

A GIS based Decision Support Tool for the Management of Industrial Risk

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Abstract

A decision support tool for the management of risks from accidents in chemical industrial sites handling hazardous substances (toxic or flammable) is presented. Management of risk refers to potential land use plans and/or emergency response plans that are based on geographical considerations of the extent of risk. A tool has been developed on a GIS (Geographical Information System) computer platform using digital maps to provide visual focus to the relative magnitude of the consequences of the operation of such chemical sites to the human health and environment.

The tool uses the capabilities of a GIS platform to combine each map with the corresponding information at each level offering a new dimension to the management of industrial risk to the human health and the environment. It is built using the advantages of a GIS and complements the risk assessment with geographical information useful in supporting relevant management decisions.

Introduction

During the last decades considerable development of the handling of geographical data has been reported in the literature [1]. Spatial data from different sources integrated within the environment of a GIS have been used in various applications. Users can link data, combine different information, visualize the results and find answers to multiple questions. Digital maps providing a global overview of the lower or larger scale environment are used as background and help in the visualization of spatial data in revealing relations between them.

GIS functions very well in decision support systems [2]. Decision support tools (DSS) can be applied to land use planning/policy management methodology [3,4]. GIS based Decision Support Systems generally include visualization of models of geographical data and they benefit from the integration of various models for the management of specific information, as industrial risk, in a flexible approach.

According to a definition of Decision Support Systems, suggested in [4,5], a DSS should have six characteristics: 1) explicit design to solve ill-structured problems; 2) powerful and easy-to-use user interface; 3) ability to flexibly combine analytical models with data; 4) ability to explore the solution space by building alternatives; 5) capability of supporting a variety of decision-making styles; and 6) allowing interactive and recursive problem-solving. Capabilities and functions of GIS based Decision Support Systems, are needed to 1) provide mechanisms for the input of spatial data; 2) allow representation of the spatial relations and structures; 3) include the analytical techniques of spatial and geographical analysis, and 4) provide output in a variety of spatial forms, including maps.

The management of the industrial risk that comes from accidents in chemical sites is a very severe application for the environment and for the human health. Any decision should affect both of them and a tool that possibly will be used for the support of relative decisions should act in a way to support the decision maker to choose the best. All the related information, should be available and easily visualized. The developed system implements a hierarchical structure of the needed information into three levels with different properties. The properties are automatically inherited to the objects belonging in the same level. The levels are linked in a way that the user can move from the less detailed (larger scale) which corresponds to the level of the country, to more detailed levels (lower scale) containing information of the internal area of each site. The consequences of a possible accident, in the form of risk indices, are linked with the objects of the third level that can be seen from all the upper ones. Each level uses digital map as a background over which the all these data, which are strongly spatial, can be seen. The decision maker can build at any time his own complicated scenarios and is able to notice the extent of the individual risk. The system has been developed using the GIS environment of ArcView 2.1.

This paper is organized in four sections. The second section contains a detailed description of the structure of the information related with the management of industrial risk. In the third section is presented the way that the risk is estimated from the information stored through the GIS and the fourth section contains our conclusions from the use of the described tool.

Structure of the Information : Geographical Considerations

The information related with the chemical sites is structured in a hierarchical way. This structure is important because it reflects the properties of each element and also maintains the availability of each entity to all levels. Each entity is a different *object* and is presented by a symbol. The *objects* are organized into three levels. Each level contains similar objects having the same properties. The hierarchy of the levels ensures that properties of the higher levels are inherited to the objects of the lower ones. The properties of each object define the fields of a table. Different objects are stored as different records in the corresponding table and each table completely describes a level. All records in all tables, that is all the corresponding objects, have a common field: the geographical coordinates of the object. These coordinates make the object identical, independently of the level and denotes its exact spatial location on a digital map used as background.

The first level which is the higher one, contains objects that correspond to *industrial regions* and are presented over a map of the whole country. It is the entry level and each industrial region can be seen as a point on the map. Each of these points is also a link to the map of the next level containing objects corresponding to *plants* that belong to the *industrial region*. The second level of information contains information that describes the *plants* existing within an *industrial region*. Similarly to previous level, each *plant* is described by its properties that are fields to the corresponding table and its exact geographical information. The third level is the level of detailed description of the *plant* in terms of equipment. The map used in this level is a detailed topographic diagram of the internal area of the *plant* and the *equipment* are shown as points. It is obvious, but useful to note, that moving from the higher to lower level, the scale of the maps is reduced reaching to a detailed view of the inside of the *plant*. This structure of the hierarchical levels of information is shown in Figure 1.

