EPM: a GIS-Based tool for Emergency Preparedness and Management of industrial-related accidents

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The paper regards the development of a GIS-based software tool supporting local civil protection authorities in Emergency Preparedness and Management for industrial risk. Technological accidents (chain of events, domino effects, transport of dangerous substances, etc.) and natural hazards (floods, earthquakes, hurricanes, etc.) may generate heavy damages for industrial activities and surrounding areas (deaths, injuries, building or infrastructure collapse, …). The software is developed by considering the need of collecting the appropriate available information sprawled within different geo-databases in hand of several entities (local governments, infrastructure's managers, rescue services, …) when an emergency occurs. This information may support civil protection activities during the emergency to maintain and improve the level of safety and protection of people working within and living around the industry involved in the accident.

1. Introduction

Industrial accidents occurring in urban areas might provoke so many effects that require a combination of several response actions to cope effectively with them. This could happens both in case of they have been originated by a technological and by a natural hazard (Na-Tech event).

The UE ("Seveso Directives") and Italian (D.Lgs. 238/2005) legislations define as "major-accident" an event such as a major emission, fire, or explosion resulting from uncontrolled developments in the course of the operation, and involving one or more dangerous substances. In this conditions, civil protection actors should be able to face toward new emergent demands: the emergency represents an extreme event where stakes and needs are so high to require technical and relational capabilities to perform specific tasks with other people, under strong psychological pressure (Caragliano, 2007). The emergency demands safety measures for the industrial installation and medical care for workers involved in the industrial accident. In addition, competent authorities for civil protection have to provide for protecting people and property located outside the involved plant as soon as possible. They must take actions in order to fulfil their duties, namely maintaining order, clearing the possible debris, restoring public services, and provide for population needs. Consequently, information about damages and occurred circumstances, crisis evolution, possible scenarios of risk, and

available material and human resources must be known. An inter-organizational emergency management, involving competent authorities for civil protection and population, is needed.
Therefore, industrial accidents might represent an event requiring early and prompt decisions about interventions that should be quickly organized and carried out; unfortunately, these are often based on rough, confused, limited, and not-reliable information. Many aspects of the emergency management depend upon the accurate and realistic risk information. A great deal of information is generally available, but they may be not immediately recognized: some information may simply be very difficult to obtain and collate (Ferrier and Haque, 2003). This may be true for some authorities not adequately prepared for emergency management, especially when high level of hazards, multi-risk contexts, or particular vulnerable groups (children, disables, etc.) exist. Consequently, the information management before and during an emergency is of paramount importance. Particularly, data on physical, social and systemic vulnerability and data on available resources need to be organized in emergency preparedness; in this way, they could be easily and better managed during the emergency response.
For this reason, *emergency management systems* often resort to software tools supporting their activity in emergency preparedness and response. These are useful for detecting hazards, assessing elements at risk, and defining scenarios of risk. At the same time, they allow to get all the information for carrying out emergency procedures during a crisis: to asses the happening situation, to estimate occurred damages, to identify the more appropriate operational strategy, and to activate the chain of actions for overcoming the state of emergency.
Software tools are based on suitable meta-connections among all the information that must be such interrelated that they cannot be only easily recovered from different sources, but also they can give useful hints in real-time. As a consequence, the main aim of this work has been to built up an innovative set of connections among a large amount of information made readily available from different sources, as well as to implement such meta-connections in a suitable software tool called EPM (Emergency Preparedness and Management). This allows to acquire the information available in various formats and to organize them through their interconnections. EPM is designed to be suitably used by local emergency managers, mostly at city or inter-city level in emergency preparedness and management. Finally, a case study involving an industrial accident in a high populated area is currently under development in order to validate and to improve the developed tool.

