S.I.T.P.A.C.: The Territorial Information System of A Coruña

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Abstract

In this paper, it is presented the experience of the development of the E.I.E.L. application, a software system that allows the creation and exploitation of a huge database with alphanumeric and geographic information regarding local equipment and infrastructures of the municipalities of A Coruña province. Furthermore, it is shown how the E.I.E.L. application is integrated, together with already existing legacy software, into a general territorial information system (S.I.T.P.A.C), for the Provincial Council of A Coruña. The S.I.T.P.A.C. is a software layer that will provide such legacy systems with the ability to represent some of their entities in a geographic space, and, at the same time, with a more friendly user interface.

Keywords: Geographic Information Systems, Spatial Databases, Software Engineering, Legacy Software

1 INTRODUCTION

In this paper, the development experiences in the Databases Laboratory of the University of A Coruña of two geographic information systems for the Provincial Council of A Coruña are presented. The first system, the E.I.E.L project, is in phase of development, while the second one, S.I.T.P.A.C, is phase of analysis and design.

The aim of the E.I.E.L. project, as detailed below, is the creation of a huge database with both alphanumeric and geographic information regarding the infrastructures and equipment of the Province. Tasks included in the project are, therefore, the design and development of the applications needed for the creation of such database and the maintenance and exploitation of the data stored in it.

On the other hand, S.I.T.P.A.C aims for the integration of a wide data set through a geographic information system. Among the data that S.I.T.P.A.C will integrate, we found the database that the E.I.E.L project will create, and other already existing databases used by old business legacy applications. It must be emphasized that the goal is the integration of the alphanumeric data used by such legacy software with geographic references to their positions in a geographic space. Thus, for example, each apartment of the database of "*Impuestos sobre Bienes Inmuebles*", I.B.I. (taxes on immovable assets), will have among its data, besides the postal address already included, a geographic reference to its position on a map.

The goal of S.I.T.P.A.C is to keep the old software working, because such software is reliable and has been strictly tested for a long time. But at the same time, to provide these legacy systems with a graphic user interface, which makes easier tasks such as launching some processes or visualizing the retrieved information. On the other hand, S.I.T.P.A.C will work as a software layer that surrounds the existing applications, allowing the association of data that was isolated up to the moment. As an example, when an apartment is clicked on a map, it will be possible to visualize alphanumeric data coming from the I.B.I database, data about the occupants coming from the "*padrón*" (municipal register) database or data about the quality and kind of sewage treatment available coming from the E.I.E.L database.

S.I.T.P.A.C will allow maintaining and exploiting each one of the databases in the system. That is the reason why the applications for maintenance and exploitation of the E.I.E.L database are not considered and described as separate applications but subsumed into the structure of S.I.T.P.A.C.

The remainder of the paper is organized as follows. In section 2, a brief description of the reality of A Coruña province within the global administrative structure of Spain is presented. The E.I.E.L project is described in section 3, while its integration into S.I.T.P.A.C. is shown is section 4. Finally, the conclusions of our work are provided in section 5.

2 A CORUÑA PROVINCE DESCRIPTION

In order to introduce the reader in the situation of A Coruña province within the territorial and administrative structure of Spain, a brief description of the organization and division of the Spanish territory is provided in the present section. Furthermore, a short introduction to the reality of A Coruña province is also presented.

The Spanish territory is divided into 17 "*Comunidades autonomas*" (autonomous regions) and 2 "*Ciudades autonomas*" (autonomous cities). Each autonomous region is further divided into a set of provinces. The total number of provinces in Spain is 50. Each one of such provinces has a local administration that deals with the set of tasks that the Spanish administration has delegated at the level of province. The institution for provincial administration is called "*Diputación Provincial*" (Provincial Council). Each province is further divided into municipalities (counties). Again, each municipality has it own local administration that deals with the set of tasks delegated at its level. Such administrative subdivision allows the Spanish administration to provide the population with services at different levels. Thus, in the case of the road network, the Spanish administration is responsible of the national roads, provincial councils deal with provincial roads and the municipalities deal with municipal roads. The population of the municipalities is grouped into population centers. A population center must include at least 10 dwellings or more than 50 inhabitants.

For the scope of this paper, we are interested in A Coruña province, which is geographically located in the autonomous region of Galicia, at the northwest corner of the Iberian Peninsula. A Coruña has an extension of 7.951 km^2, divided into 94 municipalities, and a population, at the 1st of January of 1999, of 1.108.980 inhabitants, spread over more than 3500 population centers.

Regarding the set of tasks that are delegated at the level of each municipality, there is a heterogeneous situation in A Coruña province. Thus, there are some very populated municipalities that are capable to collect and manage its own information, while other rural and very sparsely populated municipalities must delegate such tasks to the Provincial Council. As an example, there are some municipalities that have staff and tools to produce their own urban planning, that is, to determine what building land is available and where to build is forbidden. Obviously, the urban planning has a clear influence on the development of new infrastructures, like roads, etc. Some big municipalities have a strict urban planning which leads to the development of multi-annual plans, while some rural small municipalities, without land management, simply use very general rules. A different example is the collecting of some taxes, which is directly managed in some big municipalities and delegated to the provincial council in small ones. As a conclusion, the functionality required from the information systems vary from one municipality to another. This characteristic has a deep implication in the design of S.I.T.P.A.C, as will be shown in section 4.

3 THE E. I. E. L. PROJECT

The "*Ministerio de Administraciones Publicas"*, M.A.P (Public Administration Ministry), requires every five years from each *Provincial Council* an inventory of the equipment and infrastructures of the municipalities of the province, together with their characteristics, condition, etc. In order to provide the M.A.P with such detailed information each *Provincial council* must perform the "*Encuesta de Infraestructura y Equipamientos Locales"* E.I.E.L (Local Infrastructure and Equipments Survey). To perform the survey it is necessary to send, all around the municipalities of the province, a big team of specialized experts to collect a huge amount of data about infrastructures and equipment.

The set of data required by the M. A. P. includes a huge amount of alphanumeric data and some predefined thematic maps, where the condition of several infrastructures and equipment can be visually recognized. An example is a thematic map where the color of each street stretch is determined by the value of its condition attributes. In order to achieve a homogeneous result for all the provinces, the M. A. P. provides each provincial council with a set of questionnaires to be filled with the results of the survey, together with instructions to guide the filling process. The task of the Provincial Council is to gather the data into the questionnaires and to store it into a database whose basic schema is also provided by the M. A. P.