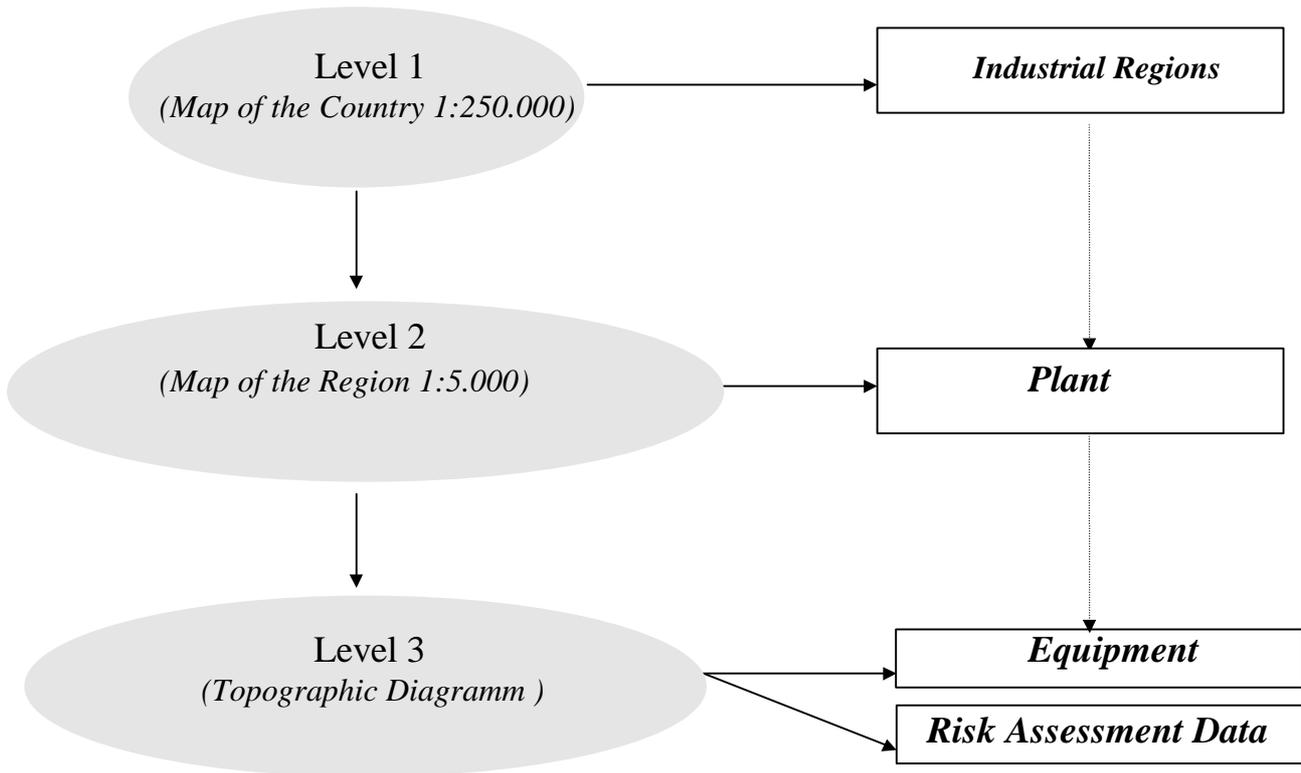


Figure 1. Hierarchical Structure of the Information

The approach described above is a top-down approach. The user can search information from the current level to all lower ones. Particular information for any level is available easily either by moving to the corresponding level or by setting up queries. The queries can be set through the map, using a dialog box in which the user defines variables describing the properties of the objects, values for each properties that will be searched and symbols to build expressions combining the values of more than one field. The results of the queries are displayed on the map and the user can view them in different scales depending on the density of the interesting points. Building a query which will search for the equipment containing propane, on the first level, the level of country, is shown in the Fig. 2.

