LADM SPECIFICATION OF A RELATIONAL DATABASE FOR THE REPUBLIC OF CAPE VERDE

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Key words: Land Administration Domain Model, Specification, UML, Relational Database, Cadastre of Cape Verde.

SUMMARY

The Land Administration Domain Model - LADM describes the relations between person and land regarding rights, restrictions and responsibilities. This relation is described through diagrams of UML classes, a graphic language which focuses on objects, and represents different levels of abstraction of the real world by visualizing the work flux of the database and its planning. In this article the classes and their relationships were modeled using a unified modeling language, which considered the national reality and the law decree that establishes the judicial regime of the Cadastre of the Republic of Cape Vert. The transformation of this model into a relational database by using the Postgres and PostGis, was not an easy task due to compatibility problems. The study was based on the application of the OMG (*Object Management Group)* models, MDA (*Model Driven Architecture)* and the CASE (*Computer-Aided Software Engineering*) tools. As a result, the study presents the transformation of the model into a relational database and consequent generation of SQL Codes. For this specification the *Visual Paradigm for UML* was used, which is a CASE tool with various modeling options with the UML2 diagrams, offering support for specific transformations for source codes of some programming languages, such as C++ and Java etc. Despite the fact that this platform offers a direct solution for the transformation of UML into a Java code, and consequently into SQL commands, it has a great disadvantage which is the absence of the OCL language, used as one way of validating the model.

1. INTRODUCTION

In February of 2008, the International Federation of Geometers – FIG presented a proposal for the elaboration of an international standard for the modeling of territorial administration systems, the Land Administration Domain Model - LADM. This model was described in the ISO 19.152 and establishes the relation between person and land regarding rights, restrictions and responsibilities.

The main objective of the LADM is to provide an extensive base for the development and improvement of an effective and efficient cadastral system, based on a MDA (*Model Driven Architecture*) that permits the parts involved, both inside a country and among different countries, to communicate through a shared base implicit in the model. Therefore, the LADM is a standard for territorial administration, supported by software for its implementation.

In the Republic of Cape Verde, the municipal cadastres began to receive greater attention with the publication of the Decree-law n° 29/2009, which establishes the judicial regime of the cadastre of the municipalities of Cape Verde (Cabo Verde, 2009). In this context, the objective of this research study was to propose a conceptual and abstract model based on the LADM and to test its application in a specific database model. With this aim, the study of a platform was carried out for its specification in a relational database, analyzing its limitations and advantages.

Initially, an abstract and conceptual model named the LADM_CV was proposed, with its basic classes and respective attributes; however, with the possibility of other entities being added or removed according to the reality of each municipality or institution. The LADM_CV establishes the relations between the person and the land, described through the rights, restrictions and responsibilities which reflect over the parcels. For the elaboration of the model, the national reality and the decree that establishes the judicial regime of the building cadastre in Cape Verde were considered.

The specification of this conceptual and abstract model through a relational database was carried out by using the platform VP-UML, synchronizing the UML profile to a relational entity model and by exporting to the relational database Postgres. The LADM_CV profile was structured to allow the integration of graphic notation for the stereotypes of the Geoprofile model, where GeoFields, GeoObjects and Networks, Temporal Classes and Spatial Operations are defined. It is also possible to carry out the importation/exportation of models by using the standard format of model exchange XMI (*XML Metadata Interchange*), which allows the operation of the LADM_CV in other platforms.

2. LADM - LAND ADMINISTRATION DOMAIN MODEL

The idea of standardizing a territorial administration model appeared initially as CCDM (*Core Cadastral Domain Model*), through a proposal of the International Federation of Geometers (FIG) in 2002, with the objective of defining a standardized cadastral model, considering the great differences that exist among cadastres in the world (Sucaya, 2009).

In 2008, the FIG presented a new project proposal to develop an international standard named LADM, described in the ISO 19.152. It is not the objective of this article to discuss the ISO 19152, but it is important to point out that the LADM presents the basic packages, with its respective attributes for territorial administration. The system must be capable of allowing the addition and removal of entities according to the reality of each region. The basic classes are the following:

- Parties (people and organizations);
- Basic administrative units, rights, responsibilities, and restrictions (ownership rights);
- Spatial units (parcels, and the legal space of buildings and utility networks);
- Spatial sources (surveying), and spatial representations (geometry and topology);

The model can be implemented by one or more organizations which operate at the national, regional and local levels. This highlights the importance of the model, because different organizations have their own specific responsibilities with regards to the maintenance and supply of data. Besides these basic classes, the LADM presents its basic packages, which represent the extension of the basic classes, facilitating the maintenance of different sets of data by different organizations.

3. THE CADASTRE OF CAPE VERDE

In Cape Verde the territorial information unit is the parcel (*predio*), whether urban or rural, defined as: the bounded part of the judicially autonomous land, including waters, plantations, buildings and constructions of any nature present on them or with any characteristic of permanence and any autonomous fraction in the horizontal property regime (Cabo Verde, 2009). The registration of this parcel in the land registry secures the right of property.