The Provincial council of A Coruña decided to face the problem of the completion of the E. I. E. L. of the year 2000 through a two-year project with more ambitious objectives. More precisely:

- The amount of alphanumeric information to be collected from each municipality was extended.
- Furthermore, besides the alphanumeric data of each item, geographical references are also stored now.

The data model resulting from such extension is described in section 3.1.

For the realization of the project, an agreement was signed between the Provincial Council of A Coruña and the University of A Coruña, by the mean of which this university is in charge of the both process of data collection and the development of the geographic information system that simplifies the management of such huge amount of alphanumeric and geographic data.

In order to collect the data, three different groups of experts, specialized in water cycle, infrastructures and equipment, respectively, were made. Each one of these three groups is currently visiting the different municipalities, collecting the real data by interviewing the respective responsible staff in the municipality or by direct observation. According to the previous three groups of experts, the set of data to be collected was classified into the following three kinds:

- *Water cycle information* (from water collecting to sewage disposal and treatment): It includes information about the characteristics, condition, types, quality, etc. of water sources, water pipes, water distribution networks, water tanks, waterworks, hydrants, fire hydrants, springs, pumping stations, sewage pipes, sewage treatment plants, etc. Furthermore, the quality of the water supplying and sewage disposal systems is measured at the level of population center.
- *Infrastructures*. It includes information about the characteristics, condition, types, quality, etc. of the road networks, electricity networks, power stations, transformers, gas networks, telephone networks, street networks, streetlamps, sidewalks, urban planning, garbage collecting systems, etc. Information about some of such infrastructures is collected at the level of province (provincial, autonomic and national roads, etc.), some is collected at municipal level (municipal roads, etc.) and some at the level of population center (streets, sidewalks, etc).
- *Equipment*: It includes information about the characteristics, condition, types, quality, etc. of sport facilities, markets, hospitals, educational institutes, slaughterhouses, cemeteries, fish markets, churches, town halls, cultural centers, morgues, hotels, parks, street markets, fire stations, etc. Information about equipment is collected at the level of population center.

A fourth group of Cartography experts deals with the manipulation of the digital cartography.

Our work involves the design and development of the applications needed to store the data (both alphanumeric and geographic) and to maintain and exploit the final database. That is, our work was the realization of all the necessary tasks to develop the whole geographic information system. Such set of tasks is described in section 3.2.

3.1 E.I.E.L Data Model

We describe in this section the data model for the EIEL database in order to provide an insight into the nature and amount of data that are stored. We use E-R diagrams that are explained in Sections 3.1.1 to 3.1.4, but some remarks must be given before entering in more detail.

Since the EIEL project surveys only municipalities with less than 50000 inhabitants[1], there might be (and actually are) infrastructures and equipment that are not surveyed because they are placed in one of those *non surveyed* municipalities. Nonetheless, these elements might render a service to a population center in a neighboring surveyed municipality. Therefore, it is necessary to distinguish between surveyed and non-surveyed elements. The first ones have the full set of data, whereas, of the second ones, only its existence is known. We represent this in the data model by using the notation of specification (a relationship where a small circle takes the place of the rhomb).

Due to the size of the data model, we have tried not to display it in its full extent. Rather, we have tried to find similarities among the entities in the model, regarding the relationships they have with some central entities. Once we identify these similarities, instead of presenting all the tedious details, we describe the general behavior using a template that can be instantiated with the actual entities to build the data model. As an example, we present in Figure 1 how dumping sites and sewage treatment plants are modeled. On the left side of the figure, we can see the entities for municipalities and surveyed municipalities. On the right side, the entities *Population Center* and *Surveyed Population Center* are placed. The entities for dumping sites (*Dumping Site* and *Surveyed Dumping Site*) can be found in the top of the figure, whereas the entities for sewage treatment plants (*Sewage Treatment*

[1] Municipalities with more than 50000 inhabitants deal directly with the Central Government instead of the Provincial Council.

Plant and *Surveyed Sewage Treatment Plant*) are placed in the bottom of the figure. It can be easily seen that the relationships *has* and *serves* are similar for the case of dumping sites and the case of sewage treatment plants. Thus, instead of displaying an E-R model that depicts the whole set of entities, we use a template to describe common configurations, and then enumerate the entities that are used with the template so that the E-R model remains small. The templates we use can be seen in figures 4 and 5 (sections 3.1.3 and 3.1.4).

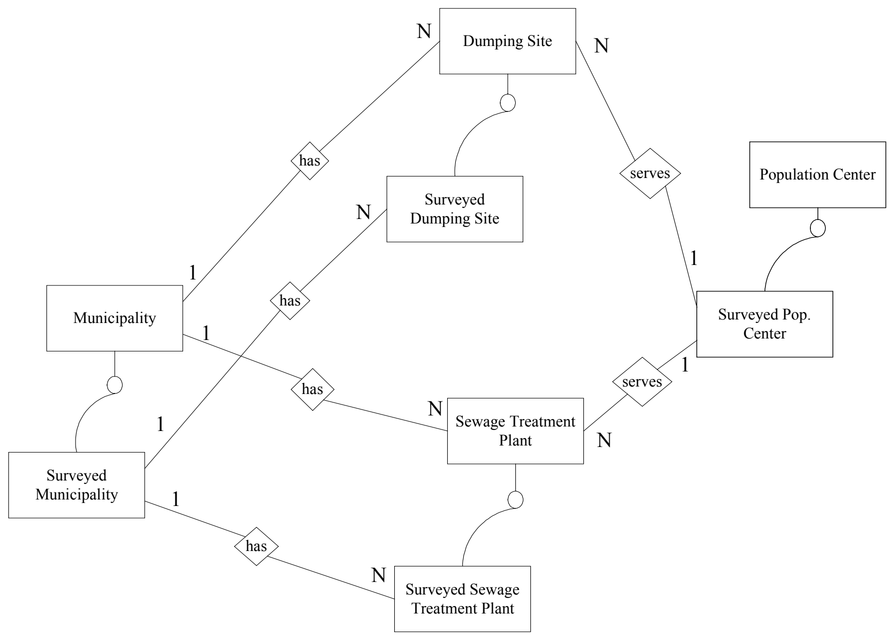

Figure 1 Similarities in the treatment of the entities *Dumping Site* and *Sewage Treatment Plant*.

