"Bridging the gap" between professionals involved in risk prevention using GIS as a shared decision support system. A comparative study on UK and Dutch practices

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Abstract
Recent studies explored the suitability of using Geographical Information System to support decisional processes in the field of risk assessment & management. In particular, the elaboration of GIS "risk-maps" has been recognized as functional to two objectives: connecting decision-makers and stakeholders during decisional processes and communicating risk to non-experts audiences. In both cases, the use GIS results in increased transparency, as it gives clear ground and evidences to risk-related decisions. In order to elaborate on these findings and to verify the current use of GIS within European decisional processes, we have begun a comparative study between the United Kingdom and The Netherlands. Their land-use planning practices (LUP) are explored with respect to the risk of major accident as derived from the EU Directive Seveso II. The contribution and the role of GIS within decisional processes is analysed, and recommendations for further developments are discussed.

Introduction
Although different, all technological and natural disasters have much in common. The fire accident in Enschede of 2000, the Tolouse industrial accident of 2001, the severe floods in Germany of 2002 up to the Tsunami of 2004 and the Katrina hurricane of 2005 teach a general lesson: a top-event like an industrial failure or a natural phenomenon can lead to unexpected human loss in both the developed and developing world. Reasons are several: an increased urbanization of European and extra-European countries, which led to increased at-risk populated areas; massive utilization of intrinsically risky technologies and increased transportations of both ordinary and dangerous goods, which affect the magnitude and the consequences of disasters. But what do urban, technological and transportation systems have in common? First of all, they all have relevant territorial and environmental impacts. More importantly, they are derived from our development pattern and consequently from our decisions on *how* and *how much* to allocate land for our economical necessities. Therefore, paraphrasing Beck, contemporary risks are not only technological determined (Beck 1986:1992), but also territorially eradicated and land-use increased.
Recently, a general tendency of reformulating many environmental and urban problems in terms of spatial development policy has been developed (De Roo 2000; Faludi 2002). Furthermore, a proper land use planning (LUP) has been recognized to play a crucial role as a risk prevention measure (Moen & Ale 1998). The lack of proper land-use policies in the vicinity of chemical factories was, for example, the tragic pre-condition for the disaster of Seveso, occurred in 1976. As well known, the accident is the corner stone of the European legislation regarding major accident prevention, and gave the name to the Seveso Directive of 1982 (Arcuri 2004). Recent developments of the second version of the Directive – the so-called "Seveso II" of 1996 – assigned to LUP the role of mitigating the consequences of industrial accidents involving dangerous substances. Art 12 of the Directive Seveso II (96/82/EC) states that land-use planning policies should ensure that appropriate distances between hazardous establishments and natural/residential targets are respected [1].

In applying this European "external safety" requirement we recognise two important aspects: an active cooperation between all the actors and the use of Geographic Information Systems (GIS) for elaborating and delivering all information necessary to "plan the safety" (Basta & Jongejan, 2005). The two issues are strongly interconnected: where Civil Protection, Fire Brigades, Environmental Protection Agencies, Planning Agencies and citizens are to be involved in the assessment and implementation of risk prevention policies, a proper elaboration and communication of risk-related information is a crucial factor.
These aspects were explored, among others, by Moen and Ale [2]. The two authors pointed out how the communication of risk-related information to stakeholders was facilitated by means of GIS (unambiguous) "risk-maps". Afterward, Contini et al. provided an extensive study on GIS-based tools used, at both European and national levels, to elaborate and manage the enormous amount of information involved in all phases of risk management (i.e. risk assessment, LUP implementation, emergency management) [3].
In order to elaborate on these issues, we have started a comparative study between the use of GIS within risk prevention practices in United Kingdom and The Netherlands, whose risk management regulations were part of a broader comparative analysis [4]. This paper discusses some of our initial findings. In the first section the Dutch land-use planning in risky areas practice and the role of GIS as decision support are described. In the second section, the same description regards United Kingdom. In the third section, we compare the two approaches and we discuss the challenges encountered by both countries in relation with the use of GIS. The article concludes with some suggestions for further developments of GIS as decision-support system for risk-related matters and offers directives for further research.

