Integrated Geoprocessing for Generation of Affected Assets and Rights Reports for High Voltage Electrical Infrastructures

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***Abstract*— The development of linear construction projects, such as roads, railways, gas pipelines and electricity installations among others, whose execution on the territory impact a number of real estates, implies calculation of the effects over the plots in order to rewards landowners in terms for the influence of these new constructions on their properties as the case of Assets and Rights. This paper is about the high voltage electrical installations projects, focussed on the optimization GeoProcessing workflow for the generation of affected Assets and Rights Reports (ARR) for landowners due to the impact of affections for building electrical installations. This calculation and the generation of reports are carried out in different stages, requiring geoprocessing of different types of electrical constructions affections over the land, whose data come from different local and remote (Web services) sources. These overall characteristics make the process complex, time-consuming and requiring many resources. This paper shows the study case of the Integrated Geoprocessing for calculation of the affected ARR as a result of the new electrical conveyance infrastructures in Spain. The challenge consists of complying with the planning objectives as defined by the Ministry of Industry, Tourism and Trade (MITYC) for 2016, and reviewed for 2020, which implies the new creation of circuits and substations. In order to assisting in the accomplishment of those objectives and with the purpose of automating part of that workflow, an application software has been developed that integrates parts of the stages of that flow. The integrated stages are: (a) encoding of the plots susceptible to be affected; (b) calculation (geoprocessing) capable of processing 15 types of affections; (c) generation of an alphanumerical report with information about the owners of the affected plots and the ARR; (d) storage and Internet publishing of the affections caused by the projects through OGC Web Services and an ISO TC211 standard-based server for result dissemination in other formats. Up to five different data sources (two local, three remote) may come into play. The use of this application in the creation of the ARR has allowed improving productivity by optimising the amount of ARR generated per annum, the amount of calculated affections, the reliability of the calculations and the terms, thus reducing the cost of this activity.**

Keywords - Geoprocessing, SDI, Assets and Rights Report, Electrical installations, Landowners, Real estates.

I. INTRODUCTION

The development of linear construction projects whose execution on the territory touches a number of real estates implies calculation of the effects over the plots in order to rewards landowners in terms for the influence of these new constructions on their properties as the case of Assets and Rights. This paper is about the high voltage electrical installations projects, focussed on the optimization GeoProcessing workflow for the generation of affected Assets and Rights Reports (ARR) for landowners due to the impact of affections for building electrical installations; examples are the constructions of streets/roads [1], railways [2], gas pipelines [3], and electrical installations [4]. Spanish Electrical Network (REE) is the private/public company in charge of the maintenance and construction of the high voltage distribution network in all over Spain, which is also responsible for the calculation of affections and the ARR derived from the electrical installations. This calculation and the generation of reports are carried out in different stages, requiring geoprocessing of different types of electrical constructions affections over the land, whose data come from different local and remote (Web services) sources. These overall characteristics make the process complex, time-consuming and requiring many resources. This paper shows the study case of the Integrated Geoprocessing for calculation of the affected ARR as a result of the new electrical conveyance infrastructures in Spain.

REE owns the entire high voltage electricity network on the Spanish territory; it is also the operator of the conveyance system, responsible for the management, development, extension, maintenance and improvement of the network [5]. Fig. 1 shows both the present state of the high voltage network and the planning for 2016 on the Spanish peninsular territory.

The dimensions of the Spanish high voltage electricity network (up to 2010) are: 35,875 Km of electrical circuits [6], with approximately 70,000 electricity pylons and 450 substations [6][7]. The planning worked out on May 2008 by the Ministry of Industry, Tourism and Trade (MITYC) [8], whose objective is looking ahead to the future energy needs based on the increment of the demand experienced in recent years [6] that allows an estimation for 2016 of approximately 15,000 Km of circuits, 35,000 new electricity pylons and 200 new substations [9].

A. Background

The conventional method to calculate the affections caused by the high voltage electrical installations of REE and the generation of the ARR involved the use of different programmes and the manual execution of several tasks, partially automated in each stage of the process.

Figure 1. High voltage electrical energy distribution throughout the Spanish peninsular territory (adapted from [10]).