The rural cadastre is of state responsibility, through the Rural Ministry, the General Directory of Agriculture, Forestry and Livestock; while the urban cadastre is the responsibility of the municipalities, with guidelines from the Ministry of Habitation and Territorial Ordinance and Urban Planning, through the sector of cadastre. Since the cadastral services were decentralized to municipalities, they became the responsible entities for the elaboration, maintenance, update and management of the urban cadastral cartography. The information from the cadastre and land registry is not integrated and this institutional vacuum can lead to irregular situations of one or more tittles being recorded over the same parcel, something which could be avoided by instituting a single database, based on the LADM.

There is a deficiency in the organization of cadastral data, however, practically all municipalities have access to cartographic information in digital format (CAD), through which the plants of the location of the land units are emitted. Normally, these localization plants do not guaranty the judicial reliability of the parcel, and are used exclusively for tax collection. With respect to descriptive data, they are filed in analogical format. Some municipalities timidly transformed this descriptive data from analogical format to digital, developing a database in Microsoft Access. In this case, a lack of connection between the graphic and descriptive aspects can be observed. (Andrade and Carneiro, 2012)

The technical details of the cadastral system of Cape Verde will be described in more detail in the following sections, including its modeling according to the LADM standard.

4. MODELING OF THE LADM_CV

The modeling of the LADM_CV was based on the entities of the territorial administration model described in the ISO 19.152, considering the national reality and law-decree that establishes the judicial regime of the Cadastre of Cape Verde.

4.1 CV_Party Package

The package of the Parties can be constituted by one person or group of people, and it maintains the relation with the administrative package. This means that the parts have or don't have a kind of right, restriction or responsibility at the level of an administrative unit denominated CV_BAunit.

The CV_GroupParty is a subclass of the CV_Party, it can be constituted for two or more people, that is, it can be a family, a tribe, an association, a company, etc. The CV_PartyMember is a class of optional association, and it occurs when the condition of property extends to more than one individual, that is, when a spacial unit possesses many owners, which allows shared property (see Figure 1).

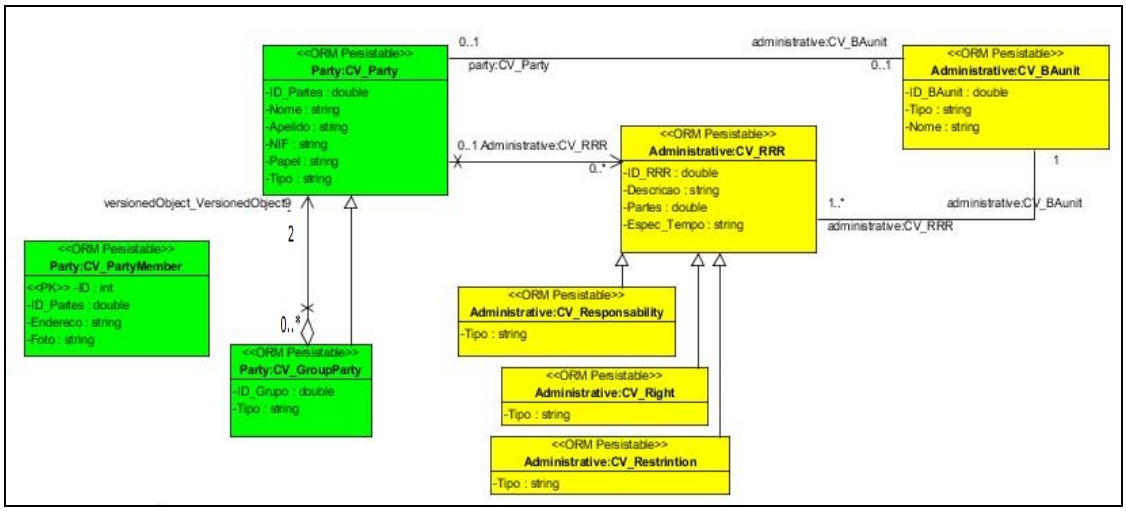

Figure 1. The basic classes of the CV_Party

4.2 CV_ Administrative Package

The land administration model establishes the relation between the people and the land. This relation goes beyond guarantying the right to property of the person, it also establishes the restrictions and responsibilities for each type of property according to the reality and the legislation of each country.

All three CV_Right, CV_Restriction and CV_Responsibility are subclasses of the CV_RRR, and are based on a legal document which, in the model, would be the CV_AdministrativeSource . The CV_Right guarantees, aside from the right to property and of possession, various other rights: the right to lease, of water, electricity, etc. The CV_Responsibility, is applicable when there is a right (recorded / registered). This responsibility, for instance, would be that of maintaining a monument, maintaining a watercourse, preserving a natural reserve, etc. The CV_Restriction can be both of private or public right, especially as easements, areas of public domain, by way of zoning and planning restrictions, as well as other limitations of environmental character. The relations among these classes are represented in Figure 2.

Within the CV_RRR there is the CV_Mortgage, which cannot be seen as a separate relation from the CV_Party.