We have used an attribute named *geometry* to mark each entity that has a geographic object. This is only done when the entity is described, not in all the diagrams. The actual type of the geographic object is detailed in the text when the entity is described, using the following types:

- *Point.* A single point in the Euclidean plane. Used to store the position of an object.
- *Points.* A collection of *point* values, used to represent the position of a set of objects without information for each individual.
- *Line.* A collection of line segments, used to describe a network.
- *Region.* A collection of polygons with (optional) holes, used to represent surfaces.

Following this strategy, the data model of the EIEL database can be split into four different categories, namely:

- Territorial structure, collaboration relationships and urban planning,
- road network,
- water cycle and dumping sites,
- and equipment.

We describe in the following sections these categories, giving for each of them an E-R diagram with a partial view of the data model there. The central entities that connect all the diagrams are population centers and municipalities.

3.1.1 Territorial structure, collaboration relationships and urban planning

This category comprises the entities that describe the administrative division of Spain, together with the collaboration relationships between municipalities, and the urban planning for those municipalities that have one. The E-R diagram for this section of the data model can be seen in Figure 2.

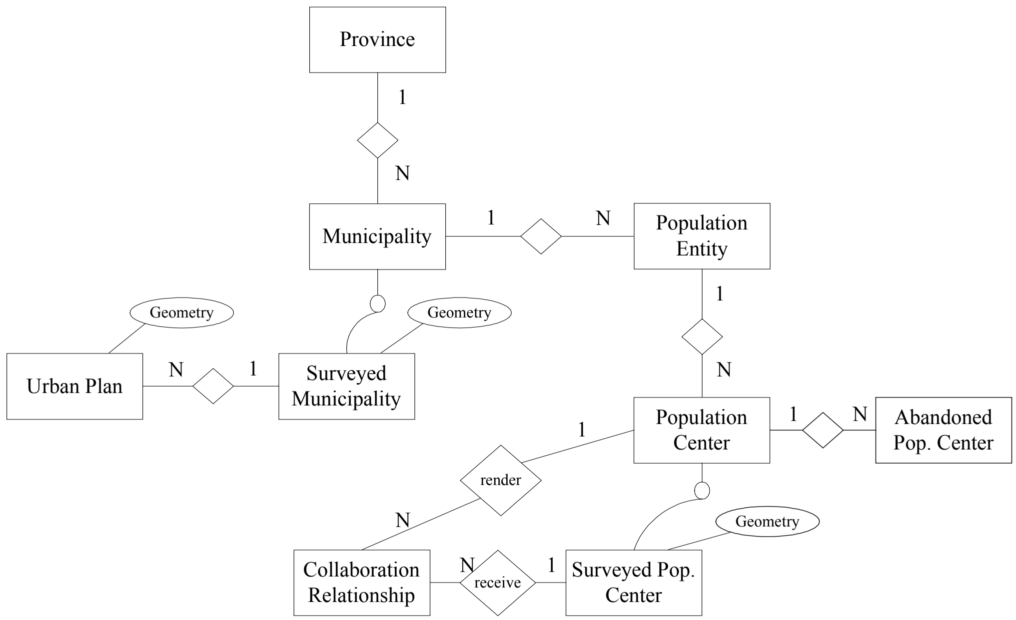

Figure 2: E-R model for the territorial structure, collaboration relationships, and urban planning.

These entities store information that is surveyed at the level of municipality and population center without entering in details regarding the equipment or infrastructure being surveyed. This includes:

- *Demographic information.* Inhabitants, both seasonal and resident, housing and hotel availability.
- *Urban planning.* Scope of the planning and details regarding each type of soil, in particular the surface of the municipality dedicated to that usage as a *region* value.
- *Water supply.* Scope, availability, state, and deficit.
- *Autonomous water supply.* Scope and state.
- *Water disposal.* Scope, availability, state, and deficit.
- *Autonomous water disposal.* Scope and state.
- *Radio and TV reception quality.*
- *Quality of gas and power supply.*
- *Geographic information.* The boundary of each surveyed population center as a *region* value, and the boundary of each surveyed municipality as a region.

3.1.2 Road Network

Roads and streets are modeled according to the diagram shown in Figure 3. The data that these entities store includes:

- *Roads.* Ownership, management, type and state of the pavement, length and width, suitability of the dimensions and the route, and suitability of the roadsigns. The geometry of each complete road is stored as a *line* value in the entity *Road*. The geometry of each section is stored as a *region* and a *line* in the entity *Road Section*.

- *Street network.* Type of street (street, square, etc.), state, paved and unpaved surfaces, number of buildings affected by a paving deficit, and the geometry of the street both as a *line* and a *region* value.

The goal of storing a redundant representation of road sections and streets is to capture both their network nature, and the actual extent of each component, so that network algorithms can be applied, and at the same time roads can be stored with their actual size.

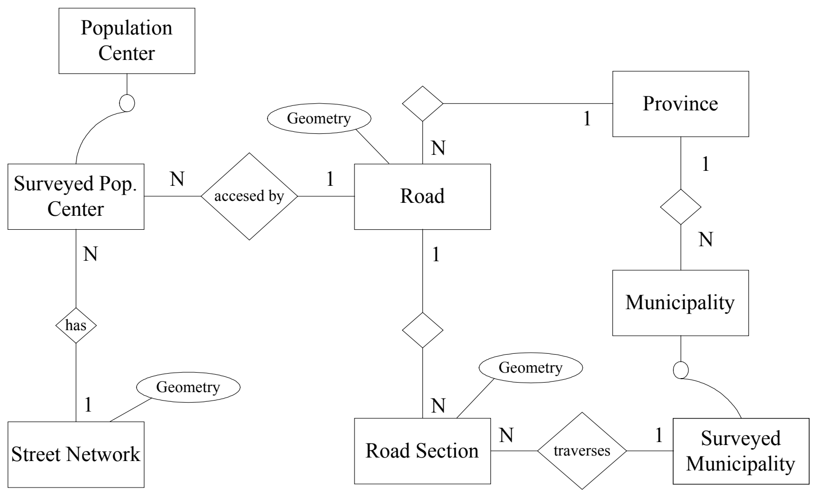

Figure 3: E-R model for the road network.