Stage 1 consisted of manual encoding of the plots likely to be affected by a new installation. Stage 2 consisted of the calculation of only four types of affections over the plots. In this stage, an AutoCAD script was used to calculate the affection due to the flight area of the high voltage electrical cable produced for the wind influence, the other three affections (felling area, permanent occupation due to the electrical installation infrastructures, and flight linear length of the high voltage electrical cable) were calculated manually. The script showed a dialogue window that visualised the value of the area affected by the overhead easement as a plot was selected. That value was used in stage 3: generation of the ARR in alphanumerical format as the values identifying the plot and the affected surface were being registered. This calculation method was useful for the REE until 2008. If we consider 250 the average amount of plots that may be affected by a new electrical line of 50 Km length and four the possible types of affections that may exist at present, the time needed to carry out these iterative processes with the traditional method would be approximately 200 hours.

B. *Motivating Scenario*

The ambitious planning of the MITYC for the electrical sector [8][9] and the traditional way of carrying out the calculation of affections and the subsequent generation of the ARR allow identifying the following critical points in the processes: (1) need of producing more ARR in less time, (2) excessive duration of the process (200 hours in our example), (3) high cost of data preparation for each programme, (4) questionable reliability of data transfer between programmes without fully automated procedures, and (5) variety of affection types to be managed (up to 15). These five critical points warrant the design of a working methodology and the creation of a software application tool supporting optimisation of the processes of calculation of the affections and generation of the ARR through automating of the largest part of the workflow. The software application called RBD-MercatorREE has been developed so that it will implement the identified requirements to face the challenges of the new planning, integrating and automating the workflow. The integrated stages are: (a) encoding of the plots susceptible to be affected, (b) calculation (geoprocessing) of up to 15 possible types of affections, (c) generation of an alphanumerical report with owners' information and the ARR of affected properties, and (d) storage of the history of the affections on a server with geospatial standards (ISO-OGC) [11] for results dissemination in other formats. Five data sources (two local, 3 remote – Web services) may come into play along the process.

II. Calculation of Affections and ARR Generation: Processes and Information Characterisation

The processes and data needed for the development and maintenance of high voltage electrical installations share generic characteristics with other types of lineal construction projects and infrastructures [12]. Some of the shared characteristics are: (1) affected properties on the territory, this fact implies the second characteristic, (2) the use of cadastral information, (3) one or more areas of direct affections on the plots by the elements to be built, and (4) one or more indirect affections on the plots by pathways which will allow access of the needed mechanical means for building and for future maintenance.

The source/destination of the information to calculate the affections and ARR involves several agencies. Table 1 resumes the actors involved in the workflow; the relationship between them are shown in Fig. 2.

TABLE I. Actors for affections and ARR.

Player	***Player Description***	***Main Source***
SEC-PR	Web access to the Cadastral Cadastre Electronic Headquarters (SEC) [13] to obtain protected information from the plot owners.	GOV
SEC-CA	Web access to the cartography of the Cadastral	GOV
GOV	Administrations and Spanish media in which the affections are communicated: Official State Gazette (BOE) [14][4], autonomic media [15], provincial media [2] and widely-read newspapers among others. for publishing on the BOE	GOV
DMA	Department of the Environment	REE
DIL	Department of Line Engineering	REE
DTR	Department of Handling	REE
REE/ UPM	A set of Web services temporarily on the Technical University of Madrid (UPM) which are conformant with the Spatial Data Infrastructure (SDI) standards in order to provide interoperability [16].	REE / UPM
CTC	Consulting Service for Surveying and Field	NGOV
CTO	Consulting Services for Surveying and Processes	NGOV
CMA	Consulting Service for the Environment	NGOV
GEN	public in general –not operating as yet	NGOV

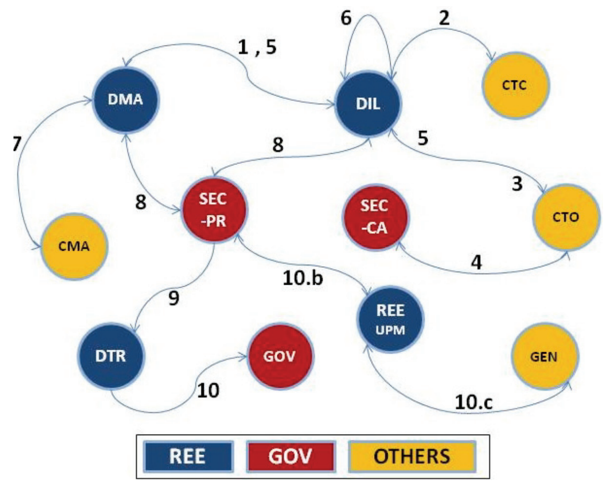

Figure 2. Relationship between actors involved in the calculation of affections and the generation of ARR

In Table 1, the main source column indicates a classification of actors corresponding to REE departments, the government agencies (GOV), and the non-governmental agents external to the REE (NGOV).