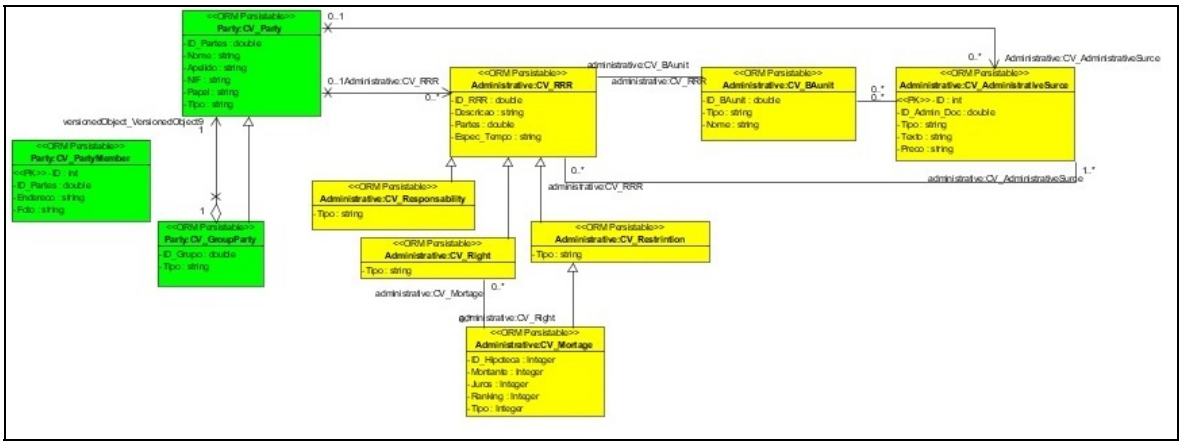

Figure 2. The basic classes of the CV_ Administrative Package

4.3 CV_Spatial Unit Package

The package of the CV_SpatialUnit is the essential element of this model and it is subdivided into the cadastral units CV_LegalSpaceBuildingUnit and CV_LegalSpaceUtilityNetwork. The concepts of the law decree 29/2009 were considered for the creation of the CV_SpatialUnit. The information which describes this unit is distributed through its attributes, from its description to its update (Figure 3).

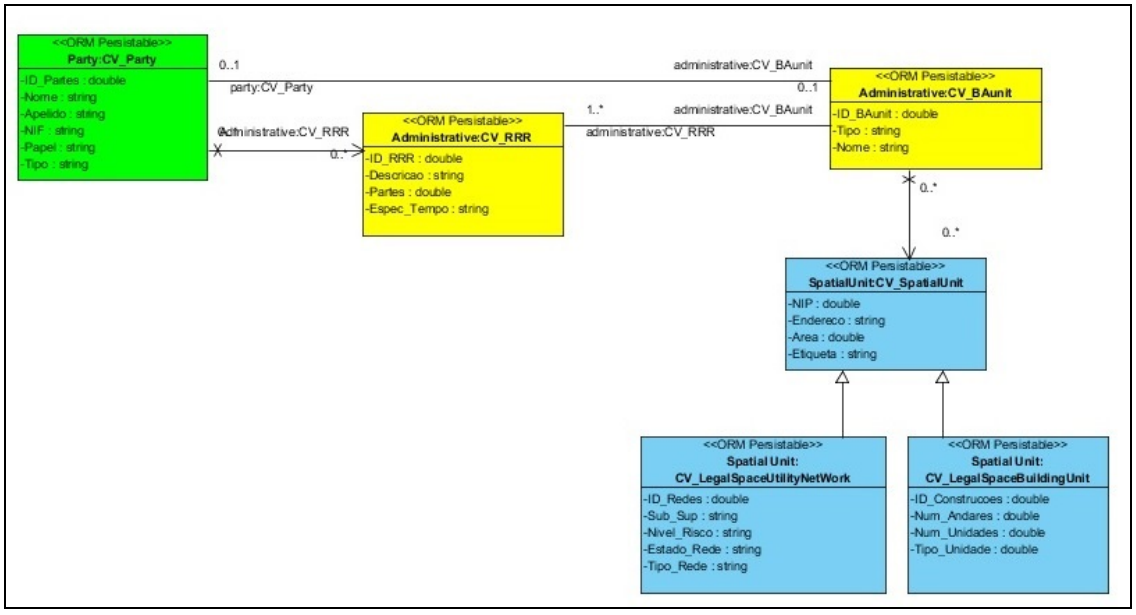

Figure 1. Basic Classes of the CV_Spatial Unit Package and their relationships.

The subclass CV_LegalSpaceBuildingUnit is of extreme importance for this model, since the law decree 29/2009 describes the parcel as a cadastral unit for the Republic of Cape Verde. The same sort of relationship and cardinality occurs between the CV_LegalSpaceBuildingUnit and the CV_Sub_LegalSpaceBuildingUnit.

The subclass CV_LegalSpaceUtilityNetwork was contemplated in the model and described according to the type of network and the level of risk it presents. In this CV_LegalSpaceUtilityNetwork, it is possible to highlight roadways, telecommunications networks, electricity networks, sewage networks, water network, etc. (see Figure 3).

4.4 CV_Surveying and Representation Subpackage

The CV_SpatialSource package presents the metadata of the model. It identifies all the documentation of the observations carried out in the field, the measurements, the method or the way of surveying of the spatial unit and type of document used, for instance, orthophotos and field sketches. The LADM proposes the modeling in 2D and 3D, however, the LADM_CV only contemplates 2D, represented by the subclass CV_BoundaryFaceString, which describes the CV_SpatialUnit, which is associated to CV_Point for the documentation of all its geometry (Figure 4).

