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Proposal of a Reference Geo-database to Support Safety Tasks Involving the Land Context of Seveso Establishments

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The paper describes the geo-spatial database developed to manage geospatial data necessary to describe the technological safety of the land surrounding a "Seveso" establishment. The work was part of a project having the environmental conditions of the Terni area (central Italy) as target. The contents and structure of the database can be considered of general validity, as core of a Geographic Information System aimed at managing, displaying and delivering key geographic information needed for those safety tasks descending from the Seveso regulation, that involve the land outside the perimeter of the establishment. Consequences analysis, compatibility assessment, Na-Tech risk assessment, land use planning, external emergency planning, global area risk evaluation strongly rely on geo-spatial information, and their products should be fully correlated. The increasing use of realistic simulation models and of maps as means to present results, as well as the need to effectively disseminate information to population, address towards searching approaches to make a set of reliable and up-dated geo-spatial data, specifically focused on land technological safety, widely available.

1. Introduction

Many aspects of the Seveso European Directives imply a good knowledge of the spatial relationships between the establishment capable of causing major accidents and the surrounding land. Consequences analysis, compatibility assessment, "Na-Tech" (Natural event-triggered Technological accidents) risk assessment, land use planning, external emergency planning, global area safety risk evaluation, as well as dissemination of information to people, are tasks descending from the Seveso regulation that strongly rely on geo-spatial information, particularly when possible effects of the accident involve areas outside the plant perimeter.

Use of maps is explicitly stressed in the 2003/105/EC Directive (EC, 2003) where it is stated that the Safety Report shall include the "Assessment of the extent and severity of the consequences of identified major accidents including maps, images or, as appropriate, equivalent descriptions, showing areas which are liable to be affected by such accidents arising from the establishment".

Spatial data are also needed to constraint realistic simulation models for consequence analysis, and to contextualize results of risk analysis and area risk studies. Indeed, software applications for risk analysis support geographic information at different levels, from the simple display of a reference map to fully GIS-based algorithms – e.g. ARIPAR-GIS (Egidi et al., 1995) or Risk Curves (TNO, 2008).

But, despite of the availability of suitable tools to exploit spatial information, difficulties are often found when feeding the models with the geographic information of interest. In fact, it is hard, for non specialists, to identify, choose and use the right spatial information in the huge amount available, and

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searching and extracting useful information is a time- and means-waste activity. Similarly, obtaining an up-dated and good quality representation of the relevant land parameters to be included in the safety report can be difficult, with the result of non-reliable or non-coherent documentation (e.g. among establishment located in high concentration sites).

This problem is shared by many communities committed in tasks involving the analysis of environmental variables: it gave origin to the 2007/2/EC Directive (EC, 2007) establishing an Infrastructure for Spatial Information in the European Community (INSPIRE), which purpose is to provide measures to "address exchange, sharing, access and use of interoperable spatial data and spatial data services across the various levels of public authority and across different sectors." to "assist policy-making in relation to policies and activities that may have a direct or indirect impact on the environment." The INSPIRE Directive was implemented in Italy in 2010 (D.Lgs., 2010), and the National Cartographic Geoportal managed by the Italian Ministry of Environment and protection of Land and Sea is the reference point of the Italian infrastructure.

However, a "general purpose" database does not solve highlighted problems, also because needed information (mainly great scale, thematic information) is not yet included in the general repository. As a contribute to fulfill the above quoted issues, the Italian Ministry of Environment, through its research Institute ISPRA, has developed an integrated Information System (ARIA334 – ARIR) (Astorri et al., 2006; Ricchiuti et al., 2007) encompassing all alphanumeric and cartographic information regarding the Seveso establishments and the main parameters involved in the consequences of a possible accident.

The ISPRA database is mainly focused on the establishments: only base maps are provided for the surroundings (ortho-photos, digital elevation model, hydrographic and roads networks, etc.). The system is distributed to Regional Environmental Agencies with the aim of having a common reference that each local authority can integrate with features needed for specific issues (e.g. emergency plans, land-urban planning).