2. The use of GIS-based tool as a support to Emergency Preparedness and Management

Civil protection actions in case of an industrial accident include all the relief interventions performed by institutional rescue teams, local authorities, volunteers, industrial and lifelines managers aimed at controlling the accident and at minimizing its consequences. These actions need to maintain and improve the level of safety and protection of all people involved in the accident, within and outside the plant. In this case, information on local hazardous and vulnerable elements are needed to support relief and rescue actions planned in the emergency procedures. Particularly, the use of software tools allows to reduce times of response facilitating the decision-making and implementation processes in front of particular hazardous and vulnerable factors.

According to the fact that catastrophic events and their effects are mostly geographically distributed and location dependent, *Geographic Information Systems* (GIS) have significantly enhanced our society to deal with risks by providing critical analysis, characterization, and evaluation tools in support of decisions (Wilson and Fotheringham, 2007; Chang *et al.*, 1997). When an accident occurs, GIS-based tools allow to quickly collect information and to know characteristics about the specific area involved in the accidental event. This makes easier the organizational and technical interventions during the hours and the day following the accidental event (Santoianni, 2007; Goodchild and Haining, 2004; Verter and Kara, 2001). GIS allow to edit, store, analyze and manage data and associated attributes which are spatially georeferenced to the Earth. In this way, GIS constitute computer systems capable to create databases containing data that are identified according to their location. This allows to treat information, traditionally included in different maps, by comparing, merging, and overlapping georeferenced data; consequently, new integrated information can be created.

Cutter (2003) highlights that the use of georeferenced data is particularly useful for risk prevention and emergency response, thanks to the technological progresses on mapping strategic resources and procedures. Disasters are the outcome of risk situations due to pre-existing hazardous and vulnerable factors that can be identified, evaluated, and collected by integrating geospatial data. When organized in phase of emergency preparedness, all these information can support emergency response. The integrated information can be used to plan alternative traffic directions in case of emergency, to count people in case of evacuation, to identify and to update hazardous areas, to localize logistic supports and resources, to identify the position for emergency management headquarters, to organize communication systems among civil protection actors, to direct and motoring land use planning. Emergency response needs to find and to organize data for civil protection actions, in order to facilitate interventions by consulting information specifically organized before the emergency strikes. Furthermore, the background theory about the development and the application of GIS, the so-called *Geographic Information Science*, suggests the importance of the definition of haw and what information should to be mapped for a specific goal. In order to decisions and interventions being quickly made, it is important to have at disposal maps and databases that are rigorous, update, and that can be easily consulted.

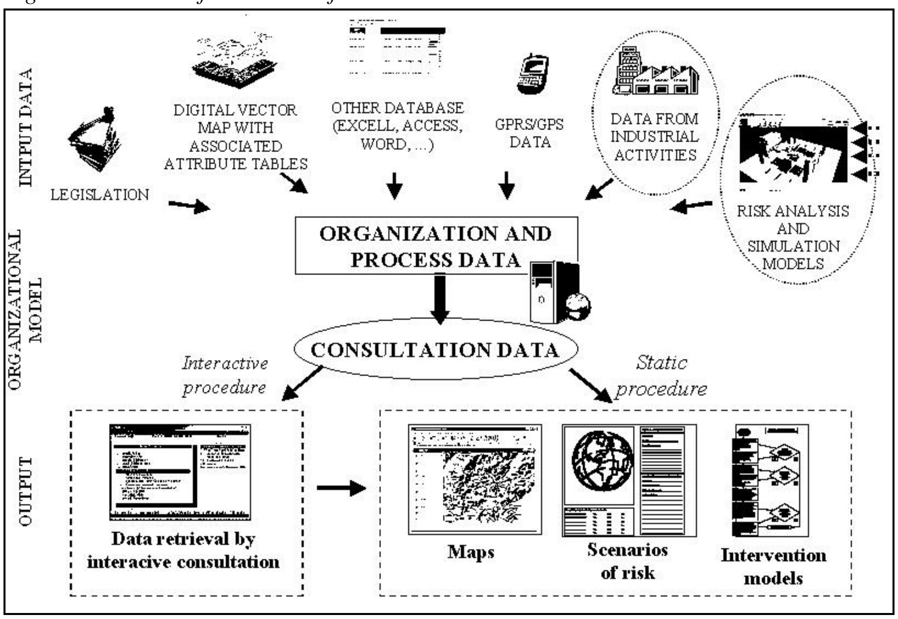
According to this, a GIS-based software for emergency management is under development at the Politecnico di Milano within the RAI^2 project (Risk in Industrial Area: an Integrated Approach). It is devoted to prepare and to support civil protection authorities in emergency response when an industrial accident occurs. The RAI^2 project is part of the strategic PROMETEO project (Public protection: methods and operational technologies) that has been internally promoted at the Politecnico on issues about Civil Protection, Personal Safety and National Security (see the project website at www.polimi.it/prometeo). In this context, main goal of the EPM software is to facilitate the data retrieval and the use of specific information for the urban emergency overcoming. This depends on the environmental situation (type of accident, direct damages, etc.), the local risk elements (density of the population, hydrological characteristics of the site, etc.), and the available resources (material and human). For this reason, the software tool is developed by considering the need of collecting available information sprawled within different geodatabases managed by several entities (local governments, infrastructure's managers, rescue services, etc.).

