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Cadastral management and maintenance in Costa Rica using the geodatabase model.

Esteban A. Mora Vargas
The University of Montana

THE UNIVERSITY OF MONTANA

CADASTRAL MANAGEMENT AND MAINTENANCE IN COSTA RICA USING THE GEODATABASE MODEL

by

Esteban A. Mora Vargas

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Cadastral Management and Maintenance in Costa Rica Using the Geodatabase Model

Committee Chair: Paul B. Wilson

The Costa Rican cadastre is in the process of becoming a digital land information system (LIS). This is being accomplished by means of converting the cadastral datasets (both geographic and alphanumeric) into digital formats for its use with geographic information systems (GIS).

The geodatabase model developed by ESRI® for use with their ArcGIS™ 8.3 software, can be used for cadastral purposes in Costa Rica if a suitable database schema is designed. Feature datasets, feature classes, object classes, relationship classes, attribute domains, and topology rules can be created to aid in the storage, management, and maintenance of cadastral datasets, both spatial and alphanumeric in kind.

The main goals of this work were the creation of a geodatabase schema and a cadastral maintenance model, suitable for the cadastral datasets and information needs of Costa Rican municipalities.

In order to develop a suitable cadastral geodatabase schema for Costa Rican municipalities, several elements affecting the cadastre and the cadastral system need to be considered and studied. Modern concepts of multipurpose cadastre (like the "Cadastre 2014" work by the International Federation of Surveyors), specific cadastral information needs in the Costa Rican setting, modern GIS and database technologies, and geodatabase schema templates (like the ArcGIS™ Land Parcel Data Model by ESRI® and Fairview Industries) among others, are important factors in the development of a geodatabase schema.

A total of five feature datasets, fifteen feature classes, eight object classes, twelve relationship classes, twenty-one attribute domains, and seven topology rules were created within the geodatabase schema designed in this work. The schema developed is suitable to aid the Costa Rican municipalities in the fulfillment of their cadastral information needs, and in the accomplishment of their functions as local governments.

To my family, my friends, and
everybody who helped me
in order to accomplish this work

CONTENTS

CHAPTER ONE

INTRODUCTION

Governments nowadays manage a considerably large amount of data about the land and the land parcels under their jurisdiction. Information about the legal owners, possessors, usufructuaries, or awardees is also stored. Other interests on land such as encumbrances or restrictions are also recorded in order to have a complete legal description of the land. Usually, the purpose of the data is to accurately describe the land and its value for taxing purposes. However, it may be used for many different governmental applications such as planning and resource management.

Cadastral data is usually of two types: the graphic representation of the land objects, and the attribute data describing them. This collection of data is usually referred to as Cadastre.[1] The graphic representations may be in the form of paper or digital maps, and are commonly referred to as geographic or spatial data.[2]

The cadastre is "a methodologically arranged public inventory of data concerning properties within a certain country or district, based on a survey of their boundaries."[3] Modern cadastral systems all over the world are maintained using Geographic Information Systems (GIS). A GIS is a stand alone computer program or a cohort of programs that are used to manipulate attribute and geographic datasets.[4]

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[1] The terms "cadastre" and "cadastral datasets" are used interchangeably throughout this work.

[2] The words "geographic" and "spatial" are used interchangeably throughout this work.

[3] Jo Henssen. *Basic Principles of the Main Cadastral Systems in the World*, in Proceedings of the One Day Seminar held during the Annual Meeting of Commission 7, Cadastre and Rural Land Management, of the International Federation of Surveyors (FIG), Delft, The Netherlands, May 16, 1995, page 1 [paper on line]; available from http://www.fig.net/figtree/commission7/reports/events/-delft_seminar_95/paper2.html; Internet; accessed on September 18, 2003.

[4] Refer to Chapter Two of this work for an extended definition of GIS and its basic components.

When the cadastre is fully managed and integrated using a GIS, and a complete multidisciplinary description of the land is maintained, the system is usually called a Land Information System or simply "LIS."