1. LUP system and risk prevention policy in The Netherlands

The Netherlands is a decentralised unitary state with a three-tier governmental system: the national government, the 12 provinces and just over 450 municipalities. Spatial planning is based on the Spatial Planning Act, which came into force in 1965. All three governmental levels have planning powers. In this respect, the Spatial Planning Act includes a consistency requirement: when plans are not consistent with the over-scale ones, corresponding Authorities have the right to impose binding measures (van der Valk, 2002). Being the Dutch plannig process traditionally addressed to consensus building, this kind of interventions is rarely activated (Faludi & van der Valk, 1994). For the scope of the present research, the local level of planning can be seen as the most relevant one. The municipal *land-use allocation plan* in fact consists of a description of the different types of land-use destinations within the municipal territory, therefore it regulates also areas at risk. Adopted by the City Council*, land allocation plans* approval passes through a consultation with the citizens, who are to be informed regarding spatial developments via ordinary information processes (like, for example, the publication of plans). These plans can be accompained also by *structure plans* defining general guidelines for spatial developments. Structure plans are, in any case, mandatory only at Provincial and National levels.

1.1 Safety regulations and decision making

The Seveso II Directive has been implemented in the Dutch legislation by the Dutch Major Hazards Decree (BRZO) and the Dutch Public Safety Decree (BEVI). The BRZO is mainly focused on the management 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 external safety management approach adopted in the Netherlands is extensively described elsewhere [5, 6]. Relevant to this study is mostly the general life-cycle of Dutch external safety management, comprising five steps (Bottelberghs, 2000):

- identification of risks;
- assessment of the identified risks;
- evaluation of risks on the basis of acceptability criteria;
- imposition of risk reduction measures;
- control and maintainance of the acceptable risk level.

The first two steps are relevant to risk assessment. The other three are relevant to disasters' prevention and mitigation and, therefore, they involve land-use planning..

Once risks are identified, the Dutch risk assessment approach involves the estimation of both effects and probabilities of the expected scenarios. Risk acceptability is evaluated against two criteria: a) the individual risk (IR) at a given location; and b) the societal risk (SR) for an establishment. The IR is defined as the probability of death for a human located in the vicinity of an hazardous installation consequently to an accident, and it is expressed as a yearly frequency (i.e. 10^{-6} event/year, 10^{-5} event/year, etc). SR is estimated as the probability of a number of persons > N to die consequently to an accident they are casually involved in. Therefore, while IR is usually represented on a map, SR is represented only in the form of FN curves graph.

Considering the risk assessment approach described above, four types of decisions related to risk prevention may arise in practice (RIVM Report "*Nuchter omgaan met risico's*", [7]):

- s*tandard operational decisions,* in which the quantitative risk assessment (QRA) output satisfies the necessities of decision-makers;
- *decision dealing with ambiguity in risk perception,* in which the perception of stakeholders differs from the quantitatvie output of risk analysis and resistance against decisions may arise (Amendola 1998; Klinke and Renn, 2002; Healy, 2001; Lijklema, 2001; Perrow, 1984; Fischer, 2003);
- *decision dealing with the dilemma of equity versus efficiency,* like those regarding the Amsterdam Schiphol airport where, standing to the output of QRA, the current IR for citizens exceed the national standards but additional safety measures would be too expensive, or would limit the activities of one of the key-element of the Dutch economical performance;
- *decisions dealing with uncertainty,* regarding all decisions where uncertainty is too big to regards a quantitative estimation of risks as a reliable tool (like, for example, in climate change assessment).