The relationship between actors is the following: DMA and DIL interact to define the passageways and alignments of the new installation, with the CTC carrying out the field revisions (links 1 and 2 in Fig. 2). This information is then used by the CTO to get the cadastral data from SEC-CA (links 3 and 4 in Fig. 2) and they encode the plots likely to be affected. With the cadastral cartography, DIL and DMA define the distribution of the electricity pylons (link 5 in Fig. 2) so that DIL will subsequently define and calculate the affections due to the influence of the trace (link 6 in Fig. 2) and DMA, interacting with CMA, will define and calculate the affections due to accesses (link 7 in Fig. 2) to the installation for building and future maintenance. After the affections have been calculated by DIL and DMA respectively, the protected information of the owners of the affected plots is retrieved from the SEC-PR (link 8 in Fig. 2), regardless of the type of affection. With the protected information, an alphanumerical ARR draft is generated (link 9 in Fig. 2), used by DTR to process and generate the final ARR. This report is then submitted to GOV for approval and publishing on the BOE and media (link 10). Simultaneously the information of the affections and all their geographic components are submitted to REE/UPM for OGC-standard-based web publishing (link 10.b in Fig. 2) which allows alternative publication as maps; at the same time the geometric history of the affections is saved for future access by the general public (link 10.c in Fig. 2).

The information exchanged by the players may be characterised as follows:

A. *Based on its format*

The fact of having several actors involved in all the ARR process implies having to deal with heterogeneous data formats. Five groups of formats are identified as follows: (1) twenty one GIS layers, (2) at least one XML protected file with the landowners information, the land price and more private data for each project that will be processed, (3) one alphanumerical database (DB) of provinces and municipalities (all of them are necessary input data for the processes). All of these three data formats are used as input for the ARR process. As part of the output data, there are sixteen more GIS layers containing information about the affected surfaces on the plots, and the next two data formats: (4) several spreadsheets files, containing the assets and rights report (prior to its publication on the BOE and pertinent media), and (5) a set of geospatial Web services (OGC) for storage and publishing over Internet all the historical ARR projects and its results, such as the graphic reviews of the affected plots, the pieces of geometric calculations and so on, all the different kind of produced output. Table 1 shows the different data formats and its main characteristics.

B. *Based on its purpose*

a) Plots: It represents the real estates involved in each electrical installation project. The encoding that identifies ordinally each plot, according to the direction of the electrical trace and accesses, are registered in addition to the values of the surface calculated for each type of affection. This information is generally obtained from the Cadastre through its SEC [13].

b) Layers with the affections: REE carries out studies for every new electrical installation project to take decisions and to process the information by affections. The data may be categorised according to affection on the ground as follows: (a) intangible affections, e.g. area affected by the flight of the high voltage electrical cable due to the wind influence, (b) tangible affections, e.g. area of permanent occupation by each electricity pylon. On the basis of their attributes, the data may be categorised: (c) with codes, e.g. every electricity pylon has an identification code, (d) without a code, e.g. area affected by tubing. According to the type of their geometry, the data may be: (e) polygons, and (f) lines.

TABLE II. DATA FOR AFFECTIONS AND ARR.

Data + (number)	*Group*	*Format*	*Source*	*Source Type*
Plots (1)	1	GIS	SEC	Remote
Layers for Encdoding (6)	1	GIS	REE	Local
Layers for Affections (15)	1	GIS	REE	Local
Landowners Data (1)	2	XML	SEC	Remote
Prov/Municipalities DB	3	BD	IDEE	Remote/ Local
ARR Draft	4	XLS	SEC	Remote
Histoy of Affections (16)	5	GML/ WFS-T	UPM/ REE	Remote