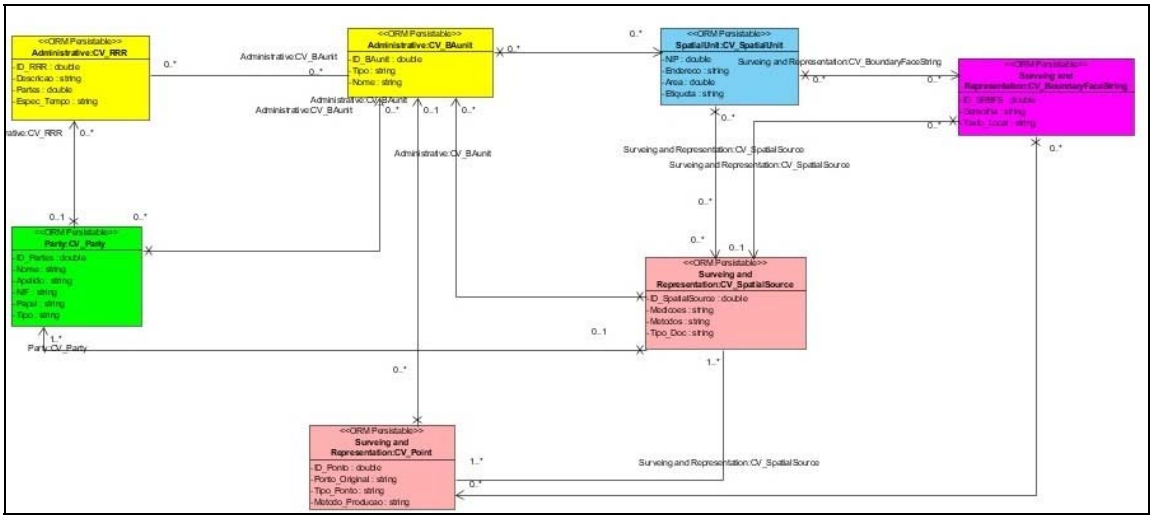

Figure 4.2 Package of the Document of CV_SpatialSource.

5. SPECIFICATION OF THE LADM_CV INTO A RELATIONAL DATABASE

The implementation of the conceptual model demands the study of the most adequate platform for the implementation of the model. Hespanha (2012), for example, presents the specification of UML in a relational database, where the procedure begins with a number of UML packages being exported from EA (where all the original modeling was done) and parsed into Eclipse UML 2.0 class models and diagrams, enabling then subsequent

processing, which ultimately produced an implementation into a PostgreSQL/PostGIS spatial database. More precisely, the final result corresponds to an Object-Relational Mapping with two components which are consistently synchronized: A Java abstract layer, accessible to other applications running under the Eclipse IDE; and the corresponding database schema, which can be further populated with data through either one of the components.

In this study, the option was to test a platform that allowed the specification of the conceptual and abstract model into a relational database more directly. The choice of the VP-UML resides in its capacity of executing the whole modeling cycle, from the construction of the UML diagrams until its implementation in a database.

For this modeling, the MDA *(Model Driven Architecture)* technique was used, supported by CASE *(Computer-Aided Software Engineering)* tools, being implemented in the IDE *(Integrated Development Environment)*, denominated as Visual Paradigm for UML.
This procedure started with the modeling of the LADM_CV packages in UML. After, these packages were synchronized in models of relational entities allowing their exportation to the PostgreSQL / PostGIS. The Figure 5 shows the steps of the work.