Starting from the above considerations, and with the objective of promoting a rigorous geo-spatial approach, we have conceived the idea of providing all subjects involved in evaluation, management and communication of technological safety (plant managers, risk specialists, population), with a general reference to extract information from, and with a basic framework where to add more specialized information for specific tasks. This could be done through the shared availability of a set of reliable and pre-selected data, mostly oriented to information concerning the land surrounding a Seveso establishment. In fact, rarely thematic maps are created on purpose for industrial safety analysis tasks, and the use of available data involves a considerable pre-processing, including selection of the source, evaluation of quality and resolution, extraction of the information of interest, transformation of geographic reference, format change, etc.

The work is part of a project funded by the Italian Ministry of Health (PMS/32/04), aimed at finding digital tools to support characterization of the environmental conditions of a strongly industrialized area (Terni, central Italy). In this framework, an inventory of the geo-spatial information necessary to describe the technological safety of the land surrounding a Seveso establishment was carried out.

Information retrieved was organized in a geo-spatial database able to archive and manage spatial and alphanumeric data. The contents and structure of the database are presented in the next chapters: they can be considered of general validity, as core of a Geographic Information System (GIS) focused on the theme of technological safety, having the areas surrounding Seveso plants as a domain. The system is aimed at managing, displaying and delivering key geographic information needed for those safety tasks descending from the “Seveso” regulation, that involve the land outside the perimeter of the establishment.

2. The data-model and the geo-spatial database

The core of the GIS is a relational database containing an *ad hoc* archive of pre-selected, pre-processed geospatial datasets.

The starting point to its creation was the identification of relevant thematic information. Themes were identified mainly analyzing law requirements by a "spatial" point of view. Needed information is largely defined in the technical sections of the Italian "Seveso" regulation (D.Lgs., 1999; D.M., 2001; D.P.C.M., 1989; D.P.C.M., 2005), where factors to be taken into account to estimate risk and to plan land use and emergency are listed. Among them, we selected information having dominant geographic significance, as a geographic reference or as a factor affecting the spatial distribution of risk (in terms of hazard or vulnerability). The second driving criteria of selection was the purpose of obtaining a simple, multi-purpose group of themes, available throughout Italy, still containing the detailed information needed for the tasks.

Next step was the definition of the data model, that is characteristics and organization of the datasets conveying each information theme. It included the definition, theme by theme, of the model of spatial representation (vector/raster), of the alphanumeric dataset to be associated to spatial features, of the spatial extent and spatial resolution, of the relationships to be set among datasets. Suitable spatial resolution strongly depends on the scale to which data will be used. Different scales of analysis are expected, and the resolution will vary for different datasets. Reference scales for maps are defined by law. Accordingly, the minimum scale of representation was set to 1:25,000 but the minimum detail of data was set to correspond to the scale of 1:10,000 whenever possible. The maximum scale was set to 1:1000. At larger scales, the area that can be shown in a map is usually inside the perimeter of the plant, and the elements reported with sufficient detail are its facilities and structures. Consequently, at scales larger than 1:1000, only events having consequences contained into the plant boundary can be shown and the absolute (geographic) position of objects is no more relevant to analysis: a CAD system and the CAD maps provided by the plant managers could directly be used at that scales.

As for the spatial extent of the datasets, the legislation provides an extension of at least 5 km around the plant to be considered. In areas where there is a high concentration of industrial plants, we considered a buffer of 5 km enveloping all the installations. An exception to the above rules is required for datasets concerning natural hazards that can trigger a Na-tech event: in some cases the natural event can originate at a greater distance, so greater extents are usually required to account for them.

On the basis of the defined characteristics, a survey of available datasets was carried out for each theme, to select the best source in terms of compliance to requirements, reliability and availability. Free resources from the National Cartographic repository or from official sources were chosen whenever possible. Often, the information of interest has to be extracted by selection and/or generalization from complex datasets created for different tasks (e.g. urban planning datasets): the processing steps required to extract and format the needed information from the original sources were defined for each dataset, in order to provide the dataset in a readily exploitable form.

Table 1 reports the conceptual outline of the geo-database, showing the datasets grouped according to the kind of thematic information they convey. For each dataset, the selected data source is also listed. As above quoted, sources are mostly Italian public datasets, in some cases available from national organizations for the whole country, in other cases (detailed information) from local authorities. Most data are free. The main dataset that comes with a cost is the high resolution remote sensing image. Other alternatives are the orthophotos available at the National Cartographic Geoportal (poor updating rate) or Google Earth: the main limitation to the latter is the not uniform positional quality of Google Earth imagery that may be unacceptable at largest working scales.