As mentioned before, the power of a GIS comes from the capability to relate different information in a spatial context so that to derive a conclusion on the basis of their relationships; this is also synthesized in new integrated georeferenced information. In this way, GIS represent strategic tools to organize and to address the knowledge system into civil protection activities. Usually, not all the available data for emergency management are structured in geodatabases (phone number of institutional forces, localizations of material equipments, etc.), but only data for urban planning are often reported. For this reason, EPM software is developing by considering the possibility to integrate data coming from several different kinds of softwares. Available information and widespread knowledge constitute basic requirements to define emergency response procedures, as contextual characteristics that need to be collected in an organized structure. Particularly, in industrial risk management, information coming from risk analysis should to be included in technological tool for emergency response. Software for risk analysis generate output data (geometric features with related attribute tables) representing area of damages that can be used by EPM. Moreover, missing data can be directly collected on-site by means of *GPS data loggers* (Dong, 2005) suitably linked to EPM.

According to the exposed remarks, the GIS-based software in RAI^2 project is developing for organizing a flexible database adequate to support emergency management in consulting maps and personal data, identifying direct and indirect damages, choosing operational procedures and the like. Information could be consulted by user interfaces through *ad hoc* queries specifically addressed to emergency response. Particularly, during the emergency the software facilitate the emergency managers by providing them selected data in interactive and printed schema, diagrams, and maps. These documents can support emergency managers for identifying technical alternatives, defining actions to do end forces to mobilize (Figure 1). In this way, EPM software represents not only a Decision Support System, as tool to support the estimation, evaluation and the comparison of technical alternatives, but an implementation software as it provides operative directions to carry out the selected alternative. Emergency management need to be based on risk assessments and organizational plans, despite many difficulties associated with identifying, defining and classifying them. Many people make decisions and take actions for risk management based on measures that are developed by competent technicians; nevertheless, although these are developed on the basis of scientific and humanistic knowledge, their estimation is influenced by their personal and collective perception of risk (Caragliano, 2007). This aim to the fact that an emergency implies not only technical uncertainties but also to social and managerial influences.

As the literature shows, high level of emergency preparedness can facilitate these technical and organizational activities during the emergency response (Zuliani, 2007; Tierney *et al.*, 2001). The goal of the emergency preparedness is to improve the level of technical, social and organizational capabilities to deal with unexpected events, as industrial accidents are. These capabilities can be enhanced by developing interinstitutional response mechanisms, by planning inter-organizational operational procedures, by promoting socio-organizational networks, by improving public education and by building early warning systems. All these activities share the information exchange as the main requirements to know and define what to do in each specific emergency situation. Consequently, emergency preparedness calls for technical tools able to facilitate the information exchange in the emergency management, by preventively defining structured databases that allow to organize sprawled digital data.