The Purpose of this Work

This work involves the interaction of the author with two municipalities. These are the Municipality of Barva County and the Municipality of Heredia County, both located in the province of Heredia, Costa Rica. The main purpose of this interaction is to get acquainted with the activities that the cadastral departments perform and the data needs of Costa Rican municipalities.[5]

The main goals of this work are a geodatabase[6] schema and a maintenance model suitable for a Costa Rican municipality, using Barva County and Heredia County as representative examples of Costa Rican municipalities. These must consider the needs of a modern multipurpose cadastre for the storage, management, and maintenance of cadastral data. Both, the geodatabase schema and the maintenance model should be suitable for the cadastral characteristics of these counties and therefore, for the general Costa Rican setting. The schema of a database describes its structure or design.[7]

The Geodatabase Model is the most recent development by the Environmental Systems Research Institute (ESRI®) for the storage and management of geographic and attribute datasets to be used in a GIS. This work takes advantage of the geographic information system called ArcGIS™ 8.3 by ESRI®. The geodatabase (short for

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[5] The author uses the phrases "Municipality of Barva County" and "Barva County" interchangeably throughout this work to refer to the Municipality of Barva County. The same holds for the phrases "Municipality of Heredia County" and "Heredia County".

[6] Please refer to Chapter Two of this work for an extended definition of the geodatabase model by ESRI®.

[7] Andrew MacDonald, *Building a Geodatabase* (United States of America: ESRI®, 1999-2001), 467.

“geographic database”) is an object-oriented database. An object is the representation of a real-world entity stored in a geodatabase and it has properties and behavior.[8]

The populations of Heredia County and Barva County are 104.558 and 32.481 persons respectively. Even though the Municipality of Heredia County has a larger number of inhabitants, its GIS is in a more primitive stage than the one maintained by the Municipality of Barva County. As of December of 2003, the program ArcView™ 3.2 was used by the Municipality of Heredia County to store, manage, and give maintenance to the spatial and attribute datasets of the municipality. The Municipality of Barva County was using ArcGIS™ 8.2 for the same purposes. Cadastral layers and attribute tables that describe the parcels have been created by both municipalities. This data will be analyzed and used as input for the geodatabase schema design.

Figure 1 and Figure 2 illustrate the administrative division in Costa Rica into provinces, and the counties of the southern part of the province of Heredia respectively.

Figure 1. Provinces of Costa Rica

[8] Ibid., 466.

The Costa Rican cadastral system is managed by a central office called *Catastro Nacional* (National Cadastre). This system consists basically in the legal registration of the land parcels and is the depository of the official cadastral map (plat) for each one of the surveyed land properties. This office does not maintain any national digital cadastral map or database for the local governments to access.

