

Database design and GIS application in brownfields management: the case of Torviscosa site, Italy

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Abstract

This study concern the preparation of a spatial database serviceable to the management of brownfields remediation, particularly for planning of activities, collection of subsurface data and for detailing the site conditions to a technical consulting and administrative authority. The study site, owned by Caffaro SpA, is located in Torviscosa (Udine, Italy); the industrial plants of Torviscosa have been established by the company SNIA in 1938. The large extension, importance and complexity of the site demanded a set of tools to analyse geographical data coming from various sources, in an efficient way. The database includes auxiliary data coming from geotechnical and field tests performed during the investigation phase, in order to define a detailed soil profile of the site. The GIS system used to manage the data is ARCGIS™ by ESRI™ with the extension required for geostatistical, vector and raster analyses. The designed geodatabase (in Microsoft™ Access format) contains different feature classes and tables relative to the modelled entities. All the system has been conceived and designed in order to have a reliable, comprehensive and user friendly tool to manage all the assessment, characterisation, decommissioning and clean-up operations of a huge industrial area, and to allow the full control and information exchange at any time of a presumably long duration project.

Keywords: GIS, database, DBMS, archive, brownfields, Arcgis™, Oracle™.



1 Introduction and scope of the work

This study concern the preparation of a spatial database (Geographic Information System, GIS) [1], [2], [3] serviceable to the management of brownfields remediation. The aim of the work is particularly focused to the establishment of a tool for planning of activities, collection of subsurface data and for detailing the site condition to technical consulting and administrative authority. The study site, owned by Caffaro SpA, is located in Torviscosa (Udine, Italy). The industrial plants of Torviscosa has been established by the company SNIA in 1938 an initially devoted to the production cellulose as primary component for synthetic fiber (see Figure1 for an aerial view of the industrial site). During the following decades the plants have been revamped in order to produce primary base and specialized chemicals. Currently the site can be seen as a cluster of different chemicals plants which products span from the base chemical field to intermediate products for fine chemistry. The large extension, importance and complexity of the site clearly demanded for a set of tools to analyse geographical data coming from various sources, in an efficient way. In order to establish a clean-up plan for the area, an extensive site characterisation plan has been prepared by the Management of the Caffaro Group with the co-operation of Studio Geotecnico Italiano. This latter site investigation plan has been issued according to the guideline of the Italian law in force (with particular reference to the D.M. 471/99), collecting all the available information regarding the industrial processes, industrial plants characteristics (working or not working) and the localisation of chemicals produced during the entire life of the factory. In order to accomplish the design stages described below, the characterisation plans have been analysed in details. The flows of activities has been organized according the following steps [4]: A) Database design; B) conceptual, logical and physical design of data base; C) Software development; D) Input data; E) Editing data and definition of standard procedure for analysis and mapping.



Figure 1: General view of the Torviscosa industrial site.



1.1 Data base design: conceptual design

The conceptual modelling allowed for a definition of an entities set which represent the most important feature of the data base. Throughout the development of an entities-relationship model, the entities have been traduced to geographical features with appropriate informative attributes. The most important entities are investigations and samples, which record all the data coming from subsurface coring, and chemicals analysis carried out on the water and soils samples obtained. The database include auxiliary data coming from field and geotechnical laboratory tests performed during the investigation phase, in order to define a detailed soil profile of the site. The reference documents which represent the sources for database developments are listed in the following: 1) Characterization Plan relative to the factory site; 2) Characterization Plan to the waste deposits. 3) Characterization Plan relative to the filling areas. 4) Topographic surveys of the factory site. 5) Maps, images and aerial photographs. 6) Laws and rules (D.M. 471/99). Essentially, a Characterization Plan (CP) preparation is articulated in three main phases/parts: a) Gathering and organization of the existing data, also defined as historical data; b) Site Characterization and preliminary formulation of the general conceptual model relative to the potential contamination sources; c) Plan of further investigations. The characterization plan gathers the most important information relative to the chemical and geotechnical analysis already realized in the site. The designed database will not contain data referred to production or naturalistic features of the site. The efforts of the analysis conducted has been focused on the geographical feature which will allow for a spatial analysis between chemicals encountered in the samples and physical elements of the industrial plants as equipments, waste areas, tanks, deposits, etc.