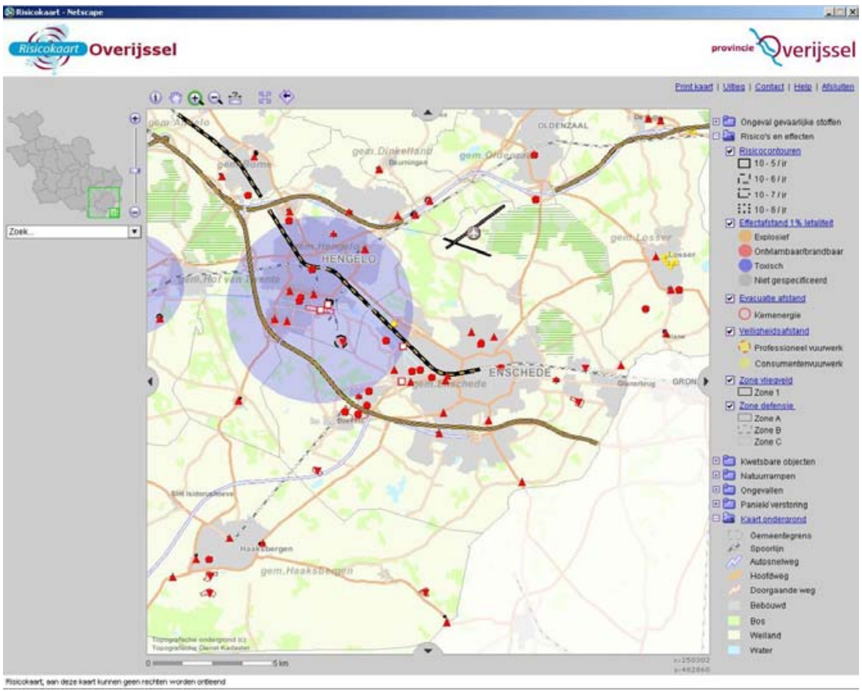
Despite appearance, it is not obvious to which of these decisions LUP in risky areas practices refer to. During the development of land-use allocation plans or planning permission procedures, several questions related to external safety may arise. Which is the individual risk involving a specific building location? which are the public safety consequences of new infrastructural or residential developments? where does the IR exceed the legal standards? Generally, these questions are not part of the traditional domain of LUP. The information necessary to their resolutions derive from the disciplinary domain of risk analysis, but their implementation involves, necessarily, also sociological and economical considerations. Therefore, althoguh QRA is the first "step" of each decision related to spatial development, standard decisions are not satisfactory to resolution of problems and new approaches and tools are needed.

1.2. GIS support to spatial planning in risky areas

Geographical Information Systems (GIS) are considered as appropriate decision support tools for the majority of land-use planning issues. The extension of its functions to environmental risk management has been the successive, relatively recent, step (Geertman and Stillwell,

2003). In the case of risk-related issues in fact, GIS can support the visualization of quantitative risk assessments. The representation of scenarios can then be overlapped to layers representing the territorial vulnerability. In doing so, relevant environmental and population data can be selected and elaborated in the desired form [8].
In The Netherlands, such functionality became operational in practices only after the accident of Enschede, occurred in 2000, as the accident attracted relevant political attention (Pronk, 2002). A direct consequence of this concern was the Installations Handling Dangerous Substances Database creation within the Netherlands National Institute for Public Health and the Environment (RIVM). Information about the type of dangerous substances, the related individual risk contours and the maximal allowed amount of dangerous substances would have had to be stored and updated in this first centralized, national d-base. Vulnerable and less vulnerable object, areas exposed to flood risk and susceptible of "panic in crowd" phenomena have been added to the d-base. In this respect, it can be said that a "bridge" between professionals handling safety-related planning matters and the Authority managing risk-related information has been built by means of a mutual necessity: sharing the information elaborated and possessed by the different professional sectors on a common, mutually usable, GIS platform. This necessity resulted in the elaboration of the first Dutch "risk-maps" (*risicokaart*). FIG 1 reports an example of the Province of Overijssel.