The "Cartography" and "Morphology" groups collect datasets that serve as geographic reference. The Digital Elevation Model allows 3D viewing and navigation of the data using GIS tools.

The datasets under "Hazard Sources" convey detailed information about the plant extracted from Safety Reports or from the information to population. It can be retrieved from the safety documentation of the establishment, but its distribution is obviously restricted. Data are organized in vector points with alphanumeric data associated and logically related to general information about the plant.

The groups "Land Vulnerability" and "Environmental Vulnerability" contain the distribution and characteristics of features likely to undergo damage from a possible industrial accident. The first one includes structures and infrastructures, facilities and population; the latter, environmental features/variables. Many of these features are part of the complex datasets of local land/urban plans: their extraction is often quite laborious since many of these map documents do not conform to a modern geo-spatial - GIS approach. The datasets grouped under "Natural risks" allow for Na-tech events to be accounted for. A group named "Analysis, risk estimates" is prepared to collect typical outputs of the analyses that can be carried out on the data.

Table 1: Conceptual outline of the Geo-database

THEME	*DATASET*	*DATA SOURCES*
Cartography	Study domain	
	High resol. Remote Sensing image	IKONOS, Quickbird (orthorect. + pan-sharp.)
	Technical Num. Regional Map 1:5000 or 1:10,000 (CTRN)	Regional Administrative Unit Offices
	Cadastral maps 1:2000	Cadastral local offices
	Administrative boundaries	ISTAT (Nat. Inst. for Statistics)
	Main hydrographic network	DBPrior (National DB of local base maps)
	Detailed road network	DBPrior (National DB of local base maps)
	Detailed railway network	DBPrior (National DB of local base maps)
	Main industrial plants (polygons + data)	CTRN, Municip. Land Plans, RS, Min. for Env., Nat. Inst. for Env. Protect.
Morphology	High resol. Digital Elevation Model - >=20 m	Geography Office of It. Army, Regional Admin. Unit Offices
Hazard sources	CAD plans of hazardous plants	Plant Safety Documents
	Top events + scenarios, damage iso-distances	Plant Safety Documents
Land Vulnerability	Commercial/industrial Land Use	Municipality and District Land Plans
	Residential Land Use	Municipality and District Land Plans
	Restricted mobility people sites	Municipality and District Land Plans
	Places subject to crowding (closed and open-air)	Municipality and District Land Plans
	Transport interchange nodes (Rail stations, Airports, etc.)	Municipality and District Land Plans, DBPrior
	Main road network	DBPrior (National DB of local base maps)
	Main railway network	DBPrior (National DB of local base maps)
	Plant employees amount and distribution	ISTAT (Nat. Inst. For Statistics), Plant Safety Documents
	Population amount and distribution	ISTAT (Nat. Inst. For Statistics)
Environment Vulnerability	Detailed hydrographic network	DBPrior (National DB of local base maps)
	Aquifers vulnerability	Cartography of local administrative offices
	Wells for drinking, industrial, irrigating tasks	Cartography of local administrative offices
	Aquifer recharge areas	Cartography of local administrative offices
	Valuable agricolture, Forests, Humid, Protected areas	Municipality and District Land Plans
	Landscape and cultural heritage	Municipality and District Land Plans
	Protected areas (natural areas, parks)	Cartography of local administrative offices
Natural Risks	Seismic risk	Civil Protection
	Volcanic risk	Nat. Inst. of Geophysics, Civil Protection, "Region" Admin. Offices
	Hydrogeologic risk (floods, landslides)	Local admin. offices, Hydrographic basin manag. Authorities
	Meteorological statistics	Local administrative offices
Analysis, Risk estimates	Damage iso-areas	Can be obtained with GIS functions
	Land and Environ. Compatibility maps	Can be obtained with GIS functions
	Individual risk	Can be obtained with GIS functions
	Social risk	Imported in GIS after model calculation
	Dangerous substances transport. risk	Imported in GIS after model calculation
	Emergency sites (Civil protection)	Municipality and District Land Plans