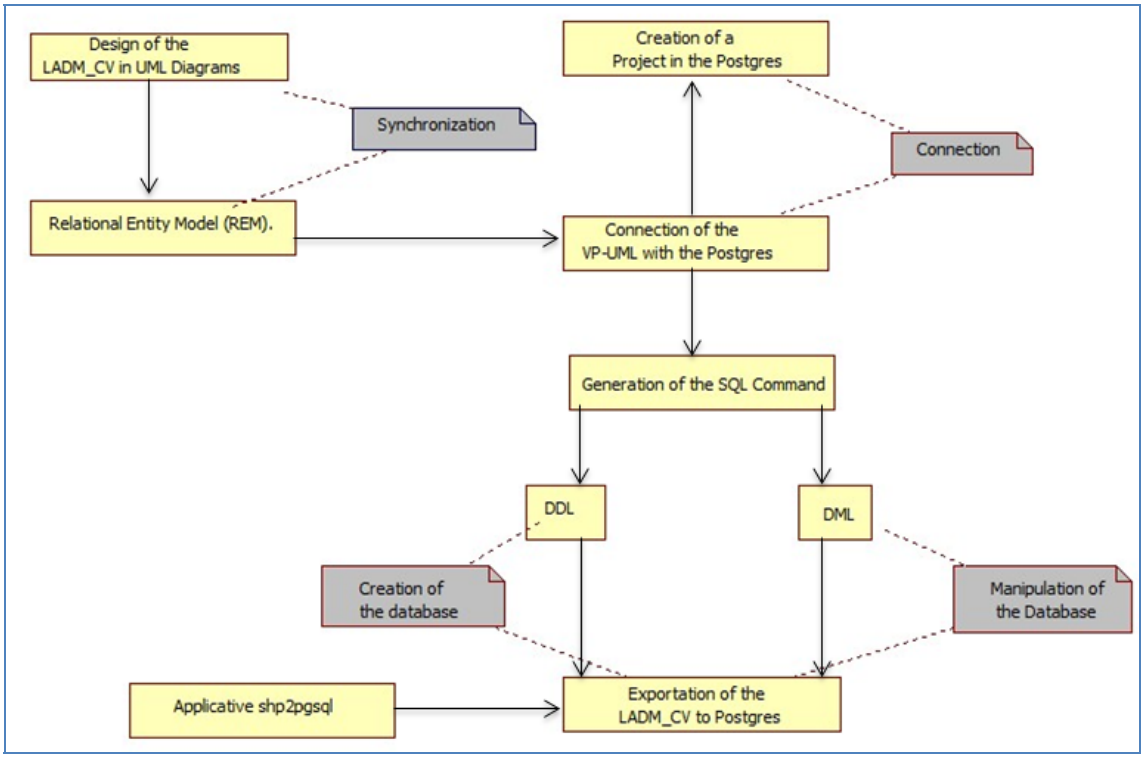

Figure 5. Flowchart showing the specification of the LADM_CV in a relational database.

5.1 Techniques of MDA for the specification of the LADM_CV

The MDA (*Model-Driven Architecture)* started with the well known and established idea of separating the different phases of the specification of the operation of a system, by detailing the way the system uses the capabilities of its platform. While the specification of a CIM (*Computer Independent Model*) does not show details of the structure of a system and

sometimes it is called a domain model, the PIM *(Plataform Independent Model)* exhibits a certain specified level of independence of platform, so that it is adequate for use with a number of different platforms of similar type. On the other hand, the PSM *(Plataform Specification Model),* sees the model from the point of view of the specific platform, that is, it combines the specifications in the PIM with the details which specify how the system uses a particular type of platform.

The Visual Paradigm platform for UML (Figure 6) is a CASE tool which has various modeling options with the UML 2.0 diagrams, and which also offers support to Relational Entity Diagrams. It has a good work environment which facilitates the visualization and manipulation of the modeling project. It is a commercial tool and also offers support to specific transformations for source codes of some program languages such as C++ and Java.

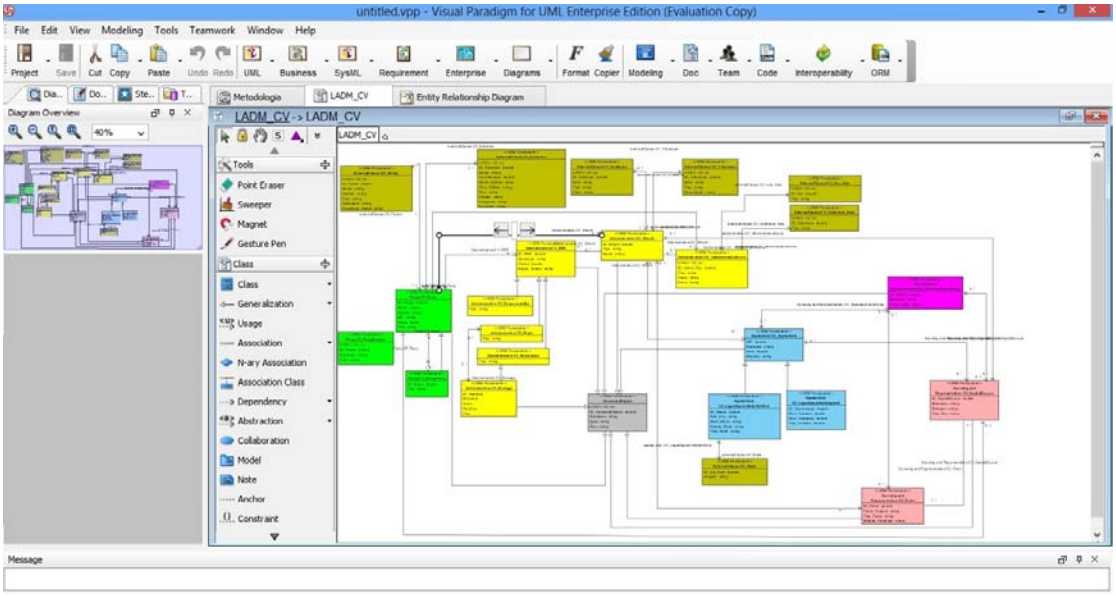

Figure 6. Modeling of the LADM_CV in the Visual Paradigm.

The Unified Modeling Language (UML) is a graphic notation for drawing diagrams of software concepts. One can use it for drawing diagrams of a problem domain, a proposed software design, or an already completed software implementation. (Martin, 2002).

Consider, for example, the following phrase: (CV_Sub_Parcel) □ (CV_Parcel). The conceptual UML diagram which represents this phrase is shown in Figure 7.

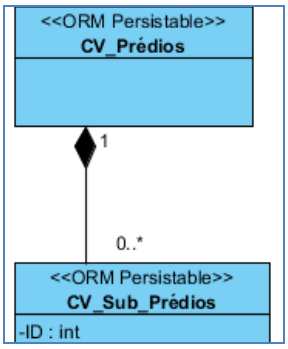

Figure 7. Spatial Aggregation (Part of a whole)

The spatial aggregation indicates that the geometry of each part must be contained in the geometry of the whole. The overlap between the geometry of the parts is not allowed and the geometry of the whole must be totally covered by the geometry of the parts, configuring a partition of the plan or subdivision.