3.1.3 Water cycle and dumping sites.

The template for the entities in this category is the one in Figure 4. Entities that instantiate the template in the data model are: dumping site, water source, water conduction, water tank, water treatment plant, water distribution network, sewage network, sewer, outlet, and sewage treatment plant. These entities store, among other information, the following:

- Diameter, length, material and geometry (as a *line* value) of every pipe.
- Ownership, management and state of each element.
- *Water source.* Collecting system, basin, and geometry and position as a *region* and a *point* value, respectively.
- *Water tank.* Placement, capacity, and geometry and position as a *region* and a *point* value, respectively.
- *Water treatment plant.* A throughout description of the plant is given, including placement, quality controls, processes used, geometry and position as a *region* and a *point* value, etc...
- *Outlet.* Distance from the dumping to the nearest population center, description of the dumping site, and geometry as a *line* value and a *point* value.
- *Sewage treatment plant.* A throughout description of the plant with a complete description of the processes and the geometry and position of a plant as a *region* and a *point* value, respectively.
- *Water service elements.* The position of hydrants, pumping stations and some other elements are stored as a *points* value in the entity *Surveyed population center*.

- *Dumping site.* Type of dumping site, problems, capacity, expected life length, and geometry as a *region* value.

Those entities that are at the same time part of the water network and a set of buildings store two geometries. A *point* to capture its position as part of the network, and a *region* to capture its real extension.

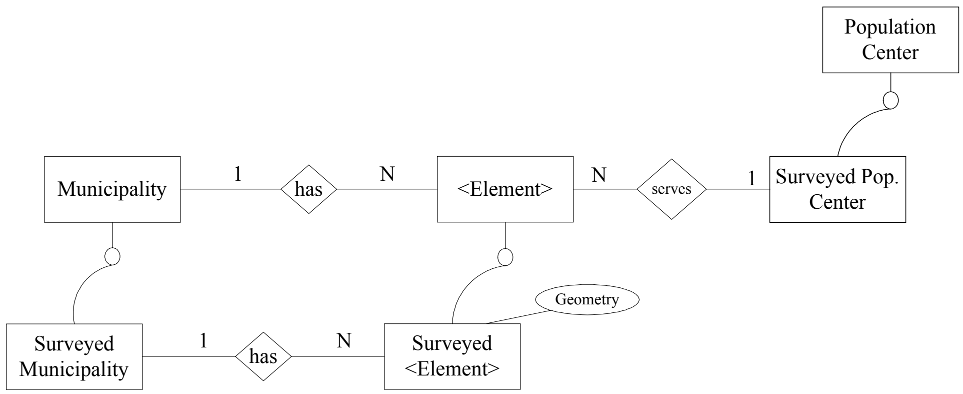

Figure 4: E-R model template for the water cycle and dumping sites.

3.1.4 Equipment

We use the term *equipment* to refer to the set of resources serving to equip a municipality in order to render a service to the population. The template shown in Figure 5 is instantiated by the following entities: street lighting, teaching institution, town hall, unused public building, civilian volunteer center, market, sport facility, park, cultural center, slaughterhouse, cemetery, morgue, health-care facility, and welfare center. Information contained within these entities includes:

- State, ownership, management, surface (indoor, outdoor, and parcel), and the geometry as a *region* value (unless otherwise stated) of each the elements.
- *Teaching institution.* Levels taught, pupils per level, number of classrooms.
- *Civilian volunteer center.* Type, scope, number of professional and volunteer members, and amount and type of rescue equipment.
- *Sport facility.* Type and sports played.
- *Park, garden and natural area.* Presence of water, electricity, sanitary fittings, and playground.
- *Slaughterhouse.* Type, capacity, percentage of usage, type of livestock the equipment is suited for.
- *Cemetery.* Distance to the nearest population center, suitability of accesses, presence of chapels and morgues, degree of saturation, and extension possibilities.
- *Morgue.* Number of rooms.
- *Health care facility.* Type, number of beds, presence of intensive care unit.
- *Welfare center.* Type and maximum number of occupants.
- *Street lighting.* The state and quality of services of the street lighting. The position of each point of light (street lamps and similar) is stored as a *points* in the entity *Surveyed Population Center*.

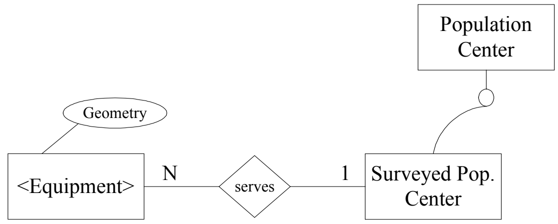

Figure 5: E-R model template for an equipment.

3.2 System Description

In this section, we describe the different tasks that are necessary to perform the E.I.E.L project. The set of tasks, described in Figure 6, includes the creation of the database, development of the application for the maintenance of the database and the definition of statistic algorithms for the complete exploitation of the huge amount of data that the E.I.E.L will collect. Some of these tasks are supported by several software modules, while others are supported by just one software module. In the following subsections we describe such tasks and the software modules implemented to accomplish each one.