Figure 1- Scheme of the EPM software



3. EPM software

EPM is designed as a part of a more general digital platform that is technical resource for emergency managers and security operators since it refers to methods and tools for assessing and managing hazard characteristics, vulnerability factors, and possible scenarios of risk. Knowledge contained in integrated information is a requirement to define and to plan technical interventions that have to be adopted during both the preparedness and the response phases. The available information with the EPM software highlights criticalities and strong points characterizing the accidental event and its consequences,.

When an hazard occurs civil protection actors should be able to face toward the emergent demands in an inter-organizational way. Technical and relational capabilities to perform specific tasks and to share knowledge with other people are required. Therefore, information about the damages occurred, the crisis evolution, the occurred circumstances, and the material and human resources available to manage the crisis are needed to know. The emergency should be considered as result of both possible different hazards (big industrial plants, small and medium businesses, transport of dangerous substances, natural hazards) and vulnerability factors characterizing the exposed assets (buildings, lifelines, people). To this purpose, EPM software is planned to collect all the available information about the hazardous and vulnerability factors influencing the direct and remote consequences that can be generated by the industrial accident, both in the case that the accident is provoked by a technical failure and in the case that it is caused by a natural hazard.

According to this, particular attention in the software architecture has been addressed to the organization of the input data, that are organized into a prototype *EPM SpatialDataWherehouse* (SDW). This is made up of a set of main *Thematic Sections* (TM), each of them collecting a different type of data (Table 1). Furthermore, some TM also contain sub-sections for better organizing the integrated data. In this way qualitative and quantitative information about local risk elements can be downloaded, entered, stored and processed (type and amount of dangerous substances in an industrial plant, flooding area and related return periods, buildings with high density of people, etc.).

Table 1 - Content of different Thematic Sections of the SDW

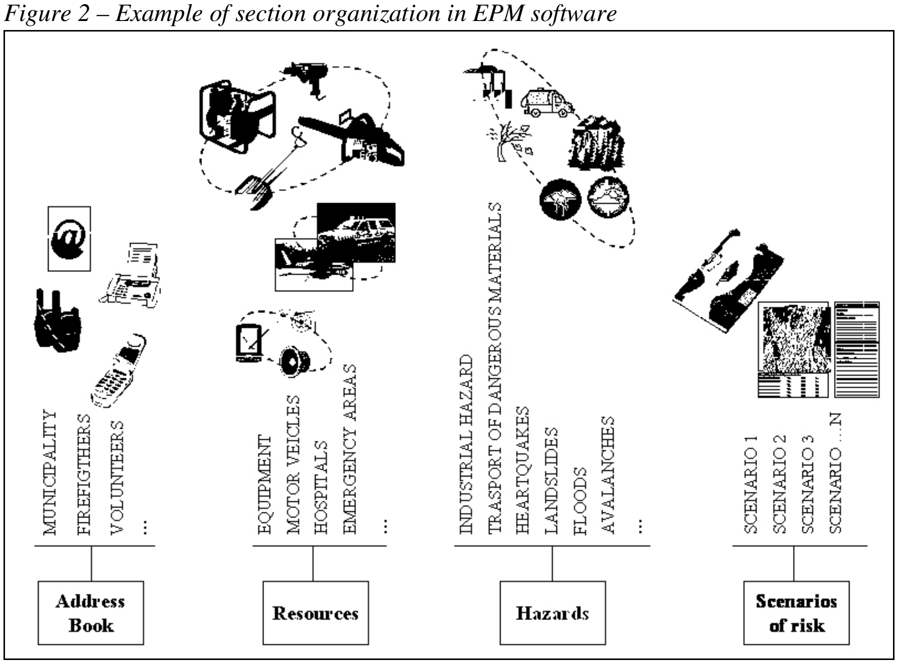
Thematic Sections	***Data content***	***Data format***
Geo-DB, Raster maps & orthophotos	Digital vector map with associated attribute tables (according to Italian standard format) at 1:1k or 1:2k nominal scale for urban areas, 1:5k or 1:10k for countryside and mountain areas. Reference digital maps.	ESRI Shapefiles, GEOTIFF, ECW, TIF, World file
Hazards	Localization of sources of possible accidental events and their characteristics.	ESRI Shapefiles
Scenarios of risk	Description of the evolution of each a possible accidental events on the local vulnerable area. It includes map, data of competent people involved and procedures for emergency response.	PDF or Word documents
Intervention models	Schema of the procedure that different competent institutions should to do in the emergency response.	PDF documents
Maps	Map representing critical infrastructures, vulnerable buildings, hazardous areas, etc.	PDF documents or ESRI Shapefiles
Address book	Addresses of civil protection authorities	DB formats
Resources	DB and Geo-DB containing available resources (equipment, motor vehicles, base camps, etc).	DB formats & ESRI Shapefiles
Annexes	Other related documents.	PDF documents
Legislation	Inherent laws and regulations European, Italian and Regional Level.	PDF or words documents