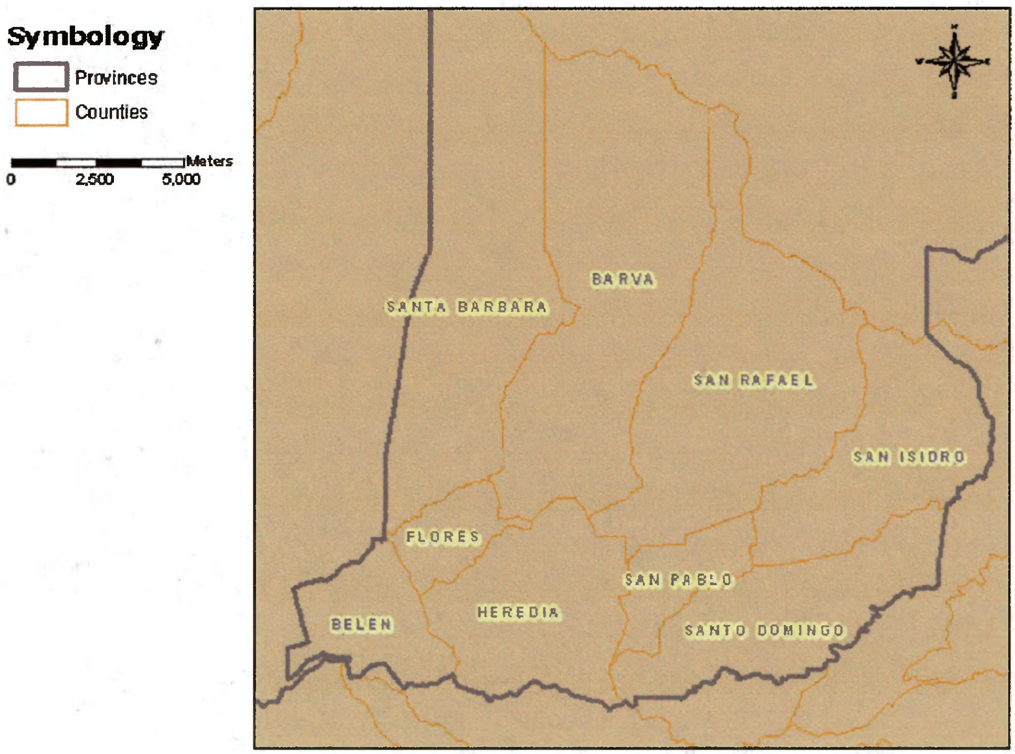

Figure 2. Counties in southern Heredia

Local governments (Municipalities) in Costa Rica have their own cadastral maps and records. The Costa Rican cadastre is a fiscal cadastre, that is, it is based on the concept of tax parcels. Tax parcels arise from the real property tax systems, where land is valued, assessed, and taxed to support government functions.[9] The collection of taxes from land ownership, and fees due to patent awarding are the primary sources of income of Costa Rican municipalities.

A main goal of most municipalities is to have an accurate description of the parcels under their jurisdiction in order to be able to perform an accurate value assessment if needed. According to the Costa Rican law, the value of a parcel can also be provided by the legal owner or possessor by means of an official declaration. Once the value has been determined, the appropriate taxes are calculated and billed according to Costa Rican law.

A large share of municipal efforts and resources are invested in updating the databases and maps with the modifications that land parcels undertake. These modifications usually involve one or more of the following: a change in the shape and/or size of parcels that affect the geographic datasets; a change in the legal situation, rights, or interests on a parcel; a change in other attributes that are being recorded in the descriptive database for the parcels.[10]

Once any event that affects a parcel's shape, size, or description takes place, the cadastral datasets need to be updated. The map that represents all the properties and the attribute database with all the related information must both be modified as soon as possible. If this is accomplished, the local government will have the updated information that is required to perform its functions, and also to make it available to the general public.

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[9] Nancy von Meyer et al., *ArcGIS Parcel Data Model Version 1* (July 2001), page 32 [paper on line]; available from http://support.esri.com/index.cfm?fa=downloads.dataModels.byLabel&dmid=11; Internet; accessed on November 11, 2003.

[10] The descriptive database is usually called "attribute database."

Modifications regarding the rights and interests in a parcel, or the shape and/or size of the parcel itself are usually recorded in official plats and/or deeds. Both the deeds and the plats are common inputs to the cadastral system in Costa Rica. A deed is a written document, properly signed and delivered, that conveys title to real property.[11] Deeds are usually created by a certified lawyer in Costa Rica. A plat is a plan or map of a specific land area.[12] In Costa Rica, a plat is the product and representation of an official survey performed by certified surveyor. The plat is composed of both graphic and alphanumeric data describing the shape, size, and location of a parcel along with brief information about the rights and interests on it.

The updating processes of cadastral datasets may be accomplished using a cadastral maintenance model. This is simply a set of procedures to update the cadastral records with any modification that has taken place. The use of a cadastral maintenance model may improve the cadastral activities and therefore, the tax assignation to the property owners. Furthermore, this may increase the income of the municipality. As an example, currently the Municipality of Barva County is not charging taxes to every parcel owner because not all the properties are properly mapped and registered in the cadastral database.

The base of the cadastral system is without a doubt the cadastral data, both spatial and tabular (i.e. descriptive attributes) in kind. The emphases of this work are the data storage structure itself and the maintenance procedures needed to keep the cadastral datasets updated.

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[11] Jack P. Friedman, Jack C. Harris, and J. Bruce Lindeman, *Dictionary of Real Estate Terms, Third Edition* (United States of America: Barron's Educational Series, Inc., 1993), 85.

[12] Ibid., 255.

CHAPTER TWO

CONCEPTS IN CADASTRE AND GIS

The use of geographic information systems (GIS) to store and maintain the cadastre is common in many countries of the world.