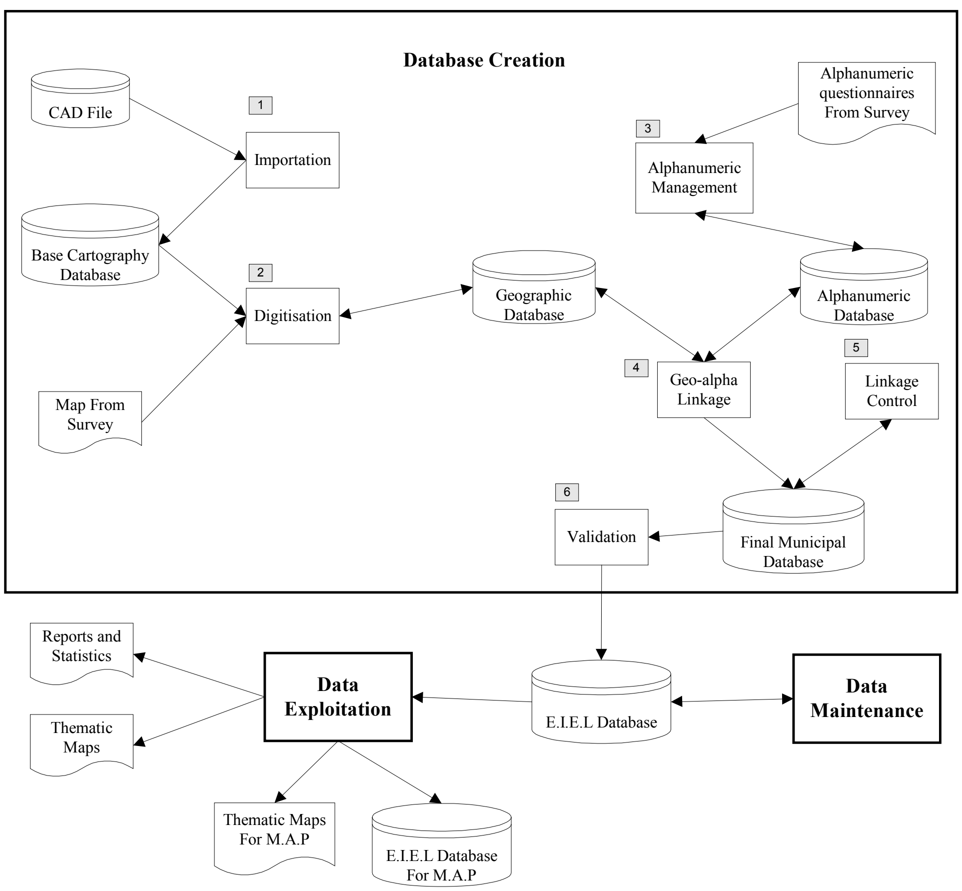

Figure 6: Data flow through E. I. E. L application modules.

Such tasks are briefly described in the following subsections. Among the different tasks, we are mainly interested in the Database Creation task, whose implementation details are provided in section 3.3. We do not describe with detail the applications for the maintenance and exploitation of the database, because those tasks will be integrated into the S.I.T.P.A.C, which will be described in section 4.

3.2.1 Database Creation Tasks

The Database Creation tasks involve the creation of a huge database with the data collected during the survey. Due to the vast amount of data to be inserted, this task has been divided into five subtasks, which may be done concurrently by different groups of specialised users. We describe below these subtasks, together with the software modules that we developed to accomplish each one of them.

3.2.1.1 Geographic Data Insertion subtask

It involves the introduction into the database of the collected geographic data. The result of the present subtask is, therefore, a digital cartography of the municipality in process containing the geographic objects of interest for the project. To simplify the creation of the geographic objects, a digital cartography of only some municipalities is already available. However, the quality of such cartography is far from being the desirable and some modifications must be done, in order to obtain a clean and error free cartography. Once the available cartography is cleaned and imported from its original CAD format, it is ready to be used as a base to create the set of geographic objects of interest for the project.

Although the geographic data regarding water cycle, equipment and structures is, respectively, collected by the three previously mentioned groups of specialized users, all of it is inserted by the cartography users group. The present subtask is supported by the following two modules, depicted in Figure 6.

Module 1: ***Importation module***. This module allows the experts in cartography to import the available cartography to a database with the final format used by the geographic information system. Therefore, it takes as input the available cartography from the *CAD File* and produces de *Base Cartography Database*. The geographic objects contained in the *CAD File*, one for each municipality, may be classified according to their usefulness:

1. Geographic objects without any kind of interest for the E.I.E.L. project. This is the case of greenhouses, private swimming pools, etc. Such geographic objects are not imported to the *Base Cartography Database*.
2. Geographic objects used as context information for the visualization of the E.I.E.L. data. This is the case of contour lines, rivers, railway lines, etc. Although they are not geographic objects required by the E.I.E.L. project, they are useful to include in maps where other geographic objects interesting for the E.I.E.L. are included. Therefore, it is worth to spend a reasonable effort to clean and import the objects of this kind.
3. Geographic objects used as context to digitize other spatial objects for which the E.I.E.L collects alphanumeric information. This is the case of roads, which appear as parallel lines in CAD format and are used to digitize road stretches. Such objects are only used to help in the creation of other objects, therefore, they are dismissed from the final cartography.
4. Geographic objects for which the E. I. E. L collects alphanumeric information. This is the case of some public buildings corresponding to several equipment, transformers, etc. They are treated by the importation module and then directly stored in the final cartography.

Thus, the present module allows the experts in cartography to perform various modifications mainly to the spatial objects of kinds 3 and 4. Such modifications include, for example, the process of linking contour lines that are broken and introduce their height above sea level as an alphanumeric attribute. Closing the limit of the municipalities to construct areas, drawing the different elements of the hydrography as surfaces or lines and introduce their name as an attribute, constructing areas from the boundary of some buildings that appear as non closed lines, etc. The final result that this module produces is a database with the *base cartography*. Entities containing geographic objects from the second and fourth of the previous types will have a numeric identification attribute and a geographic attribute, while entities containing objects from the third type may include one or several alphanumeric attributes, for example, the name for rivers, the height above sea level for contour lines, etc.

Module 2: ***Digitization Module***. It uses as input the *base cartography* from the previous module and the *field maps*, where each group of specialized users has collected the geographic data, to produce the *geographic database*, where all the geographic data of the municipality is stored. For that end this module provides functionality to:

1. Draw geographic objects using as context the *base cartography*. For example, to draw the road stretches using as a base the parallel lines that represent roads in the base cartography, draw water pipes, water tanks, sewage pipes, etc.
2. Classify geographic objects from the base cartography into the appropriate tables of *the geographic database* of the municipality. For example, classify the buildings into hospitals, sport facilities, markets, private constructions, etc.

Furthermore, geographic objects that are used as context for visualization, like hydrography elements, railway lines, etc, must be copied directly from the *base cartography* to the *geographic database* of the municipality. The geographic database of the municipality will include therefore two kinds of entities:

1. Entities containing geographic objects collected during the survey.
2. Entities containing geographic objects used as context for visualization purposes.