The diagrams of UML classes denote the static content and the relations among the classes, therefore while the class diagrams are being modeled, their source codes are being generated. The class diagrams, aside from representing the visual structure of the model, also generate their source codes (Preparata and Shamos, 1985).

5.1.1 Elaboration of the Relational Database Project

An empty database project was created (LADM_CV) in the PostgreSQL, 9.1 with the spatial extension Postgis 1.5 (Figure 8). The data base server was configured, and here the user name and password for the superuser were defined.

```
CREATE DATABASE "LADM_CV"
  WITH ENCODING='UTF8'
       OWNER=postgres
       TEMPLATE=template_postgis
       CONNECTION LIMIT=-1;
```

Figure 8. Command SQL for the creation of the Database Project of the LADM_CV in the Postgres.

Immediately after, the work began on the configuration for the connection of the Visual Paradigm for UML 10.1 with the Postgresql, using the Java language, with the JDBC (*java database connection*) connection driver and doing the connection through the server created previously in the Postgresql, using the name and password of the superuser (see Figure 9).

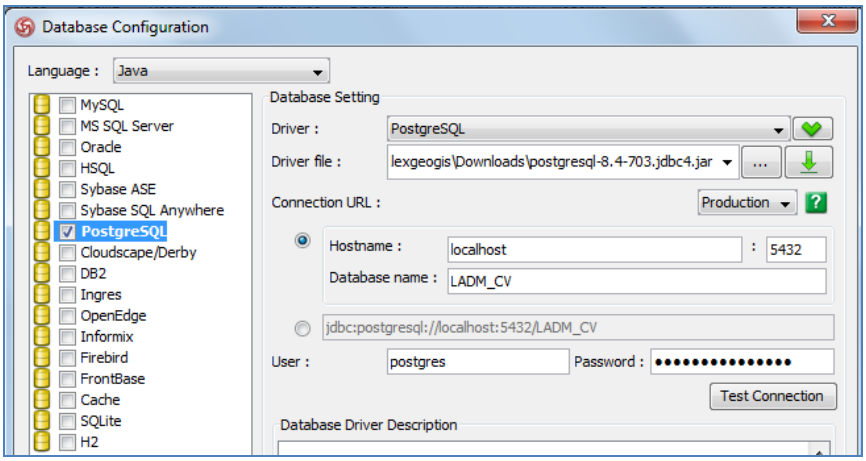

Figure 9. Configuration of the Visual Paradigm connection with the Postgres.

When the connection was made between the Visual Paradigm and the Postgres, the model in UML was transformed into a relational database schema (see Figure 10). The Entity-Relation Model describes the whole logical structure of the LADM_CV, constituted from the conceptual and abstract model.

Figure 10 shows the representation of the LADM_CV classes in a relational entity model, where it is possible to observe the classes which were generalized and the class which stores the information of the database history. The class which was generalized into a UML project, when converted into tables represented by lines and columns in a relational database, carries all the attributes of those classes. Class CV_VersionedObject stores the information of classes CV_BoundaryFace , CV_Point , CV_SpatialUnit , of CV_Party, CV_AdministrativeSource , CV_RRR, CV_Source, and class CV_Mortgage. When it was converted into a rational database, a single table was generated which carries with it all the attributes of those classes.