The structure of SDW has been defined in order to make easier the use of the software outputs during the emergency (consultation of interactive map and data, identification of emergency procedures specific for each risk scenario, phone book, …). As previously mentioned, this innovative meta-connections among all the information available represents one of the main innovation of the project.

The EPM software is devoted to conduct queries specifically addressed to manage a current emergency (Figure 2). By these tools EPM allows during an emergency: the immediate availability of preventively processed data by means of a well-known and user-friendly GUI; the availability of digital and paper information to help emergency operators in decision-making and implementation processes; the use of updated information for the assessment of the risk and the contextual emergency; to supply a guideline for defining appropriate operational procedures according to pre-defined

intervention models.The same information can be obviously used for emergency preparedness.
Currently the architecture of the prototype version of EPM is based on two main modules: the desktop GIS software ESRI *ArcMap 9.3* is adopted as graphical interface to access geographical data and related attribute tables and documents (i); the *Dynaform* (Intercad, CH) module allows to register a set of predefined queries on the SDW (ii). *Dynaform* might run within *ArcMap* if a geographic query is needed, but it might operate also as a stand alone program to directly access the SDW; in the latter case no geographic queries are possible. In a further stage EPM will be made up of a unique software integrating main functions of module (i) to those of (ii). EPM prototype is under development and it will be tested using a case study. In this way the design and content limits will be highlighted and, consequently, a final release of the software will be issued.

Figure 2 – Example of section organization in EPM software



4. Conclusions

Starting from the experience at issue, GIS-based software tool might support emergency managers in finding the appropriate information for acting procedures to cope with industrial hazards. Particularly, in this paper the EPM software has been presented as an intermediate technical tool for selecting useful data within a bunch of information, as well as to meta-connections among them. It allows to get punctual information regarding the hazardous, vulnerable and exposure factors that characterize the area involved in a current emergency. This local factors can refer both quantitative and qualitative characteristics on which possible immediate and delayed damages might depend. For this reason, EPM could be of support for risk prevention, especially for

land use planning in risky areas; in fact, it allows to collect graphic representations and digital DBs including information about both industrial plant, natural environment, and society.
Furthermore, the use of technological tools highlights which level of emergency preparedness is needed to facilitate the technical and organizational activities during the emergency response. While a considerable effort is required initially for collecting data, the information can be used repeatedly, once it has been discovered and catalogued. In fact, information management through GIS-based software can improve emergency preparedness by sharing and integrating available knowledge. Nevertheless, it is important to recognize that information is socially constructed, as it depends on decisions and choices, themselves influenced by institutional and political contexts. Because of this, it is important to capture the community experiences acquired during real emergencies, simulations and training programs, and to introduce them in an organized structure of information (reception centre registrations, emergency services call data, survivor interviews).

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