3.2.1.2 Alphanumeric Data Insertion subtask

It involves the introduction the alphanumeric data regarding the water cycle, equipment and structures. For each one of this groups of information there is a group of specialised users in charge of its collection and insertion. The present subtask is supported by the A*lphanumeric Management Module*, shown in Figure 6.

Module 3: ***Alphanumeric Management Module***. The present module is a classical module that allows insertions, updates and deletions in the tables where the alphanumeric data collected by the specialized users, is stored. Therefore, the module takes as input the questionnaires filled by the experts and produces as output an alphanumeric database, whose schema is the result of eliminating the geographic attributes from the model shown in section 2.1. As the information managed by the present module is classified into three types, three different applications implement its functionality. Each one of such applications is in charge of the management of the alphanumeric data collected by each one of the three specialized expert groups, water cycle experts, infrastructures experts and equipment experts. Thus, for example, the water cycle application provides the water cycle experts with a user interface where they can insert, delete and update the data they have collected. Each screen of the user interface resembles the questionnaire used to collect the data that it is going to manage. This characteristic makes the applications user-friendly.

3.2.1.3 Geo-alpha Data Linkage subtask

It links the alphanumeric data of each item with its corresponding geographic reference in the digital cartography, storing both of them as different attributes of the same entity. The subtask is supported by the following two modules, both shown in Figure 6.

Module 4: ***Geo-alpha Linkage Module***. The present module allows a specialized user to join, interactively, the alphanumeric data from the *alphanumeric database* and the geographic of the *geographic database*. Through such join process the *final municipal database* is constructed, whose schema matches the data model described in section 2.1.

Module 5: ***Linkage Control Module***. It allows the specialized user to check if the linkage process was correct and to undo it if needed.

3.2.1.4 Validation subtask

It involves the validation of the data inserted for a given municipality. There is just one module to support the present subtask.

Module 6: ***Validation Module***. The module allows one reviser to validate the final database of the municipality by checking if several conditions hold. If the data is correct and the reviser is satisfied with the quality of the data, the database can be copied to the final database where the data of all the municipalities will be stored, that is, the *E.I.E.L. database*. Note that, there exist some geographic objects, like roads, rivers, railway lines, etc, whose geometry may extend through several municipalities. Therefore, the pieces of them contained in each municipality are created separately as different fragments. Therefore, whenever one of such geographic objects is inserted into the E.I.E.L database, the *validation sub-module* must check whether a fragment of it already exists, and in such case join both fragments into one geographic object. Note that the alphanumeric values of all the fragments of the same object must be identical.

3.2.1.5 User management subtask

It involves the management of the user accounts of the applications that implement the previous set of modules. Each time that one of the applications of the systems is started, a user login and password is required. Only the users with the required privileges can enter a given application, and therefore, modify the data related with the application. For example, an expert from the water cycle group is not allowed to enter neither the infrastructures alphanumeric application nor the digitization application used by the cartography experts. Besides, by storing information about the user whenever a tuple is inserted or modified, it is possible to know who is the responsible of each piece of information inserted in the system. Thus, for example, during the geo-alpha linkage subtask, it will be possible to know who has entered each piece of alphanumeric and geographic data in the system. Therefore, if an error in some value is detected, the process of contacting the user who inserted the data to correct the error is simplified. There is not a separate application that supports the present task. On the other hand, each one of the previous modules contains code to manage and control its users.

As a final remark for the whole *Database Creation Task*, although a unique subtask allowing the insertion of geographical objects together with their alphanumeric information, one object at a time, would be must simpler, the previous subdivision has the following advantages:

1. It allows each specialized group of experts to collect and introduce its data concurrently.
2. Specialized cartography users do not need to worry about alphanumeric characteristics of geographic objects, while the remainder users do not have to worry about geographic data insertion.
3. It allows the cartography users group to have a global vision of the geographic aspect of each municipality.
4. The expert who is performing the *Geo-alpha Data Linkage subtask* behaves as a supervisor of the data that has been introduced through the *Geographic Data Insertion* and *Alphanumeric Data Insertion* subtasks.

3.2.2 Database Maintenance Tasks

The *Database Maintenance* task involves the insertions, updates and deletions done to the database once it has been created by the previous task, in order to keep its information up to date. Such modifications may be caused mainly by two reasons: The first one regards with changes in reality which must be reflected in the database, while the second one involves the correction of errors that may be detected in the future.

Regarding the insertion of new tuples, now, both alphanumeric and geographic attribute values must be provided. Alphanumeric values may be inserted in classical forms, while geographic values must be inserted through a digitization graphic user interface.

In the case of updates and deletions, a first step that locates the object to be updated or deleted must be done. Such locating process is in turn done in two steps: In the first one a query, which may include both alphanumeric and geographic conditions, is issued, to select a subset of the elements of the table. Once the query is performed, in the second step, one tuple is selected, by browsing the set of tuples resulting from the query. The selected tuple is used to be either being updated or deleted. Additional functionality may include the possibility of updating or deleting all the tuples resulting from the query.

3.2.3 Data Exploitation Tasks

The *Data Exploitation* task involves the exploitation of the information collected during the survey. It includes the generation of thematic maps, alphanumeric reports and statistics. Finally, one more task deals with the generation of the database and the thematic map printouts required by the M. A. P. every five years.

For the scope of this paper, a *map* is considered as a set of graphic elements, each one with a set of visualisation properties, like colour, style, filling pattern, etc., obtained from another set of geographic objects, where the visualisation properties of each graphic object is obtained as a function of the alphanumeric attributes of its correspondent geographic object. The Data Exploitation Module allows the users, having required privileges, to define, in an ad-hoc manner, maps from the information of the database. Such maps are, in principle, visualised on the screen, however, they may also be printed out or even exported to some kind of graphic file format, like image files or CAD files. Besides the maps that users may define, a set of predefined maps are available, that can be generated directly without having to be defined.

Besides the ability to produce thematic maps, this module also provides functionality for the generation of alphanumeric reports. Such reports may range from simple queries to complex statistical data analysis. Again, as in the case of maps, the user may define his own reports in an ad-hoc manner or directly use already predefined ones.