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Improving the number of affections that may influence plots from four to fifteen was one important issue in order to accomplish the MITYC requirements. In the previous working way it was infeasible to work with more than 3 manually made affections. These 15 affections are: (1) aerial trace (superficial electrical cable generally suspended between pylons), (2) underground trace (part of the electrical cable is buried), (3) flight (safety area represented by the possible maximum movement of the electrical cable due to the influence of wind with a velocity of 120 Km/h perpendicular to the axis of the electrical line), (4) tube (representing the vertical projection of the cables on the ground with wind of 0 Km/h), (5) Felling (area that should be felled around the trace for safety purposes), (6) permanent occupation area (area occupied by the pylons), (7) permanent underground occupation (surface the underground power line will occupy permanently), (8) temporary occupation area (needed area for the building of the electricity pylons and other materials), (9) temporary underground occupation (needed occupied surface for underground electric wiring), (10) splicing chamber (area occupied permanently by concrete boxes where cable splicing is carried out), (11) telecommunication boxes (surface permanently occupied by the boxes used for telecommunication equipment associated to underground cable for remote maneuvering of the line), (12) landmarks (surface occupied by concrete posts in place to indicate on the surface the underground channelling of electrical cables), (13) accesses (easement needed for access from the electrical installations for building and maintenance), (14) auxiliary 1 and (15) auxiliary 2 (two generic affections available in the future if needed).

c) Layers for encoding: There is a dataset that helps in the encoding of the project plots; these must be identified for future field calls. These layers are: encoding trace; access to the pylons; buffer by trace; buffer for access and supports. This information is worked out by the REE.

d) Landowners data: Information such as address or identity card is protected as a part of the real estate register system. It is obtained from the Cadastre through its SEC [13]. This service requires users to identify themselves and to have the appropriate privileges to obtain this information.

e) History of affections: The geographic information of the polygons included in a project concerning the ARR (affections and cadastral plots) is duly saved into a server compliant with the standards of an SDI by using Web Map Services (WMS) [17] and WFS-T [18].

III. APROACH

A. *Workflow automation and Integrated Geoprocessing*

Some of the processes to calculate the affections and ARR generation such as the field calls for definition of alignments by passageways or the creation of traces and affection polygons are not in the first instance susceptible to be automated in this context. However, other parts of the processes does allow being optimised by automation and the creation of a new workflow; such is the case for the following four processes: (1) encoding of the plots, (2) process of calculation of up to 15 types of affections on the plots, (3) generation of the ARR combining the plots with their affections and the owners' protected information, and (4) saving of the history of affections and its publishing on the Internet by means of SDI standards.

Fig. 3 shows every one of the above-mentioned four processes following a gear metaphor. This figure is made up of three rows and four columns and represents the automated workflow. In each column is shown the name of the automated process, the needed input data to carry out the process and an output are graphically exemplified underneath. Next we describe each process (columns) briefly.

a) Plot encoding: This part of the workflow is comprised of seven GIS layers, one for the parcels and the other six for encoding. All parcels intersecting with the buffers of influences by affections are encoded; encoding consists of assignment of an identification value to each plot likely to be affected by a new installation, taking into account the direction of advancement of the trace (numbered with integers); at the intersections with the accesses, the access path is followed (numbered with decimal values). To reach this requirement, techniques and software libraries are used for the handling of the linear reference systems. The output is the same layer of plots to which a new attribute for encoding and its values is added.

b) Calculation of affections: This part of the workflow consists of 16 GIS layers, i.e. the plot layer and up to 15 layers of affections. The process carries out integrated geoprocessing on the parcel geometries as a function of the affections, taking into account the codes identifying them. The geoprocessing operations realised are: aggregation by attributes, intersections and clipping among others. As the software application carries out the operations, the areas and perimeters are calculated for each type of affection and saved on the same plot layer which again serves as the output of this process.

c) Generation of the assets and rights report: This part of the workflow uses two input data, the plot layer with all the values of the affections for each plot and an XML file with the protected information of the affected plot owners. The process combines the two data sources and generates an ARR output as a spreadsheet. This is the initial document to be reviewed by the Department of Handling before being submitted to the Administrations for its publication on the BOE and other media.

d) Saving and SDI publishing of historical data: The plot with all its affection values as well as the geometric details of each affection are saved in an SDI standard-complying server. Data are converted to the interchange Geography Markup Language (GML) format [19][20] and they are submitted through transactional operations to the server which implements the WFS-T. Once stored in this server, they may be queried in a standard fashion by using the WMS and WFS services.

