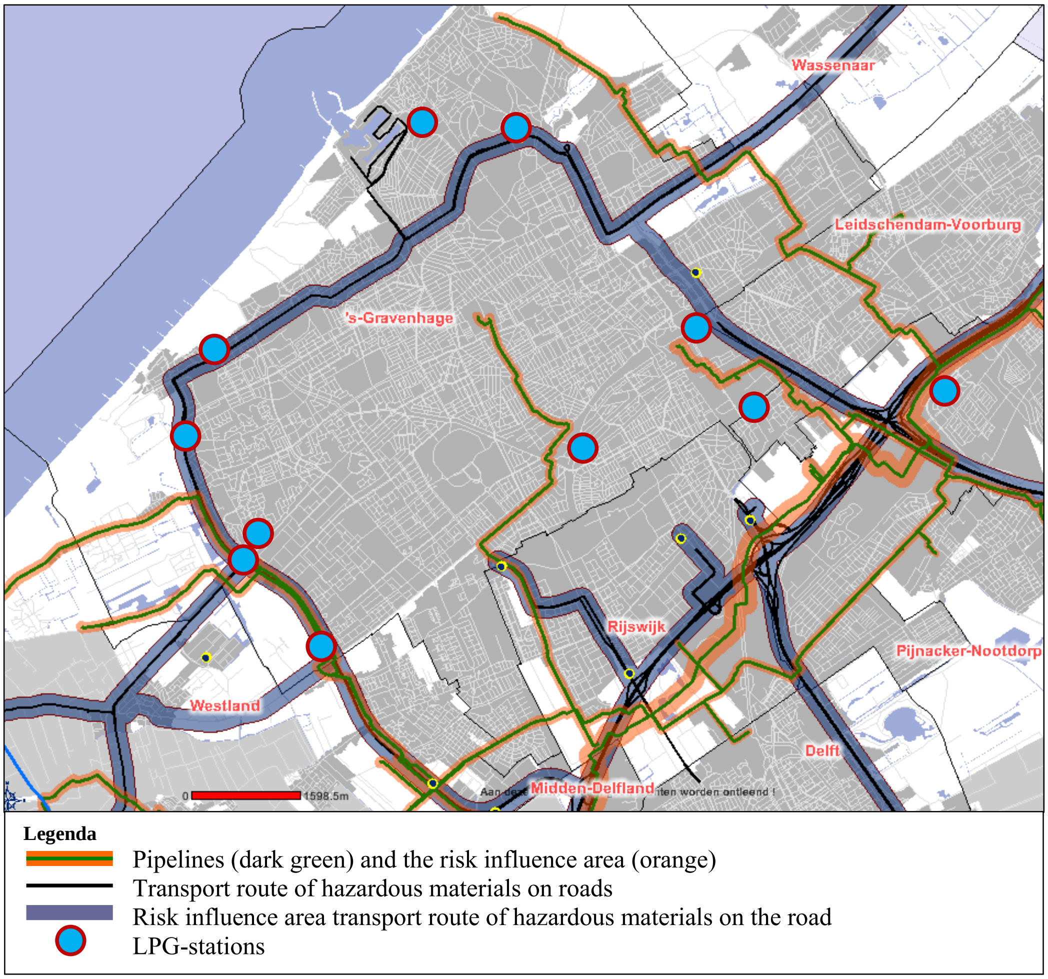


Figure 8: The risk data of transport of hazardous materials on roads.