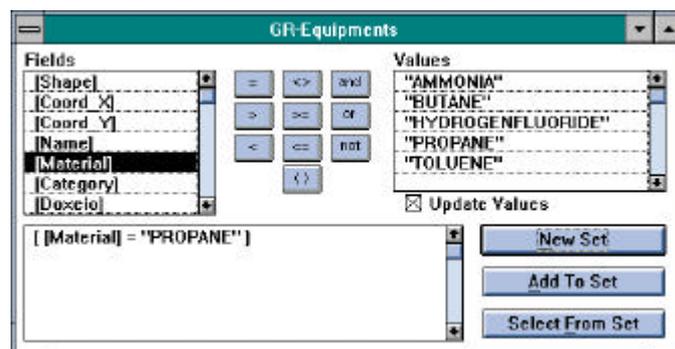


Figure 2. Construction of a query (searching for the installations of propane)

The user chooses the field on which the search will be performed. The result is shown in Figure 3, depicting a map containing the points satisfying the expression of the query and corresponding to *industrial regions* in which there are *plants* containing propane storage equipment. If a more detailed view is desired the user can move to one of the next levels where a smaller scale map can be seen, the surroundings of the *plants* or the *equipment*.

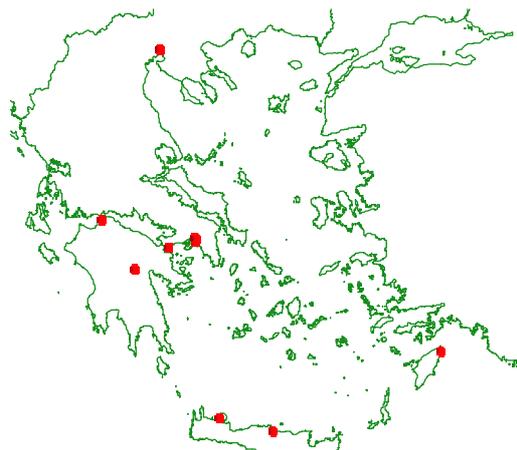


Figure 3. Results of the query (*Propane Installations*)

Industrial Region

As it is previously noted each point of interest on the map is connected to the corresponding table which containing the values of the properties that uniquely describe the object. The first level of objects describe *industrial regions*. To each *industrial region* corresponds a record with fields : (i) geographical coordinates, (ii) number of the *plants* located within this region and (iii) name of this region (see Table 1).

Table 1. Fields of record “*Industrial Region*”

<i>Industrial Region</i>
1. Coordinates
2. No. of Chemical Sites (<i>Plants</i>) included
3. Name of the Industrial region

A point on the map indicates the exact location of this region within the country. This point also implements a link to the next level which contains details for this region.

Plant

The second level of information contains objects representing industrial sites handling hazardous substances (toxic or flammable) and are called *plants*. Each object is a point on the map and is described in terms of the following information defining corresponding fields in the record : (i) geographical coordinates, (ii) name of the specific industrial site, (iii) name of the industrial region in which it belongs, (iv) category of the industrial site according, to the substances that are stored in this site, (v) holding company (iv) administrative region to which this site belongs, (vi) name and address of the contact person and (vii) other information needed (see Table 2).

The spatial location of a *plant* on the map implements a link to the next level, the third one, where the user can see in details the internal of the industrial site.

Table 2. Fields of the record “*Plant*”

<i>Plant</i>
1. Coordinates
2. Name of the <i>Plant</i>
3. Name of the Industrial Region (belongs to)
4. Category of the <i>Plant</i>
5. Holding Company
6. Administrative Region
7. Contact Person
8. Address
9. Other Information

Equipment

The third level and the lower level contains objects called *equipment* corresponding to installations storing hazardous substances. The map used in this level is a detailed one and usually is a topographic diagram of the internal area of the site. Each *equipment* is represented as a point on the diagram denoting the exact location within the *plant*. The information describing an *equipment* consists of : (i) geographical coordinates, (ii) name (or code) of the *equipment*, (iii) *plant* to which it belongs, (iv) name of the substance contained, (v) category of the substance, (vi) type of vessel in which it is stored, (vii) dimensions of the vessel, (viii) volume of the vessel, (ix) quantity of the substance and (x) other relative information that is considered useful. Each of the above corresponds to a field of the record *equipment* (see Table 3).