1.1.1 Peculiar of requisitions

The requisitions analysis of the data base is a result of a detailed analysis of the existing documentation, i.e. the cited characterization plan (in the following denoted as CP). The CP allows one to define the entities of the data base and their functional and/or spatial relationships. This entity represents in other words the “characters” of the database with their specific geometry, position, behaviour and informative and spatial-temporal attributes. For instances, the spatial extension of the site is defined not exactly coincident to the physical extent of the industrial plant, but it is enlarged up to consider the whole polluted area. For every site the data relative to the carried out investigations are collected and integrated to the topographic survey. Every investigation can be seen as composed by: a) sampling of soils and fluids to be analysed in terms of chemicals and geotechnical characters. In the chemicals analysis the verification respect to the limit concentration (admitted according to the current laws) is regularly performed; b) daily or monthly measurements of groundwater; c) on site measurements of the permeability and soil tests; d) GPS positioning and detailed topographic survey; e) stratigraphy of subsurface geology; f) Collection, description and cataloguing of the soils coring results. In order to establish a Geographic Information System, the positional information (i.e. georeferencing



aspects) of the entities has been deeply analyzed and defined. In the following the most important entities of the data base are listed as a selection of the most peculiar features among more than one hundred entities on which the data base is focused on (the complete list of such entities is supplied in database reports).

SITE, defined as the spatial extension of environmental interest on which characteristics and properties are known and defined in the PC. Every site own its geographic location within an optional administrative boundary (a county, for instance). For every site, a set of aerial photograph or simple photo are included in the database with topographic surveys eventually accomplished with on site GPS measurements. Every site contains investigations (chemical, geo-chemical, geotechnical) realized or not. Every site can be considered as a set of geographical features (polygon) within a geographical database, with appropriate shape attribute as area and coordinates.

INVESTIGATION, as any analysis, sampling o borehole conducted within the PC. All the investigations belonging to the site area catalogued according to PC prescription and sub-plane indication (for instance, preliminary plane investigations -PIP investigations -). For any investigations, a location in an official map is contemplated; generally every investigations will be modeled as a simple geographical feature (point) with given x,y,z coordinates. Some investigations will be used for measurement of the water table; other investigations will be employed in site permeability or geotechnical tests. When the investigations surround a collection of soil cores, this latter are catalogued in cataloguer boxes. The samples are carried out from the investigations, and chemical and geotechnical analysis carried out on them. Each investigation is stored in the database accomplished with a set of information reported in the so called "Investigation Card".

SAMPLE, intended as any substance collected during an investigation, despite of its form, dimension, volume and the type of collected material. General information regarding the samples are collected in the so called "Sampling Card". A sample can be submitted to the laboratory for chemical and geotechnical test². In the case of chemical analysis, the results of test are inserted by the laboratory in a file (so called "Chemicals Card") which is directly imported in the geodatabase. The "Chemicals Card" report general parameters like normative concentration or borderline limits. In case the of geotechnical test conducted on the sample a so called "Geotechnical Card" is filled with the information contained in the report of the geotechnical tests performed on the sample.

CHEMICAL BIBLIOGRAPHY, which collects all the chemical encountered in the samples analysis, classified with their complete names and optional C.A.S. number (if available).

HORIZON, as the lithologic horizons encountered in the sampling and coring of the subsurface geology.

HYDROGEOLOGICAL UNIT, defined within the site area and correlable to the permeability value measured in the permeability tests.

POLLUTER, as substances o compounds which can pollute a defined area.