The purpose of this chapter is to define the key concepts that are required to pursue this work and that will be used throughout it. These concepts are needed for the understanding of this work as a whole, with its objective being the application of modern computer programs and technologies to cadastral activities. Among these concepts are those of cadastre, GIS, conceptual models of space, multipurpose cadastre, LIS, and object oriented modeling. The concepts and theories of multipurpose cadastre and database object modeling are important for this work as well. Current technology such as object oriented computer programs and digital databases are used in this work.

The Beginnings of the Cadastre

The cadastre is "a methodologically arranged public inventory of data concerning properties within a certain country or district, based on a survey of their boundaries."[13]

The earliest direct evidence of mapmaking comes from the Middle East where archeologists have discovered several maps inscribed on clay tablets. One of the earliest was found in Nuzi in northern Iraq, dated 2300 B.C., the age of Sargon of Akkad. The map shows settlements, streams, and hills or mountains. Written information on it gives the dimensions of cultivated plots of land. The map specifies orientation using three of the four cardinal points. Clay tablets from about the same time as the Nuzi map contain

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[13] Henssen, 1.

surveying notes for the purpose of taxing property. Cadastral maps seem to have been common in ancient cartography in Mesopotamia and Egypt. Plans of properties and towns in ancient Babylonia were inscribed on clay tablets, a number of which survive, the earliest dating from 2000 B.C.[14]

The cadastre has been in the minds of people since ancient times. Once the land started to be divided and used by persons, maps that show where the land is located (in relation to other lands) and who is in charge of a given parcel were required in order to administer the land. The main purpose of the cadastre has not changed substantially since it was first conceived in the ancient time of Mesopotamia. In modern times, the main purpose of the cadastre still is to have a record of the information related to the real estate of a region or a country.

Modern Cadastre

Since its beginning, the basic purpose of the cadastre has been to keep a record of the land properties. However, at present the tools available to achieve whatever tasks are needed (i.e. map making and record keeping) are usually in digital format such as computer databases and programs. Usually, this means that these tasks can be accomplished in a more efficient manner, and automated analysis can be performed with the data.

Because society and human settlements become more complex every day, a modern cadastre or Land Information System needs to accommodate more data about the real estate and about the rights and the people related to it. A modern cadastre should then use modern tools in order to deal with modern problems and cadastral activities.

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[14] John Noble Wilford. *The Mapmakers* (New York: Alfred A. Knopf Inc., 1981), 8-9.

Multipurpose Cadastre

The concept of "multipurpose cadastre" is what may be called a modern cadastre. Multipurpose cadastre must address modern problems and their dynamic nature.

The concept of multipurpose cadastre can be very broad and even coarse. Furthermore, it is a concept that is likely to be different in every particular setting that is to be implemented. The characteristics of the data, the parcels, the laws affecting the land, and the information and cadastral needs of a given municipality or country contribute to modify the definition of multipurpose cadastre that is to be used.

The work called Cadastre 2014 is an insight in the needs and characteristics of a modern multipurpose cadastre.

Cadastre 2014

The International Federation of Surveyors (FIG[15]), through its Commission 7 called Cadastre and Land Management, makes important contributions to cadastral problems worldwide. In 1994, a working group of Commission 7 called Vision Cadastre started an analysis of the cadastral systems all around the world, and of the possible future cadastral trends and needs for the next twenty years. It was made by means of a survey that asked representatives of thirty-one countries to evaluate their cadastral systems.

The evaluation was conducted using a questionnaire created by the working group for this purpose. From this questionnaire six statements were devised and the term

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[15] FIG was founded in 1878 in Paris. "It is a federation of national associations and is the only international body that represents all surveying disciplines. It is a UN-recognised non-government organization (NGO) and its aim is to ensure that the disciplines of surveying and all who practise them meet the needs of the markets and communities that they serve." FIG Commission 7's world wide web site is http://www.fig.net/figtree/general/leaflet.htm.