4 INTEGRATION INTO S. I. T. P. A. C.

The S.I.T.P.A.C, which stands for *"Sistema de Información Territorial de la Provincia de A Coruña"* (A Coruña Province Territorial Information System) will be a general information system, where some existing legacy systems of the Provincial Council of A Coruña are integrated with new applications like the *E.I.E.L management* application. With such integration S.I.T.P.A.C provides legacy systems with the ability to manipulate geographic references of some of their entities and with graphic user interfaces suitable for the management of such geographic references.

This information system emerged as an attempt to take advantage of the provincial geographic database resulting from the E.I.E.L. project and the technologies found in the area of geographic information systems to:

1. Provide some already existing legacy software with new functionalities, like the ability to manipulate geographic references of some of their entities, new user interfaces, etc.
2. Provide the *Provincial Council*, the municipalities and the general users with new services. Some of such services access some pieces of information through World Wide Web.

The goal of S.I.T.P.A.C is, therefore, to provide both the Provincial Council of A Coruña, and each one of its municipalities, with a work environment, which makes easier the management, i.e., storage, maintenance and exploitation, of a huge heterogeneous set of both alphanumeric and geographic data.

In the following sub-sections, S.I.T.P.A.C. is described. Some preliminaries are introduced in section 4.1, while the description of the system architecture is explained in section 4.2.

4.1 Preliminaries

4.1.1 Current Situation

One of the most important issues to bear in mind during the analysis and design of S.I.T.P.A.C is the situation of heterogeneous characteristics found in the municipalities of A Coruña province. As already stated in section 2, there are some big municipalities that have capabilities, and even software systems, to perform a wide set of tasks, like Urban planning for example. However, some other small municipalities have delegated the majority of its tasks to the *Provincial Council*, thus, their software needs are clearly lower.

Regarding the existing legacy applications already working in the municipalities and Provincial Council, only the "*Rentas/Padrón*" (Income taxes/municipal register) and "*Gestion Tributaria*" (Taxes management) applications will be considered. The former is used by the majority of the municipalities to deal with the management of both the municipal register and the several taxes collected at the municipal level. The later is used by the Provincial Council to deal with the management of the several taxes collected at the provincial level. The goal, of S.I.T.P.A.C. regarding such legacy software is to keep them

The heterogeneous situation among the municipalities applies also to the set of data about infrastructure and equipment available in each municipality. Thus, some municipalities can provide a very detailed set of data while others can not. For example, some big municipalities have detailed data about the water supply network, even with cartography in digital format, while other small municipalities cannot assert with precision where a water pipe is.

4.1.2 Required Functionality

Beyond the functionalities already available in the existing legacy systems, both the municipalities and the *Provincial Council* require the insertion into S.I.T.P.A.C of additional functionality. Such functionality includes the following:

- Maintenance and Exploitation of the E.I.E.L database. This functionality has already been described in section 3. Only the Data Maintenance and Data Exploitation tasks are included into S.I.T.P.A.C.
- Tools to store and manage data regarding urban planning. Such data include both current and future plans. In addition, users must be able to study and design new plans with the available functionality. Such functionality must allow, for example, analyzing the impact that a new plan may have in the needs of development new infrastructures, like water supply systems, roads, etc.
- Tools for the management of information like tourist information, monuments, etc. Such information must be available through WEB, together with other information from S.I.T.P.A.C that may be interesting to publish.
- Tools for the management of information regarding the immovable assets. Such information include the owner of each dwelling and the corresponding information about sales and buys.

Note that it can be clearly identified a set of specific functionalities which are common to all the previous tools. Such functionality includes:

- The management of the privileges and access grants of different types of users.
- The maintenance of alphanumeric data.
- The maintenance of geographic data.
- The generation of thematic maps required by the users.
- The generation of various kinds of reports and statistics from the data stored.

4.2 System Architecture

In order to provide the functionality presented in the previous section, the S.I.T.P.A.C system was designed as shown in Figure 7. As it can be observed, the system architecture is organized in three software layers. The advantage of this modular design of S.I.T.P.A.C. is the increase produced in its scalability. Thus, new user applications that include geographic objects may be include in the system without having to modify the already existing ones.

4.2.1 User Applications

The functionality required from S.I.T.P.A.C, as presented in section 4.1.2 has been classified into a set of different user applications, again, in order to provide the system with a modular structure. Such modular structure will allow the future expansion of the system with new user application without having to modify the current ones.

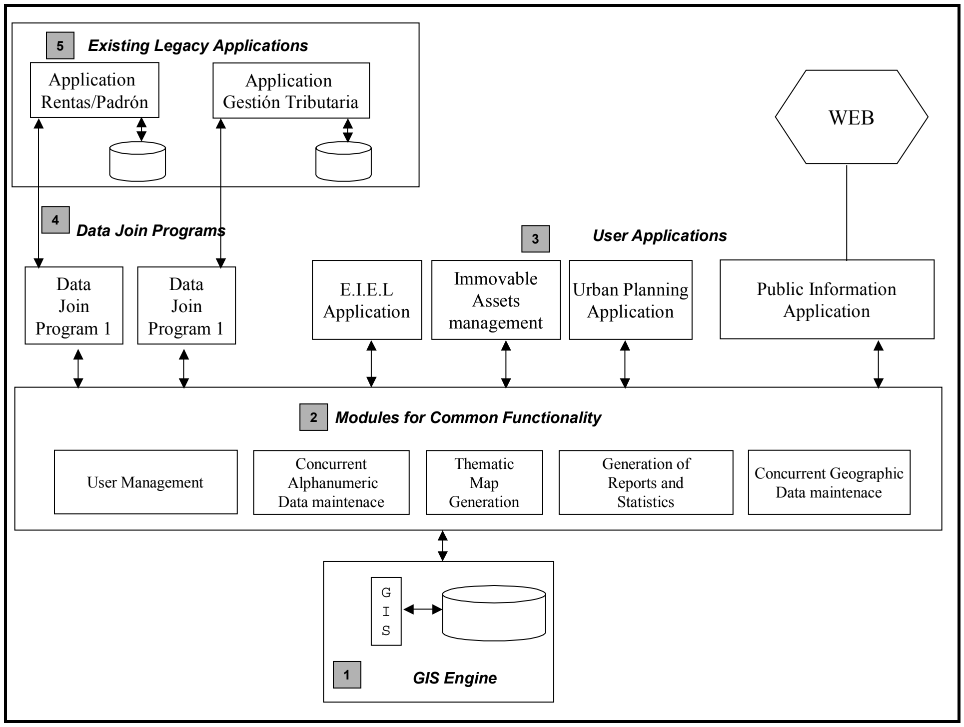

Figure 7: S.I.T.P.A.C Software Architecture.