POLLUTING PONTENTIALLY AREA, defined according to the historical information available a set of polluting potentially area are defined. These areas are characterized by the presence of the chemicals produced, stored or wasted. All the entities (site, site area, Characterization Plan, Locality etc) constitute the geodatabase™ in terms of geographic features that (see below). After the requisition of the entities definition, and relative specifications, the design of the database has been carried out following the entity relationship schema. The Entity-Relationship schema (in the follows E-R schema), has been designed through CASE (Computer Aided Software Engineering) instruments as Oracle Designer™. Being the most important feature of the database Site, Investigations, Samples, Analysis, the first rough E-R schema will consist only in a simple schema regarding this entities (see Fig. 2). The definition of a complete scheme with the full list of attribute and values has been reached gradually extending the initial simple schema. In the follows an example of the over mentioned procedure is described by means of the working flow for the section of the data base relative to the SITE, INVESTIGATION, SAMPLES and PC. These entities are tied each other according to spatial, informative and logical operation; the analysis of the connections between the mentioned entities leads to the elaboration of a complete data base conceptual schema. In Figure 2 is represented the ER Skeleton Schema relative to the relationships between SITE-INVESTIGATION-SAMPLES-PC.

Each SITE is defined by the following informative attribute (database fields; the original name in Italian language is preserved): a) COD_SITO, alphanumeric code specific for the site; b) RAG_SOC, alphanumeric value related to the administrative asset and trademark of the site owner; c) ATTIVITA', alphanumeric value related to the company mission.

Each AMMIN will be defined by the following informative attributes: a) COD_ISTAT, alphanumeric code registering the information of Region-County-Municipality where the Site is placed; b) N_REGIONE, name of the Region where the Site is Placed (for instance, Friuli Venezia Giulia; c) N_PROVINCIA, name of the County where the Site is Placed (for instance, Udine); d) N_COMUNE, name of the Municipality where the Site is Placed (for instance, Udine).

The CHARACTERIZATION PLANE (PC) will be defined by the following informative attributes: a) ZONA_PC, alphanumeric value indicating the zone of the site linked to the PC; b) PROC_PC, alphanumeric value indicating the procedure indicated by the law in force for the redaction of PC; c) RELATORE_PC, alphanumeric value indicating the reference designer of the PC (company or person); d) DATA_PUB_PC, the date of publication of PC; e) COMMESSA, an alphanumeric value indicating the order number; f) COD_EMISS, alphanumeric value indicating the internal code given to the document; g) N_ARCHIVE, alphanumeric value indicating the archive number of the document.

Each PLACEMENT will be defined by the informative attribute NOME_LOC, an alphanumeric value indicating the geographical name of the site.



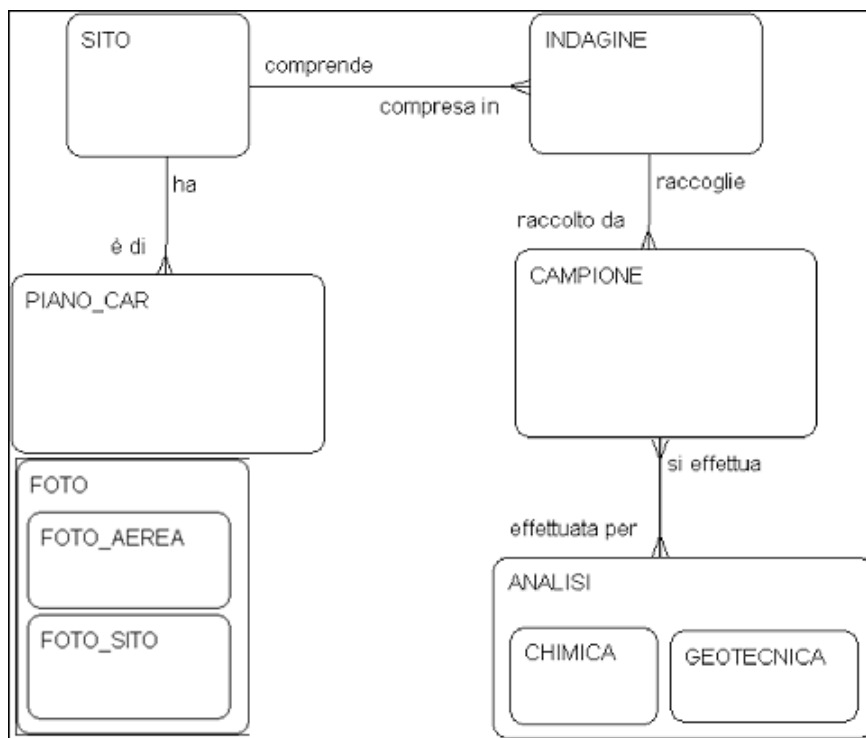


Figure 2: Skeleton schema relative to SITE. Key Ita.-Engl. sito= site; indagine= investigation; campione= sample; piano_car = characterization plan; analisi= analysis; chimica= chemical; geotecnica= geotechnical.