"Cadastre 2014" was coined and used in relation to the six statements.[16] The results of this first questionnaire were discussed in the annual FIG meeting in 1995. After analyzing these results a second questionnaire was made in the 1996 meeting focusing on the cost recovery aspects and on the privatization of cadastral systems. The six statements of Cadastre 2014 were discussed and verified again. The results of the second questionnaire were discussed and the final results approved in the annual FIG meeting in 1997. The summarized conclusions of this work are:

> The cadastral systems in developed countries attempt to be too perfect. This perfectionism results in weighty procedures and slow and expensive services. In consequence, one aim of the cadastral reform projects is to improve services of the cadastral systems.
>
> The automation of cadastral systems is widely seen as an appropriate tool to improve the performance of cadastral systems. Automation, however, of the traditional perfectible systems without re-engineering the procedure aspects may result in performance failure.
>
> The innovation of cadastral systems tends to be in the direction that cadastral systems will be embedded in land information systems.
>
> Cost recovery and privatization issues are increasingly important within the context of cadastres.
>
> Cadastre 2014 will be a complete documentation of public and private rights and restrictions for land owners and land users. It will be embedded in a broader land information system, fully co-coordinated and automated, without separation of land registration and cadastral mapping. It will remain a public task, although operational work will be done by private organizations, and it will have a 100% cost recovery.
>
> Cadastre 2014 can provide optimal services to the different societies at a lower cost than today's systems. It will not only concentrate on private rights, but increasingly on public rights and restrictions as well. (Kaufmann 1998, 1)

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[16] Jurg Kaufmann and Daniel Steudler, *Cadastre 2014*; page 1 [paper on line] (Working Group 1, Commission 7, FIG, July 1998), available from http://www.swisstopo.ch/fig-wg71/cad2014.htm; Internet; accessed on November 11, 2003.

The work presented by Prof. Jo Henssen at the annual FIG meeting in 1995 was the basis for the formulation of Cadastre 2014. The following are Henssen's concepts for land, cadastre, land registration, and land recording:

> Land: Land is defined as an area of the surface of the earth together with the water, soil, rocks, minerals and hydrocarbons beneath or upon it and the air above it. It embraces all things which are related to a fixed area or point of the surface of the earth, including the areas covered by water, including the sea.
>
> Cadastre: Cadastre is a methodically arranged public inventory of data concerning properties within a certain country or district, based on a survey of their boundaries. Such properties are systematically identified by means of some separate designation. The outlines of the property and the parcel identifier normally are shown on large-scale maps which, together with registers, may show for each separate property the nature, size, value and legal rights associated with the parcel. It gives an answer to the question where and how much.
>
> Land Registration: Land registration is a process of official recording of rights in land through deeds or as title on properties. It means that there is an official record (land register) of rights on land or of deeds concerning changes in the legal situation of defined units of land. It gives an answer to the questions who and how.
>
> Land Recording: Land registration and cadastre usually complement each other, they operate as interactive systems. Land registration puts in principle the accent on the relation subject-right, whereas cadastre puts the accent on the relation right-object. In other words: the land registration answers the questions as to who and how, the cadastre answers the questions as to where how much. (Kaufmann 1998, 13)

These concepts are embraced and used by the author throughout this work. The concept of "land object" is stated in Cadastre 2014 as "a piece of land in which homogeneous conditions exist within its outlines." These homogeneous conditions are described by laws. A "legal land object is a piece of land where either a private or a public law imposes identical juridical parameters for all the land objects." Examples of legal land objects are private property parcels, areas where traditional rights exist, units such as countries, states, districts, municipalities, etc. A "physical land object is a piece of land that is under unique natural or artificial conditions and has no definition in the legal framework" (i.e. piece of land covered by rock, a house, a street, or any other non-legal characteristic).[17]

The definition of Cadastre 2014 is considered by the author of this work as a definition of multipurpose cadastre. This definition of what a modern cadastre should be was created based in the trends and needs analyzed by Cadastre 2014 work:

> The following definition is based on that of Henssen [1995], which only refers to the private property law aspect. It has been adapted to take into account public and traditional law aspects as well:
>
> Cadastre 2014 is a methodically arranged public inventory of data concerning all legal land objects in a certain country or district, based on a survey of their boundaries. Such legal land objects are systematically identified by means of some separate designation. They are defined either by private or by public law. The outlines of the property, the identifier together with descriptive data, may show for each separate land object the nature, size, value and legal rights or restrictions associated with the land object.
>
> In addition to this descriptive information defining the land objects, Cadastre 2014 contains the official records of rights on the legal land objects.
>
> Cadastre 2014 can give the answers to the questions of where and how much and who and how.
>
> Cadastre 2014 can replace the traditional institutions of 'Cadastre' and 'Land Registration'. It represents a comprehensive land recording system. (Kaufmann 1998, 15)

Moreover, the six statements of Cadastre 2014 are considered by the author to be really important elements that must be considered in a modern cadastre. The statements were developed based in the study of cadastral systems and the questionnaires made for the Cadastre 2014 work. The six statements are:

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[17] Ibid., 14.