FIG 1 - Risk map of Province of Overijsel, The Netherlands (www.risicokaart.nl)



As mentioned in the introduction, three target-groups who might have access the information reported in the *risicokaart* are recognized: safety authorities, plannig authorities and citizens. The third target group has been defined as a non-expert audience that has to be informed regarding risk in a non-ambigous and easy-reading way [x]. In this respect, the use of GIS maps for delivering easy-reading territorial and environmental information to the public is drammatically increased in the last years and, in The Netherlands, it led to the recent publication of the provincial risk-maps on the web [9]. The amount of information delivered via provincial risk-maps is notable: extremes of companies, their classification, location, substance treated/storaged, vulnerable objects in their vicinity and additional information about evacuation plans are reported. Nevertheless, GIS serves just for illustrative purposes: any elaboration of the mentioned information by the side of users is not allowed. Users can only select different layers with the information of interest and then visualize more or less accurate data. In this respect, the function of GIS seems not that of informing the planning process, but that of delivering essential information on its outcomes in order to guarantee the "right to know" of citizens (Gouldson 2005).

2. LUP system and risk prevention policy in the United Kingdom

The United Kingdom has one of the longest European traditions with respect to risk assessment and management practice (Jones 1998; Smeder & Christou 1999). In contrast to The Netherlands, in the UK the Safety Authority Health and Safety Executive (HSE) is responsible for all risky installations of the Country. Regarding Seveso II establishments, the role of HSE is that of advising Local Planning Agencies (LPAs) about all safety related issues. LPAs are entirely responsible for what concern urban and territorial developments in areas at risk, therefore the advice is not legally binding. This advisory role of HSE with respect to planning authorities reflects the nature of UK health & safety system, based on a great autonomy of Local Authorities on the one hand, and on an efficient cooperation among different governmental agencies on the other one.

2.1 Safety and land-use planning regulations

The Seveso Directive has been implemented in several laws. First of all, the sitting of new establishment is subject to a licensing procedure. The legal references are the Installation Handling Hazardous Substances Regulations (NIHHS) and the Control of Industrial Major Accidents Hazard Regulation (CIMAH) 1999. Land-use planning in the surroundings of chemical sites is regulated by the Planning (Hazardous Substances) Act 1992 and the Planning (Hazardous Substances) Regulations 1992 as amended by the Planning (Control of Major Accidents Hazards) Regulation 1999. Finally, regarding the National land-use planning regulation, references are the Town and Country Planning Act 1990 and the Planning (Listed Buildings and Conservation Areas) Act 1990. Local Planning Agencies (LPAs) are responsible for the regulation of local plans with respect to major accidents risk. In order to fulfill this mandate, they are required to apply to HSE in order to receive a safety advice. Therefore, the three Seveso II cases of a) new establishments; b) modifications to existing establishments; c) new developments in the vicinity of existing establishments are regulated by means of HSE risk assessment. Besides these ordinary cases, LPAs can apply to HSE for any situation in which risk is involved [4].

In UK practice the two phases of risk management are clearly distinguished. The assessment phase, in which HSE acts as the advising technical body, and the implementation phase, in which LPAs (and local authorities in general) have to implement the evaluations stemming from the advice are independent. In his respect, the sustainable planning principle of assigning roles and responsibilities in a clear and traceable way is respected [10]. In so doing in fact, site-specific issues such as the economical, social and territorial specificities of involved communities are considered separately from risk estimation, and impartiality and objectivity of risk assessments are guaranteed.