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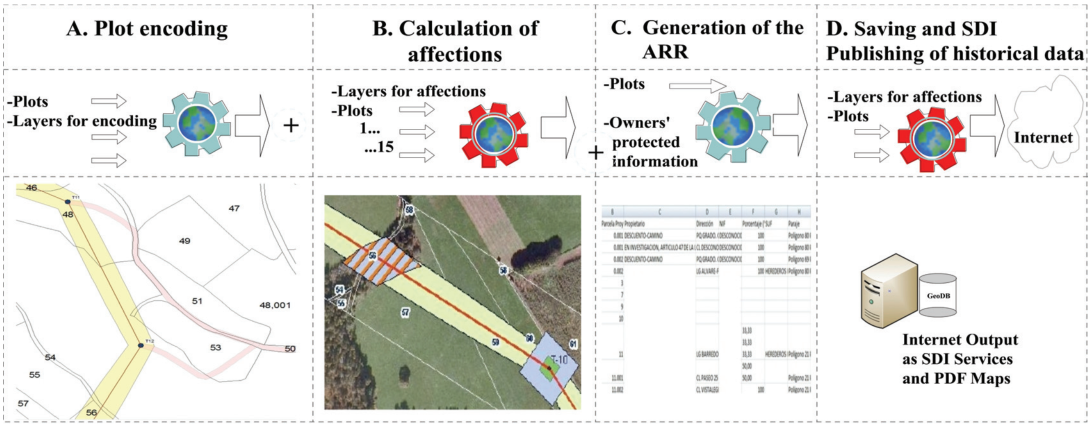

Figure 3. Automated workflow for calculation of affections and ARR generation

B. System architecture and design

The RBD-MercatorREE software application tool has been designed following the principles of object-oriented programming. This has allowed defining the objects that recap the necessary logic to comply with the software requirements and functionalities. The definition of those objects (aka business logic) allowed dividing the software into 3 uncoupled layers as independent and interrelated projects: (1) business objects, (2) user interface, and (3) remote persistence server. Fig. 4 shows the entire RBD-MercatorREE software application as a blue rectangle containing three gray rectangles inside. Every one represents a software logic layer (the upper rectangle is the desktop user interface, the central rectangle is the business logic layer and the lower rectangle represents the persistence layer). The dark blue circles on the central rectangle represent the main business objects making up the software; the sky blue circles of the rectangle on top represent forms and controls typical of a desktop user interface that instance the business objects. Fig. 4 also shows an overview of the system architecture for the integrated geoprocessing through the RBD-MercatorREE software application. Six rectangular areas are shown representing the involved players. The upper left rectangle represents the REE and its departments, with access to all the software functionalities. The upper right rectangle represents the remote server REE/UPM, used for storage of the affections; access to it is achieved from the software persistence layer through WFS-T, GML, XML and HTTP. The two lower left rectangles with the CMA, CTC and CTO labels represent the consulting firms that realise and process cartography for the REE; the circles 1 and 2 inside indicate that they have access to the option of plot encoding and calculation of affections through the local installation of the software. The lower central rectangle –under the Internet cloud– represents SEC and its different ways of access to the cadastral data (WFS, Web app and Web service).

The lower right rectangle represents the general public who can access the affections and assets and rights reports (ARR) published by REE/UPM conformant with SDI standards and Web applications.

C. Technical Resources

The RBD-MercatorREE software application has been developed using C# as programming language and .NET 4.0 [21]. The basic spatial operations have been carried out with the ArcObjects libraries for ArcGIS of ESRI [22]. The server for storage and publication conformant with SDI standards of historical data of affections and ARR is GeoServer 2.0.2 [23]. The XML encoding of the WFS-T requests Insert/Delete, etc. as well as the conversion of the data to GML format and the communication with the server through HTTP have been entirely carried out with the .NET basic libraries for C#.

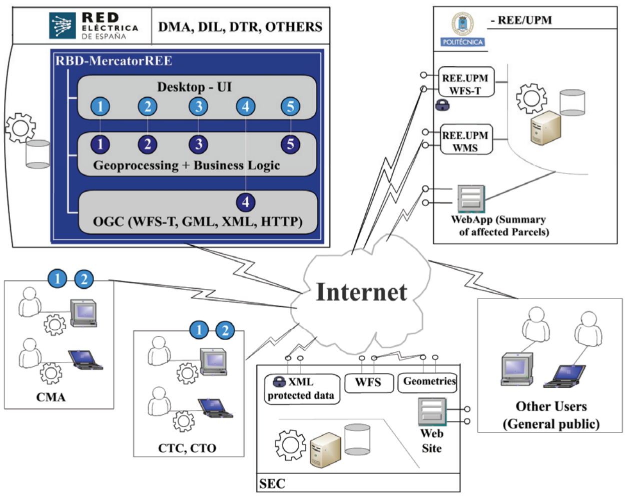

Figure 4. System architecture

IV. RESULTS

The possibility of obtaining the current cadastral cartography and the protected data of the affected parcels quickly and reliably as well as linking these to the data of each project, measuring the affection of the new installation on the territory automatically, has meant for REE the shortening of terms –in some processes over 90% reduction; in addition, it is possible now to count on the reliability of the published information, i. e. the official information managed by the Ministry of Economy and the Treasury.