The definition of SITE stated it as the site of interest which is defined by the PC (characterization plan as defined before). For each site one can have different PC's according to the nature of the site and the different sector or zone which compose it. From a database rules point of view, this type of relationship is one (SITE) to many (PC's). Every SITE is extended onto several parcels that belong to a LOCATION, inside the administrative boundary. From this point of view the relationship between SITE and LOCATION is many (SITE) to many, (LOCATION) In other words, many SITE can include many LOCATIONS. The same relationship (one to many) exists between ADMINISTRATIVE BOUNDARY (for instances County) and LOCATION.

Other graphical documents can be related to each SITE (Figure 3): AERIAL_PHOTO, SITE_PHOTO, SKETCHES etc.

The relationship occurring between SITE and AERIAL_PHOTO will be many-to-many type, with optional participation of the SITE (the SITE can be depicted by many photographs and one photo can depict many sites).

The relationships occurring between CHARACTERIZATION PLANE (PC) and SITE_PHOTO, CHARACTERIZATION PLANE (PC) and SKETCH, CHARACTERIZATION PLANE (PC) and OTHER_DOCUMENTS will be one-to-many type with optional participation of the CHARACTERIZATION PLANE (PC). In this way the CHARACTERIZATION PLANE (PC) can include several pictures, tables, figures and sketches, etc, but all this documents belongs to only one PC.

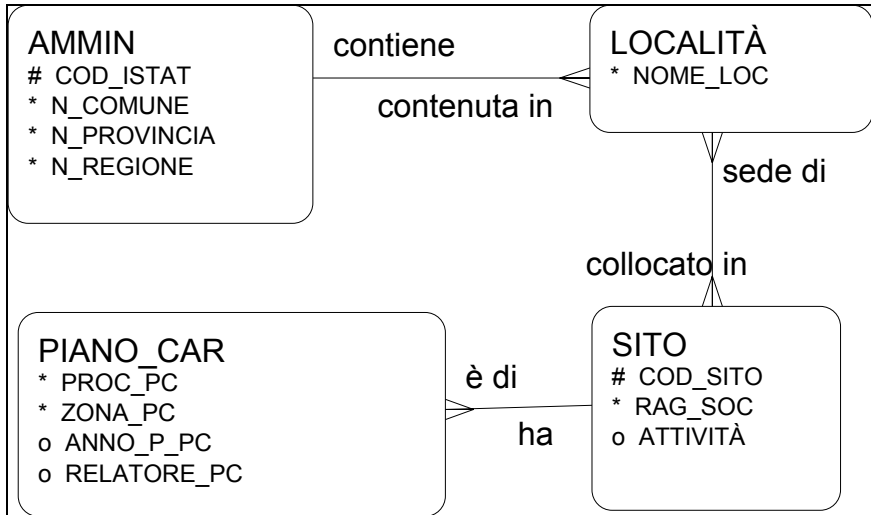


Figure 3: Preliminary enrichment of the SITE entity.

In Figure 4 a first version of the definitive conceptual scheme relative to SITE-INVESTIGATION, PC, LOCATION, AERIAL_PHOTO, PHOTO_SITE, SKETCH, OTHER_DOCUMENTS is presented. In the above example relative to SITE and other important entities as investigation, has been explained the realization of the conceptual schema for the brownfields of Torviscosa. A complete view of the Conceptual model is synthetically reported in Fig. 6. The other steps relative to logical and physical design of data base are a close consequence of the conceptual modeling and are driven by the chosen CASE tool (Oracle Designer™, [5]), and due to this reason will not be here described.