Table 3. Fields of the record “*Equipment*”

<i>Equipment</i>
1. Coordinates
2. Name of the <i>Equipment</i>
3. Plant (belongs to)
4. Substance
5. Substance Category
6. Vessel Type
7. Dimensions of Vessel
8. Volume
9. Storage Conditions (Pressure & Temperature)
10. Quantity
11. Other Information

Quantified Risk Assessment Data

Further to containing detailed information about the types of hazardous substances the conditions of handling and/or storing them and related geographic information about the corresponding equipment and plants, the system can handle information relating to the results of a Quantified Risk Assessment (QRA). Each *equipment* can be linked with information concerning a spatial risk index connected with a particular accident originating from the specific piece of *equipment*. This index can be either the intensity of an extreme phenomenon (e.g. thermal radiation, overpressure, concentration of toxic substance) or a time integrated quantity more indicative of the potential to inflict the damage to human health like the corresponding doses (e.g. thermal dose).

In its present form the tool is linked with risk related results obtained by the the risk assessment toolkit SOCRATES [6]. Each *equipment* is linked with QRA results providing the individual risk of death at each cell point (x,y) in the general area of the plant. Individual risk is defined as : *the frequency (probability per time unit) that an individual at a specific location (x,y) relative to the installation will die as a result of an accident in the installation.* The resulted risk is a spatial information and is calculated over a grid having as center point the location of the *equipment*. The values over this grid are displayed as curves of equal level of individual risk (isorisks). These results can be viewed over maps in any of the three levels of detail (see previous section). Several accident scenaria referring to the same or different *equipment* can be combined to provide a composite risk profile. Each *equipment* is linked with possible scenaria, their frequency of occurrence and the conditional (on occurring) individual risk at each point (x,y) in the area around the *equipment*. In principle this is achieved by adding to the fields of the record *equipment* three additional fields : (i) name of scenaria, (ii) probability of occurrence and (iii) name of the file containing the results spatially related to the equipment. Thus the concept of ‘record = equipment’ is extended to the concept ‘record = accident scenaria’. The user can define a number of scenaria and visualize the combined individual risk in the form of isorisks on a map at any of the available levels resolution.

An example is shown in Figure 4, where the isorisks corresponding to a Propane storage facility are depicted. The isorisks refer to the probability of fatality conditional on the release of the Propane, its dispersion and its explosion according to an Unconfined Vapour Cloud Explosion (UVCE). The slight north-east orientation of the curves is due to the prevailing weather conditions. The results shown range from 10^{-2} to 10^{-6} and of course do not include the frequency with which the accident is expected to happen.

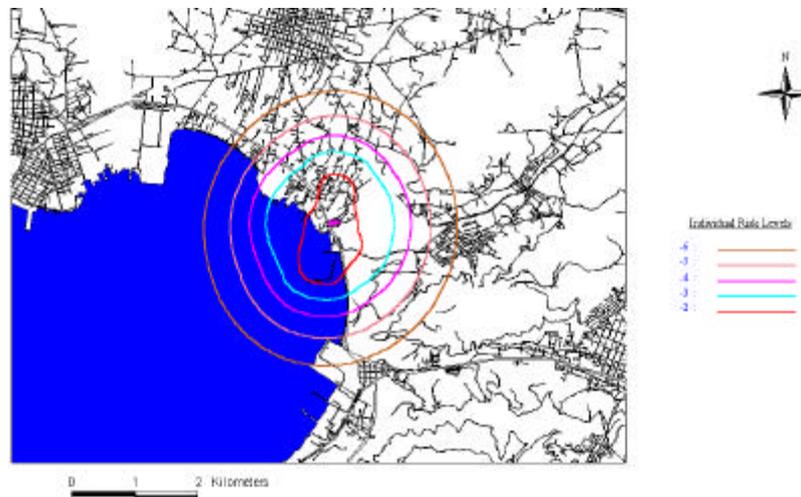


Figure 4. Curves of equal Risk Values

Conclusions

A GIS based system for aiding decisions related to the management of risks from chemical installations handling hazardous substances has been developed. The system allows the storage and visualization of information concerning the types of installations and substances handled over digital maps in three levels of geographical detail (scale). Furthermore this information can be linked (and visualized) along with calculated consequence indices or risk profiles for these installations along with other relative information (e.g. sensitive installations like schools, hospitals, residential and recreational facilities). As a result the developed tool represents a valuable tool in supporting decisions concerning land use planning and emergency plans around such facilities.

References

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