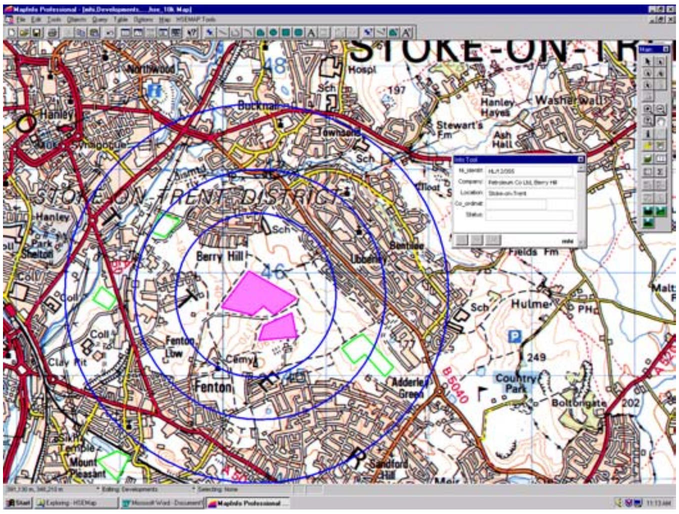
HSE risk assessment method is based on a judgmental approach. A distinction between two LUP criteria regards different accidental scenarios: for toxic releases the advice is risk-oriented, while in the case of thermal radiation and explosions (relative, for example, to LPG storages) the advice is consequence-oriented. In the first case, the "zoning" criteria is the probability to receive at least a dangerous dose, while in the second case the criteria is the receipt of prescribed thermal dose unit. Consequently, in the first case frequencies are relevant to decisions while in the second frequencies are not considered for planning purposes [11]. Risk assessments are represented on a cartographic base, where the three inner, middle and outer so-called "consulting" zones are individualized. Within these zones, the consultation of HSE for planning purposes is mandatory. As in The Netherlands, both the individual and the

societal risk are LUP criteria. Differently, the societal risk is not numerically assessed: the English concept "of societal risk" refers to general high-density agglomerates and/or specific vulnerable targets (hospitals, schools, etc) which presence has to be considered in order to integrate the judgment resulting from the individual risk criteria only. Hence, SR is an integration of IR as integrated with population data. The IR risk calculation leads to estimate the risk that a typical house would be exposed to due to a dangerous dose receipt (or worse). This is generally expressed in terms of "chances per million per annum", i.e. chance/10^{-6} or CPM (10 CPM, 0.3 CPM, etc.). Differently than the Dutch one, English law doesn't prescribe threshold values to be achieved nor respected. This difference between the two orientations will be discussed later.
The HSE advice is carried out by means of the software PADHI (Planning Advice for Developments near Hazardous Installations), a software that came into force in 2002 in order to facilitate and speed the advising process. PADHI needs to be filled with both risk analysis data – scenarios, risk contours, frequencies – and territorial data – targets, proposed developments' vulnerability, etc – in order to give the output "ADVICE AGAINST" or "DON'T ADVICE AGAINST". This advice serves to LPAs in order to review, for example, proposed developments near existing installations or modification of land-uses due to increased risk. The form in which this advice is delivered to LPAs is discussed in the following paragraph.

2.1 Evolution of the advising process: turning to GIS

In the light of the essential role of HSE in land-use planning decision-making processes, a review of its method was initiated in 1998 (refer to IFRLUP, HSE,1998). Aim of the review was clarifying whether HSE role and method were still valid, robust and in line with broader governmental policies for land development [12]. Being the HSE advice still based on the document *Risk Criteria for Land Use Planning in the vicinity of Major Industrial Hazards* of 1989 [13], verifying eventual bottlenecks in the system was reasonable. One of the outcomes of the review was the proposal of developing a modified version of PADHI enabling LPAs to carry out risk-related assessments independently. The project has been carried out by the Geographical Information Systems (GIS) team of the Risk Assessment Section of HSL [14]. The project outlined that a GIS format for HSE advices was preferred by LPAs: through a GIS-based advice they would have had the opportunity of enriching their existing d-base with compatible format data. Each time HSE assessment involves some changes in risk contours or new developments are made in fact, new "consulting zones maps" are to be forwarded to LPAs. In this respect, turning to a GIS format has been seen as an improvement of the advice procedure (FIG 2).