3. Outlines of the GIS application

The database is designed to be consumed by a GIS application that can be used to navigate and query the data, to extract sub-datasets to be given as input to simulation models, to add specific datasets, to display outputs of models, to perform spatial analyses and save results as new derived datasets that can be exchanged among users.
In the future, it is planned to create a GIS-client application to be distributed to stakeholders, that will consume the data contained in the geo-database as remote OGC (Open Geospatial Consortium) compatible services (WFS, WCS; WMS). Coherently with the INSPIRE intentions, datasets available as service from the original distributor will be accessed directly from the source, the others via a dedicated GIS web server.
To design the architecture of the future GIS-client application, a standard GIS desktop software (ESRI ARCGIS Desktop (ESRI, 2011)) has been used as test-bench. In this environment, the following features were defined:

- Cartographic reference system for display and maps: the standard will be the UTM projection - zones 32 and 33 (encompassing Italy) based on the WGS84 datum. All datasets are planned to be transformed to that reference, in order to make spatial consistence of data simpler.
- Reference (maximum and minimum) scales of display: as stated above, the range is 1:1000 - 1:25,000.
- Implementation of some customized tools:
  - a Function of graphical query of pre-existing alphanumeric ACCESS databases: clicking the feature representing the outline of a plant ("Main industrial plants" dataset) opens an external database (already available at the Department) containing information about the plant, in turn connected to an application showing graphically its facilities (Figure 1). This creates a seamless flux of increasing detail of information from the land context of a plant to the single plant units.
  - b Tool for automatic tracing of damage areas from the attribute containing the damage distances (Figure 1).

4. The Terni case study

The GIS was built up as a prototype for the Terni industrial area, filling the template geo-database with real data for the area and information about a "Seveso" establishment as a sample.
The remote sensing image was obtained from IKONOS (GeoEye, 2011) data acquired on purpose, pre-processed to increase the detail and to accurately georeference it. Most information concerning vulnerability was retrieved from the Municipality and District Land Plans (PRG, PTCP) encompassing the area of interest. Figure 1 shows an example of information accessible in the GIS.

5. Discussion and conclusions

A geo-database and a Geographic Information System were designed, focusing on the geo-spatial data needed for technological safety analysis and communication tasks, having the surroundings of Seveso establishments as a domain. The GIS was populated with data for the area of Terni (central Italy), but contents and structure of the database are of general validity.
The goal is to provide, via web and for the main "Seveso" sites, a basic but homogeneous reference containing only pertaining data, to be used as a common framework to manage the geographical aspects of safety analysis of a region. This will led to harmonized and interoperable products that could make the collaborative work easier. In fact, the lack of a uniform and shared geographic language and of common references for matter-specific geo-information hampers information transfer and exchange: each entity involved in Seveso regulation execution should be able to read, verify and integrate with own data, information produced by the others, in order to reach coherent and harmonized results.
A web map display system is also a very immediate and impressive way to report factors affecting the risk level of an area, so it can also be devised as a media to communicate and deliver information on safety to population, as requested by the European regulation.
For now the database is designed as a standalone system, where pre-processed copies of maps and geospatial data are managed and served by one server. However, in compliance with the concepts

promoted by the INSPIRE Directive and with the current web technology tendencies, the geo-database could evolve in a "data infrastructure" made up of a cloud of remote databases at the data owners: items in the database will be links to corresponding data services. As an example, the items concerning the establishments could be substituted by the largely more accurate and complete contents of the geo-alphanumeric database of Seveso plants owned by ISPRA (Astorri et al., 2006). The parts concerning high resolution data about the land context of the plant, can be managed directly by local (regional) agencies. The database structure, organization and characteristics will be preserved: they will act both as a unique front-end presentation of the map server and as a guideline for data to be served by the remote databases, in order to obtain uniform interface and uniform datasets across the country. Local and central authorities, risk specialists, plant managers and population could apply the same repository for basic geo-spatial data, obtaining a uniform, accurate geographic language to be used across the "Seveso" stakeholders community.
Management of sensitive data concerning the establishments is a very important issue consequent to the wide spectrum of users devised for the system: data dissemination and access policies have to be carefully planned and implemented.

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