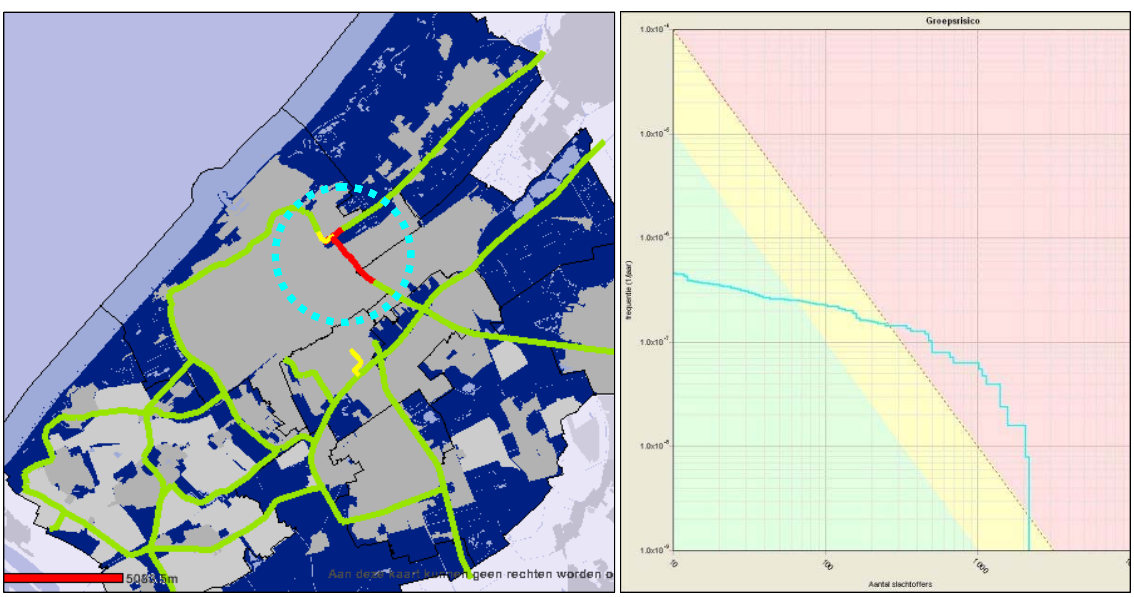


Figure 9: The GR-colour for the Hague Region (left) and the GR calculation at the Utrechtsebaan (right).

Another example of visualising het magnitude of the GR and its spatial influence is given in figure 10.

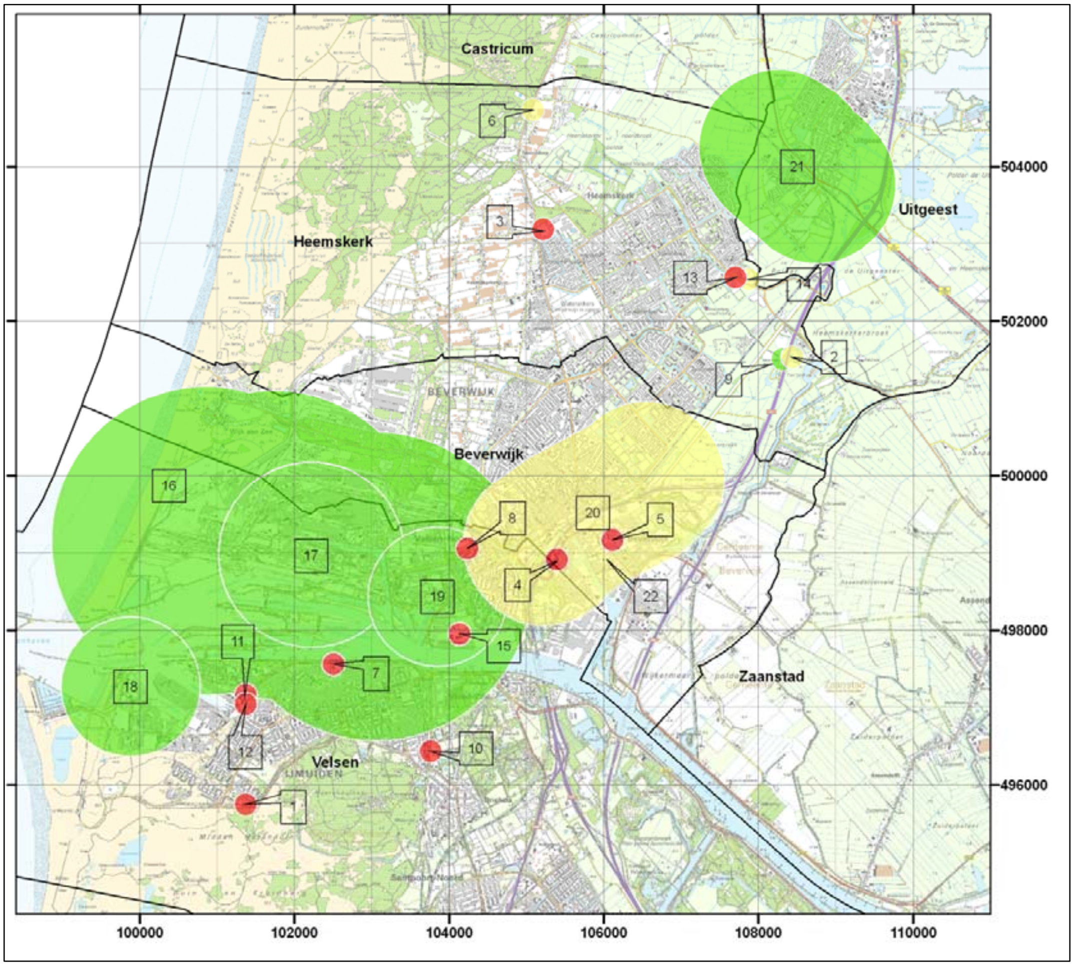


Fig. 10: GR levels of Industrial hazardous sites in the surroundings of IJmond Area in the Netherlands and its relevant spational influence i.e. within the given area GR may increase by developments for housing offices etc.