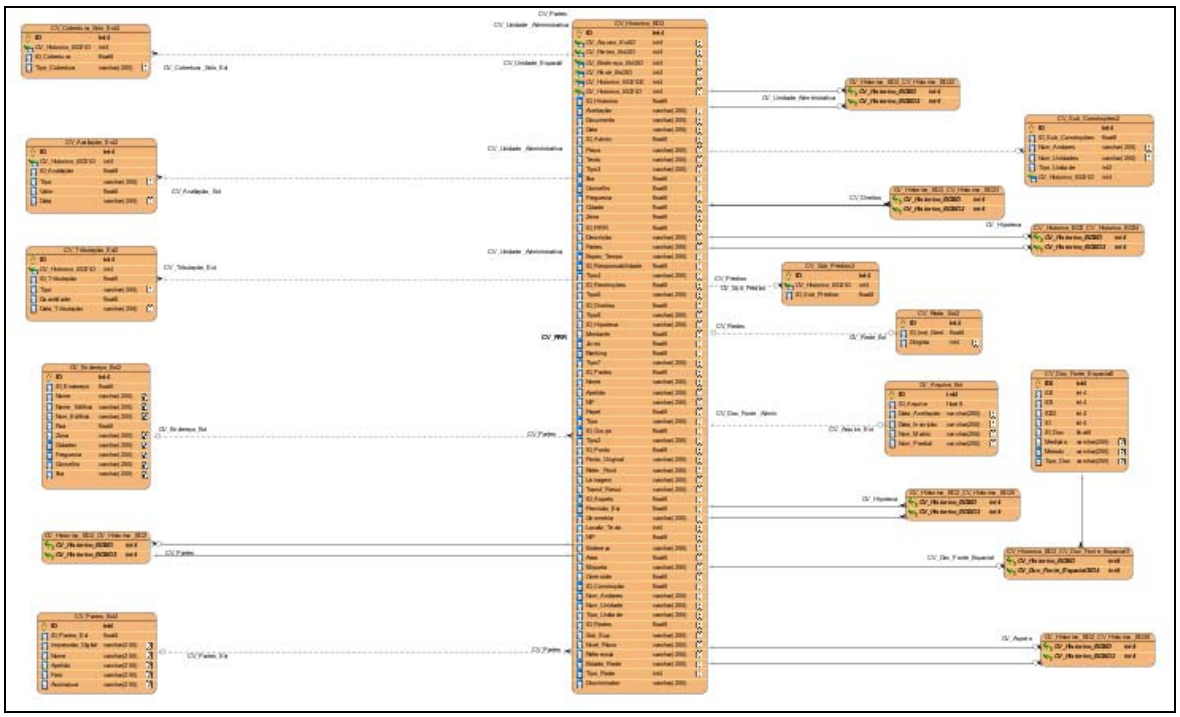

Figure 10. Generation of the relational entity model from the diagram of classes.

After having transformed the abstract model into a relational entity model, work started for the generation of the database in the Postgres (see Figure 10). From this connection, the database was generated from the SQL command (see Figure 11), which itself is generated from the Relational-Entity Model.

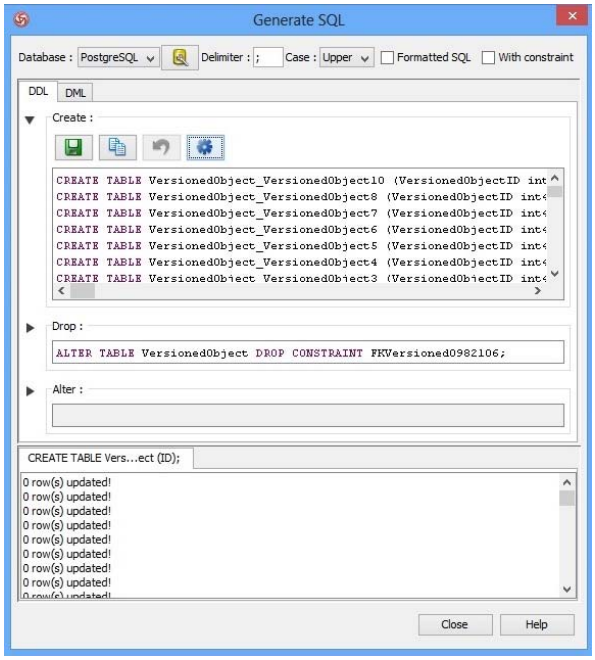

Figure 11. Generation of SQL in the Visual Paradigm for the database in the Postgres.

Figure 12 shows the screen of the Postgres with the classes which were generated from the relational entity model.

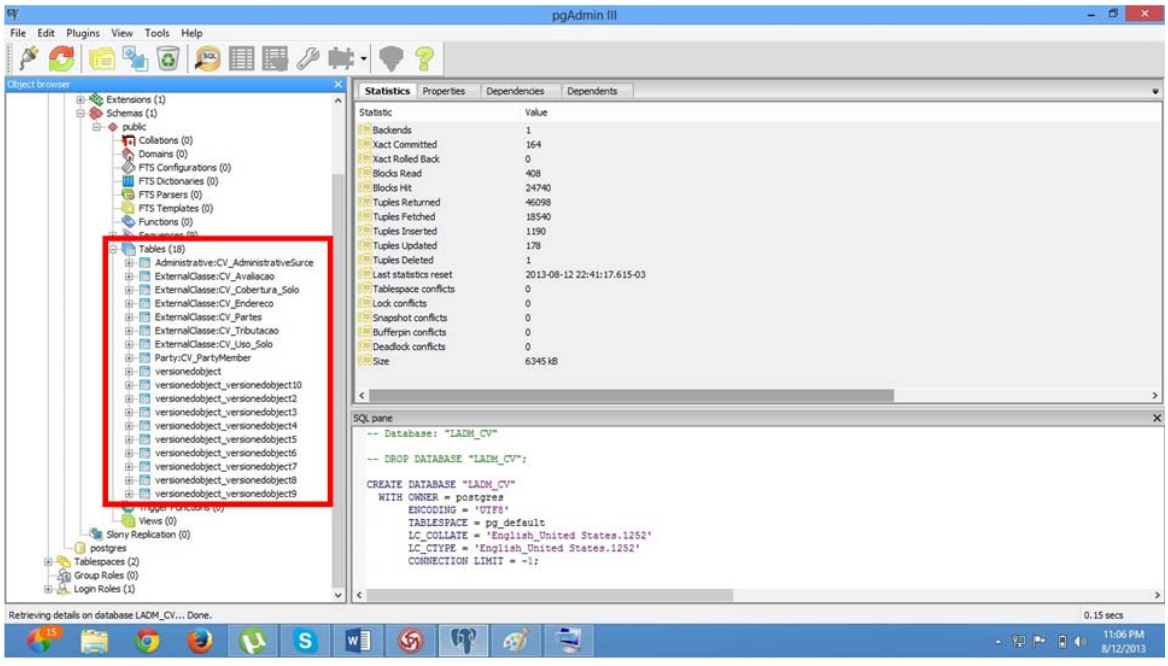

Figure 12. Exportation of the Relational Entity Model to the Postgres database.