FIG 2 - An example of HSE risk-maps (HSE 2005)



Thanks to a cooperation between HSE and Staffordshire University (UK), the Population Database for Major Accident Hazard Modelling was recently concluded [15]. Objectives of the project were to: a) refine the method and process for deriving population d-base for MAH modeling to take account of new available datasets; b) develop and apply generic population multipliers to be attached to buildings, transport routes and land uses; c) produce a d-base for estimated population associated with buildings, transport routes and land-uses across England, Scotland and Wales; d) develop a user interface to enable simple use of and interaction with the d-base by personnel from HSE. The d-base is intended to work in ArchGIS environment and, as above mentioned, it is intended to support HSE for a variety of safety-related matters.

Conclusions

This paper presented fist results of our study on the use of GIS in risk prevention in the UK and The Netherlands, who have both a well established risk prevention policy and a quite advanced use of GIS. However, the study has shown some general differences between the risk prevention practices of two countries:

- Actors involved in LUP for areas at risk are slightly different. While in the Netherlands they depend on the kind and relevance of risks, they are always the HSE and the LPAs in the UK;
- The status of LUP criteria for IR is legally binding in The Netherlands, while is a so-called "target criteria" in the UK;
- The concept of societal risk has also variations: while in The Netherlands SR is numerically assessed, in the UK population data serves to integrate the IR judgment.

Despite differences, the capacity of GIS for elaborating and representing information in an easy-reading and interactive form is increasing in both countries. Hence, decisions seem to be based on integrated data to which all parties have easily access. An important observation is that the elaboration of risk information through GIS technique served to connect independent professional domains. In both countries in fact, GIS have been primary used to create a common platform to store, elaborate and update data accessible to both professionals domains involved in risk prevention. Following this approach, both countries enforced the mutual cooperation necessary to face public safety problems, confirming the findings of the studies reported in the premise of the present work.

Nevertheless, differences between the two practices exist and are remarkable. The most relevant are:

- In The Netherlands, information stored in RIVM national d-base are accessible to planning authorities upon request; in the UK, these information are directly forwarded to LPAs each time a risk situation increases/changes;
- Risk-maps in the UK are used only to inform the planning process; in The Netherlands, risk-maps are used also to inform the public.

Concerning the last point, we place two remarks which we are going to develop afterwards. The first regards the kind of information that is delivered via risk-maps in both Countries: necessarily, they regards only individual risk. Iso-risk contours are, in fact, relative to individual risk only, since any societal risk consideration can be "visualized" in the same easy-reading form. How this IR message influences the perception of risks by the side of third-parties? And consequently: how to support a proper perception of both individual and societal risk by the side of non-experts audiences?

The second remark is, in our opinion, more controversial and regards the access to risk-related information. Although in both countries their status is public and, according to the Seveso II, their access by the side of citizens have to be guaranteed, the Dutch choice of publishing risk-maps in the Internet appears in contrast with the recent needs of increasing European security. In a multi-risks perspective in fact, the relevance of safety-related information to the security against voluntary actions should be accounted. In a communication of 2004 regarding the

protection of critical infrastructures (CI) in the fight against terrorism [16], the European Commission specify how all those "[…] *physical and information technology facilities, networks, services and assets which, if disrupted or destroyed, would have a serious impact on the health, safety, security or economic well-being of citizens or the effective functioning of governments in the Member States* […] should be carefully monitored and protected. The Communication stresses the need of enhancing the production and the exchange of information relative to critical infrastructures threats among public and private actors, but also the need of using high discretion in their dissemination.
In the light of this requirement, the publication via web of a great variety of information relative to both Dutch CI and relative emergency plans seems, when not dangerous, at least highly controversial. Differently than in UK, where subjects willing to consult risk-related information have no direct access to them via web (HSE 2005), in The Netherlands it is totally impossible to monitor who consult information and, consequently, the uses they're consulted for. Therefore, in giving priority to the "right to know" of citizens, a free access to information may represent an indirect threat to their security. The paradoxical consequence is that, while enhancing the risk awareness of users, transparency may increase the risk they are subject to.
Concluding, despite the positive developments of GIS use as decision support and informative tool, several improvements can be further realized. Further research will explore in detail those more relevant to our described, initial, findings.

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