In another project one of the authors is involved in using the approach we explained in this paper for land use planning near the industrial Camelot site (which comprises DSM and Sabic among other companies) for local governmental policy [14].

6. CONCLUSIONS

The scope of this paper was to answer two questions:
(1) Is it possible to present the different GR levels in relation to the OV and
(2) Should same safety measures be applied for different kind of levels of GR?

In this paper we introduced a methodology which examined both matters.
Regarding the first question the following can be concluded:

- It is possible to present the GR-level in relation to the OV, since the height of the GR has more a magnitude logarithmic character in stead of an exact calculated value. If the GR is limited to such an approach, the following three areas / zones in the fN-diagram of the GR can roughly be drawn:
  - Area I: The area in which the GR < 0.1*OV (relatively small GR) ➔ green GR-colour;
  - Area II: The area in which the 0.1*OV < GR < 1*OV (medium GR) ➔ orange GR-colour;
  - Area III: The area in which the GR > 1*OV (relatively high GR) ➔ red GR-colour.

- If a GR-colour is assigned to a certain hazardous activity, the height of the GR-level in a specific situation can be understood by a wide range of people. Subsequently, different scale of urban plans will provide different GR-levels, and thus mostly non-similar GR-colours. The uniqueness of this method is particularly the simplicity of a multi-dimensional constrain of the GR.

Regarding the second question the following can be concluded:

- It is possible to combine the requirements of safety measures per GR-colour as discussed before, in which the following nuance should be made:
    - A high GR means that safety measures in land use planning should be implemented at a large scale, while a small GR can be met by simple and cheap safety measures.

Though it is a political discussion to take or require different kind of safety measures to a specific GR-level, the paper presents a conceptual mythology to tackle the purpose of the GR constrain.

References

[1] C. Basta, J.M.M. Neuvel, S. Zlatanova, B. Ale. Risk-maps informing land-use planning processes. A survey on the Netherlands and the United Kingdom recent developments, *Journal of Hazardous Materials*, Volume 145, pp. 241-249, (2007).

[2] Neuvel, J.M.M. *Geographical Dimensions of Risk Management*, Ph.D. Thesis, Wageningen University, 224 pp., (2009).

[3] Jonkman, S.N., *Loss of life estimation in flood risk assessment: Theory and applications*, Ph.D. Dissertation, TU Delft, 354 pp., (2007),

[4] Bottelberghs, P.H., Risk analysis and safety policy development in the Netherlands, *Journal of Hazardous Materials*, Volume 71 pp. 59–84 (2000).

[5] Ale, B.J.M., Risk assessment practices in the Netherlands, *Safety Science*. Volume 40, pp. 105-126 (2002).

[6] Commissie Onderzoek Vuurwerkramp, De vuurwerkramp, Eindrapport, Phoenix en Den Oudsten, Rotterdam, 2001.

[7] Major Accident Reporting System (MARS), Joint Research Centre, Institute for the protection and the security of citizens, Ispra, http://mahbsrv.jrc.it/mars/Default.html (online), March 2006 (last visited).

[8] Wiersma, T., W. Roos, M. De Wit, *Gebiedsgericht groepsrisico Groepsrisico op een kaart*, TNO, Apeldoorn, 2005.

[9] Suddle, S.I., *Physical Safety in Multiple Use of Space*, Ph.D. Dissertation, Delft University of Technology, Print Partners Ipskamp, ISBN 90-808205-2-0, 2004.

[10] Suddle, S.I. & R.W. Kockx, *Cost-effectiveness of Safety Measures for Urban Plan adjacent to the railway track in Woerden (in Dutch)*, DGMR-report (2009).

[11] Suddle, S.I., Cost-Effectiveness of safety measures in multiple use of space, *Proceedings of 2005 Asia-Pacific Conference on Risk Management and Safety*, Hong Kong, pp. 512-518, (2005).

[12] Suddle, S., Ridder, H. de, Ghauharali, T. and Stoop, J., The Living Building Concept as design tool for safe buildings, Innovations for Building and Construction, *Europia Productions*, In: Dado, E., Beheshti, R. and Zreik, K., Paris, France, ISBN 978-2-909285-56-1, pp. 351-371, (2009).

[13] www.haaglanden.nl

[14] R. Geerts, R. Scheres, Local governmental policy for land use planning in the surroundings of the Chemlot site permit by considering the acceptability of GR, 2009 (paper in preparation)