2 Software development

The software component of the whole informative system is split in two main parts: a) the application of commercial GIS system (ArcGis™,[6]), and it is relative to the managing spatial (georeferenced data) contained in a geodatabase™; b) a software for managing field data (investigations, samples, analyses, etc).



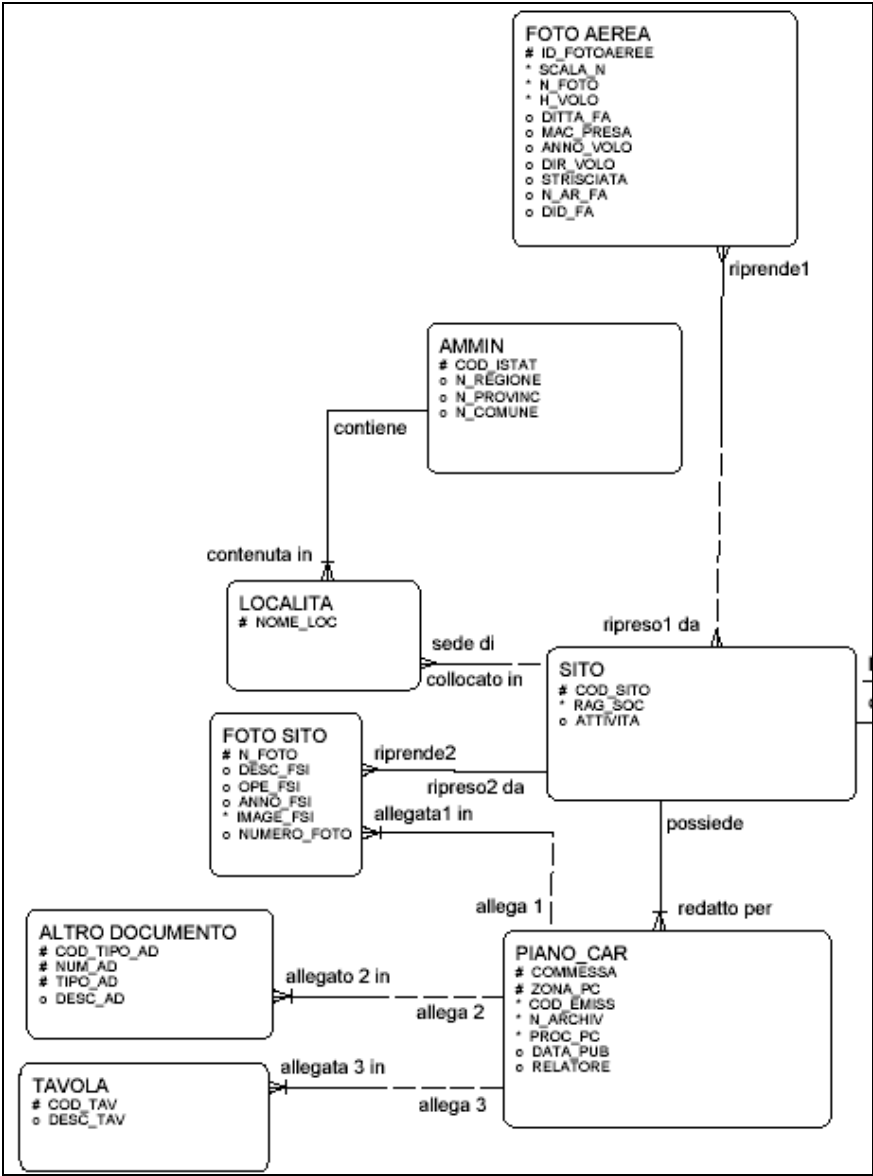


Figure 4: First sketch of definitive conceptual schema for the site.

2.1 The Geodatabase and the use of ARCGIST™

The database design phases described in the previous paragraphs allowed for a definition of a set of tables, values domains and procedures for loading , editing and elaborate data. The data management tables (either for geographic and not geographic data) have been defined inside the database, bye means of the



ARCGIS software tools. The geodatabase, on the personal version, is in the format of a Microsoft Access™_file where all the geographic data (with the geographic and informative component) and the database alphanumeric data are managed. This approach allows one to manage all data of a geographic and alphanumeric archive in a single file through the common and well known database rules. Besides the normal space analysis functions of the data, through the Geostatistical analysis tools one can calculate the maps of Probability distribution of the pollutants elements, applying the Rigging functions to the data resulting from the analyses on samples. Besides the Geostatistical analysis, some samples of 3D visualizations have been executed, allowing for the rebuilding of the three-dimensional space relationships between sampled zones and technical structures (plants, production zones, waste deposit, etc, see Figure 5).