Thus, the set of user applications to develop include:

1. ***E.I.E.L management application***: This application automates the *Database Maintenance* and *Data Exploitation* tasks of the E.I.E.L project. Those tasks have already been described in section 3.2.
2. ***Urban Planning application***: It provides the functionality needed to generate and manage urban plans. Such plans will provide a classification of the land of each municipality into disjoint surfaces, depending on its usability.
3. ***Public information Application***: It allows the management of information which is interesting and worth to be publicly available. Such information includes tourist services, monuments, etc. and some other information coming from S.I.T.P.A.C, which the municipalities may want to publish. The whole set of information will be available through WEB by the mean of predefined queries.
4. ***Immovable Assets Management***: It allows the management of the information related with the collecting of taxes on Immovable Assets. Such information includes the identification of the owner of each dwelling together with the set of information related with sales and buys.
5. ***Data Join Programs***: These programs, one for each existing legacy application, behave as interfaces between the legacy systems and the S.I.T.P.A.C modules of common functionality. They allow, therefore, to combine the data coming from each legacy system with data, both geographic and alphanumeric, coming from other applications integrated into S.I.T.P.A.C. Thus, as already explained, such data combination will enable to select an apartment on a map and view, besides its geographic position, information about it coming from the E.I.E.L and information about it occupants coming from the "*Padrón/Rentas*" application. The functionality of such programs will include:
   - Link the information regarding the same object that comes from S.I.T.P.A.C and the legacy system.

- Visualize the geographic information stored in S.I.T.P.A.C related with each specific object of the legacy system.

4.2.2 Modules of Common Functionality

As already mentioned in section 4.1.2, there is a set of common functionality that the majority of the user applications must support. Such functionality will be implemented in a software layer immediately behind of the user applications. Such software layer will provide all the user applications with such functionalities, preventing this way from having to implement it in each application, and, more important, making the system more scalable. Thus, new applications may use the common services without having to implement them again and new common services used by new applications may be included in the system without having to modify the current user applications.

The present software layer includes the following set of modules:

1. ***Concurrent Geographic data Maintenance***: It will enable the users to modify the geographic data stored in the system. Note that even if a user has the maximum privileges, if she is using the E.I.E.L application, she will not be allowed to modify urban planning geographic information. Among the functionality included in the present module, are worth mentioning, the capabilities to check geographic restrictions whenever a geographic value is modified. Thus, it will be interesting to check that a road is not modified to cross an area where the contour lines show that the slope is too high. In addition, there are some geographic values that are generated from other ones. As an example, a road line may be generated from the set of road stretches (stored as areas). Such derived information must be recalculated each time the source one is updated.
2. ***Concurrent Alphanumeric data Maintenance****:* This module is the alphanumeric counterpart of the previous one. It will enable users to update the alphanumeric data managed by each user application. Again, the module will check the correspondent user privileges and will not allow users of one application to update data belonging to other applications.
3. ***Thematic Map Generation****:* It will enable the users of each user application to generate the desired thematic maps with the geographic data belonging to the application. Thus, an E.I.E.L user will not be allowed to generate maps with taxes information coming from the urban planning application. Such thematic maps may be either predefined or defined by the user in an ad-hoc manner. The thematic map generation has already been described for the E.I.E.L application in section 3.2.3. The considerations explained there apply also to the case of the remainder user applications.
4. ***Generation of Reports and Statistics****:* It will allow the users of a given application to generate, either predefined or user defined, reports and statistics from the information relative to such application. Again, its functionality has been briefly explained in section 3.2.3 for the case of the E.I.E.L. The considerations explained there apply also for the case of the remainder user applications.
5. ***User Management****:* It will allow the user administrators of each application to insert, modify or delete its user accounts. Thus, the management of the users of one application will be isolated from the management of the others. Besides the privileges assigned by this module, it will be necessary to define in each municipality a set of workstations, each one also with a set of assigned privileges. Thus, when an user is inserted, he can be assigned a workstation where he is going to work. This mechanism will make much simpler the definition of user accounts with the correct privileges.

4.2.3 Geographic Information System Engine

This software layer will include general tools to store and retrieve the whole set of data used by all the applications. Such information will be processed and given to the upper layer in the required format. The development of the layer is supported by two commercial tools, on the one hand a database management system will deal with all the tasks related to data storage and retrieval, while on the other hand, a geographic information system engine with treat geographic data in order to provide the upper layer with the required maps.

Regarding the information stored in the database, it will include both classical alphanumeric data and geographic data in vector format. Both types of data will be stored in the database in a uniform way.

5 CONCLUSIONS

In this paper, we have presented the development experiences of the E.I.E.L project and its integration into the S.I.T.P.A.C system. Thus, we have described the set of tasks performed for the creation of a huge database with information about infrastructures and equipment of the municipalities of A Coruña province. Furthermore, it was demonstrated how the management of such huge database is integrated, together with already existing legacy software and other new applications, into the modular and scalable S.I.T.P.A.C. system.

Among the conclusions emerging from the previously presented experiences, we want to highlight the two following issues:

1. The new technologies available in the field of geographic information systems, allow the integration of some old reliable legacy systems with new applications that manage geographic objects. Such integration provides such legacy software with new functionalities, including:
    - The ability to manage geographic references of some of their objects.
    - Graphic user interfaces that make easier tasks like the visualization of the previous geographic references.
2. Beyond the classic database features, like query languages, concurrence control, transaction management, etc., obviously desired in the commercial geographic information systems; we found of special interest some specific functionalities that are not yet included:
    - The ability to check complex integrity constraints whenever a geographic objects is modified or inserted in the database. We have already mentioned the possibility to check if the slope of a given is road is not too high. The information about the slope would be obtained from the contour lines.
    - The capability to define derived attributes by applying complex geographic algorithms to already existing ones. Such derived attribute would be automatically updated by the systems whenever one of the attribute from which derives is modified.

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