5.1.2 Manipulation of the Database

One of the most practical ways of manipulating the database is to use the commands *"SELECT, DELETE, INSERT AND UPDATE"*, preparing a script SQL *(Structured Query Language)* and then executing this script through lines of command of the database. However, the whole modeling was carried out in the Visual Paradigm, where the SQL code was generated, which is subdivided into two great groups: DDL (*Data Definition Language*), used in the management of the structure of indexes and tables, and DML (*Data Manipulation Language*), used for operations of addition, exclusion and update of data. The first is responsible for the creation, modification and management of tables, while the second creates the structures which will contain the data, that is, the feeding and management of data. The *Visual Paradigm* already has ready SQL scripts which, when connected to the database and exported to the PostGres, they can be executed and the information will be stored in the database (see Figure 13).

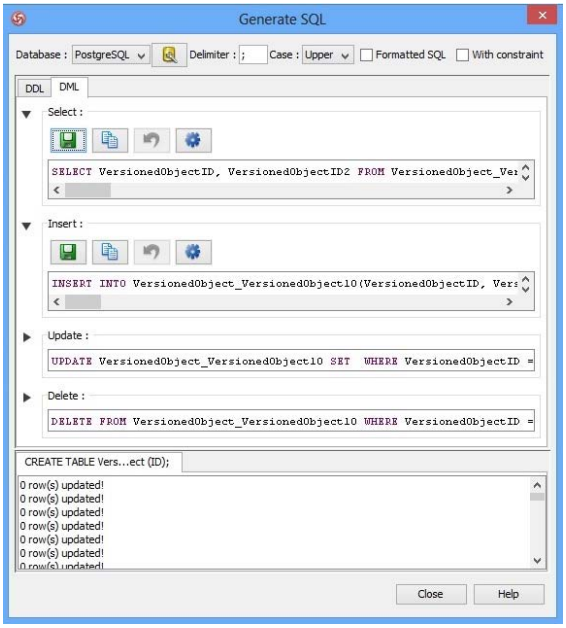

Figure 13. Interface to Select, Insert, Update and Delete information in the Database.

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5.1.3 Manipulation of the spatial classes

With respect to the spatial classes, after the generation of the descriptive databases, they are mapped in tables by using the applicative shp2pgsql of the Postgis, (see Figure 14). Another way of integrating the spacial classes into the database is through the use of a GIS (Geographic Information System) application, such as for example, the QuantumGIS, which is capable of carrying spatial data to a PostGIS database by using the "SPIT" tool *(Shapefile para Postgis Import Tool)*.

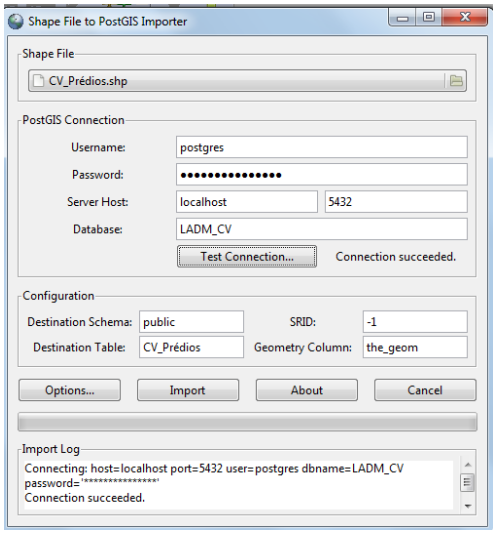

Figure 14. Importation of the spatial classes to the Postgis.

6. CONCLUSIONS

The majority of software projects involve a multidisciplinary team, therefore the modeling of a system using one standard facilitates the communication among its members. This study presented a proposal for conceptualizing the cadastre of Cape Verde based on the LADM, and its implementation through a relational database. In this proposal, the CASE tool was used to transform the abstract and conceptual model of the LADM_CV into a relational database.

The Visual Paradigm platform of this CASE tool supplies a direct solution for the specification of the UML model into a relational database. The UML is a standardization of the OMG (*Object Management Group*), and one of its main advantages is the fact that it is entirely extensible and adaptable. The UML 2.0 was used in this study because other software involve a complex application with layers implemented in programming languages directed at objects and, at the same time, the use of relational database systems.

The results showed that the LADM standard was considered adequate for the land administration system of Cape Verde, regulated by the Law-Decree 29/2009.

The relational database model presents as contributions a greater level of data independence than conventional models (of networks and hierarchies), and the unification of the representation of these models through the graphic formalism of the Entity-Relation Diagram. An inclusion dependence in a UML project represents the cardinality of “many-to-many” in a database. On the other hand, the aggregation dependence is the representation of “many-to-one”.

The VP-Paradigm platform offers a direct solution of specification of the UML model in a relational database, however, there is a great limitation with respect to the acceptance of the OCL language, for it is a language of restrictions to objects.

ACKNOWLEDMENTS

Many thanks to the *Centro de Tecnologia e Geociências (CTG), Departamento de Engenharia Cartográfica (Brazil)*, and most especially to the *Programa de Pós-graduação em Ciências Geodésicas e Tecnologias de Geoinformação*. To the City Council of S. Filipe (Cape Verde), thanks for making the information for the research study available. To the UC-CP, (*Unidade de Coordenação do Cadastro Predial*), thanks for keeping me informed of all the work that is being developed in the area of cadastre. To the *Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPQ),* thanks for the concession of the scholarship for two years to the author Alex J.B. Andrade.

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