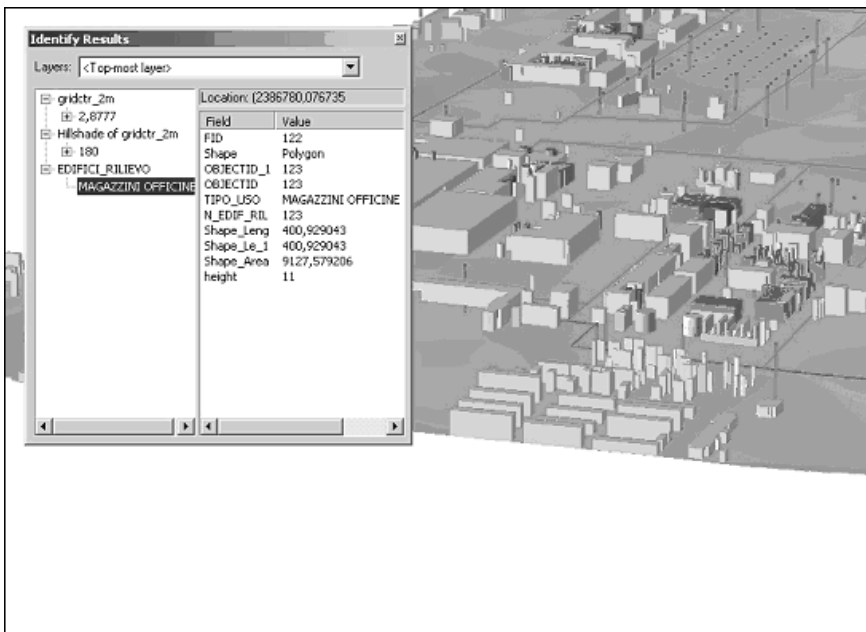


Figure 5: Distribution map of reservoirs, drillings and plan.

2.2 System devote to field data management

In order to simplify the collection, input, editing and recovery of data gathered from the chemical and geotechnical analyses, dedicated software has been developed. One of the requisites that drove the development of the software was the easy management of investigations, samples, and the analysis obtained from chemical laboratory. In particular, was required to the software to import directly the analyses data obtained from the laboratory by means of a substances and materials database, within a written protocol for the electronic transmission of data, allowing always a direct control by the user. Then, the database obtained

can be exported on the intranet permitting in that way the interaction from non-GIS workplaces, by means of a standard Windows™ interface for viewing and importing data. Stratigraphies of soil, obtained from sampling, are saved as image files in a pre-defined directory tree, directly accessible within explorer interface. As an example of software functionality, in Figure 6 and Figure 7 a set of screen captures obtained during the software utilization is presented. In particular, in Fig. 7 the main form show the fields for the management of site, investigation (either geographic or not) and sampling data. A view of the chemical analysis results is also shown, allowing for a fast exploring of such data. The investigation form allows, for the definition of the geographic localization of the entity, the method adopted and the design phase in which the investigation is enclosed (as an example in the characterization or remediation phase).

A set of ARCGIS™ macro will be developed in the near future in order to simplify the user effort during the ritual activities of data representation on screen and printing.

Figure 6: Form devoted to the exploring of chemical analysis results.

Figure 7: Sampling management form.

3 Conclusion

The use of a geographic informative system for the management of the brownfields represents an excellent system of record, analysis and reporting of the countless amount of data necessary to the editing of the plans for the placing in safety of the sites. All the system has been conceived and designed in order to have a reliable, comprehensive and user friendly tool for managing all assessment, characterisation, decommissioning and clean-up operation of a huge industrial area, and to allow the full control and information exchange at the any time of a presumably long duration project.

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