In view of this advance, the departments involved in the technical drafting of projects, have established a line of work whose information flow is quick and smooth, avoiding the choke points that occurred with the old procedures. This fact brings about an increased capability of technical drafting of projects; it also makes it easier to comply with the planning approved by the MITYC on May 2008.

This positive impact on the run times is reflected on Fig. 5 where a chronogram represents the average project timescales of a project of a 50 Km long electrical line.

Fig. 5(a) shows the times according to the old procedures and Fig. 5(b) according to the new line of work. By comparing both figures it appears that the project activity represented by the yellow bar has been shortened considerably. This reduction represents about 40%, the engineering activity has been reduced in 20% and the largest optimisation corresponds to the ARR, with more than 90% reduction.

The availability of digital geographic information together with the analysis and optimisation of the workflow have been the key elements in the improvement of the methodologies. In the second place, automation of the processes has allowed a reduction in the terms and costs and an increase in the reliability of the results and consequently an improvement in the efficiency and productivity of the technicians. Thus we can present the following comparative Table with the conventional methodology and with the developed tools that automate the new methodology put in place.

TABLE III. COMPARISON OF THE PREVIOUS METHOD AND THE CURRENT METHOD FOR THE CALCULATION OF AFFECTIONS AND ARR GENERATION

Concept	*Old method*	*Current method*
Software Development Cost	0 €	30000 € (once)
# calculated affections	4	15
# ARR per annum	10-15	>200
Terms	200 hours	1 hour
Data preparation cost	14000 €	1000 €
Total ARR	50000 €	5000 €

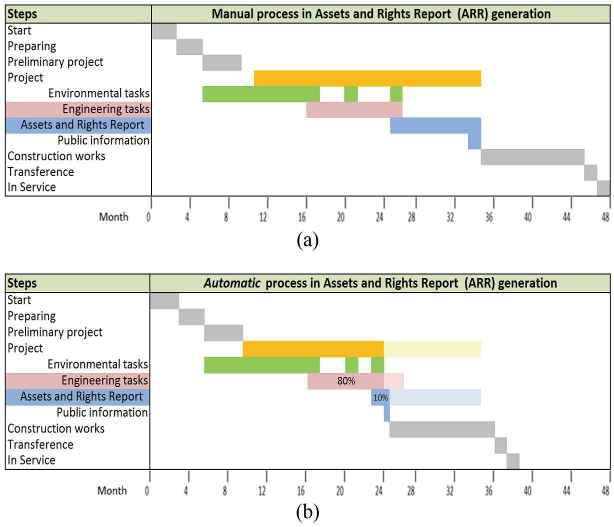

Figure 5. Result values

V. CONCLUSION AND FUTURE WORK

The use of the RBD-MercatorREE software application that automates the workflow processes for the calculation of affections and generation of ARR and integrates geoprocessing, has improved process productivity optimising the following variables: number of ARR generated per annum, number of calculated affections, reliability of the calculations, terms for completion and consequently reduction in the costs of this activity.

Characterisation of the data has allowed us determining that the affections present well defined patterns (lines, polygons, affections without/with codes). These patterns will enable us to develop a new software version that might be personalised for another type of linear construction project such as gas pipelines, roads, railways, etc., thus generalising the developed solution.

Presently and since the Cadastre through its SEC allows the users identified with a digital certificate to download non-protected cadastral data, it is possible to automate other aspects of the workflow such as downloading of cadastral cartography. Likewise the protected information of the plots can also be automated since it is electronically accessible for registered, identified users.

Advances are being achieved in the cartographic representation that will afford a better insight into the connivance of a new installation with the environment. On the one hand it will provide the technicians with an accurate tool for virtual visualisation of the environment and on the other hand it will ensure that the owners affected by a new installation may be able to fully and easily understand the project with the help of the conventional project plans.

Considering the design and architecture of the RBD-MercatorREE software application in three logic layers, the business logic functionalities (calculation of affections and ARR generation) will be exposed on the Internet in the future through programming of other software layers on top of the business logic; those layers may be Web service SOA type interfaces or Web user interfaces through web pages.

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