Statement 1 on Cadastre 2014: Cadastre 2014 will show the complete legal situation of land, including public rights and restrictions!

Statement 2 on Cadastre 2014: The separation between 'maps' and 'registers' will be abolished!

Statement 3 on Cadastre 2014: The cadastral mapping will be dead! Long live modelling!

Statement 4 on Cadastre 2014: 'Paper and pencil – cadastre' will have gone!

Statement 5 on Cadastre 2014: Cadastre 2014 will be highly privatized! Public and private sector are working closely together!

Statement 6 on Cadastre 2014: Cadastre 2014 will be cost recovering! (Kaufmann 1998, 15-25)

The first four statements are of particular interest for this work. A multipurpose cadastre should be first of all, a complete land information system showing all the conditions and restrictions affecting the legal land objects (such as parcels) and the physical objects within the borders a country, state, or county.

Traditional cadastre has two main components: the maps and the registers. This separation was necessary because the available technology (i.e. paper and pencil) did not allow other solutions in the past. This division has often resulted in two different organizational units within municipalities (i.e. the cadastral surveying and land registration) dealing with the same matter.

Among the disadvantages of this representation of the reality are: (1) the two parts of the data describing a land object are kept by different offices or departments in most cases; (2) the system is tiresome, and the participants in the land market have to address two different authorities for land transactions; (3) the information is partly redundant which creates the risk of inconsistencies; (4) every organizational unit has its own fees to at least partly recover the cost of maintenance of the system.[18]

There are many limitations of the traditional cadastre that have been eliminated with the use of the digital GIS and databases. These allow a relationship to be established between the features in the digital maps (i.e. CAD or shapefile vector files) and attribute data about those features that is stored in digital tables (i.e. dBASE4 database files).

The concept of a "model of the reality" must overcome the traditional forms of cadastral mapping. A model is a relatively more complete description of the reality (no model can totally represent reality) than a traditional paper cadastral map. In the latter, the parcels are just drafted without any other inherent behaviour or characteristics other than the ones that can be appreciated in the paper map itself. The concept of a cadastral data model will be explained in following sections of this work.

Geographic Information Systems

The term "Geographic Information System" has been used for several different purposes since it was conceived. This concept has been used for analog data archives, digital databases, or computer software. Since the digital GIS computer programs are well known and used all around the world, the term GIS is commonly used to refer to the different computer programs used to create maps based on geographic databases.

There might be as many concepts of GIS as authors have written on this topic. Based on the tools that the GIS provide is defined as "a powerful set of tools for collecting, storing, retrieving at will, transforming and displaying spatial data from the

[18] Ibid., 19.

real world for a particular set of purposes."[19] The spatial data represent phenomena from the real world in terms of (1) their position with respect to a known coordinate system, (2) their attributes that are unrelated to position, and (3) their spatial interrelations with each other, which describe how they are linked together.[20]

There are other concepts where the GIS is viewed not only as a set of tools. For example, GIS is also used to refer to "a database system in which most of the data are spatially indexed, and upon which a set of procedures operates in order to answer queries about spatial entities in the database."[21]

The author of this work uses the term GIS as stated in the first definition: as a set of tools to collect and analyze spatial data. The integration of a GIS and the cadastral datasets is usually called a Land Information System (LIS).

Components of a GIS

A GIS may be more that just a single computer program: usually it is a cohort of components. These components may be: the computer hardware, sets of application software modules, and proper organizational context including skilled staff.[22]

Computer hardware refers to physical components such as a computer and its peripherals: printer, scanner, digitizer tablet, and additional storage media (i.e. CD-ROM, cassettes, etc.). The components of the computer hardware are to be those suitable for the type and workload of a particular organization.

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[19] Burrough, 11-12.

[20] This is known as "feature topology" and it describes space and spatial properties such as connectivity, adjacency, etc.

[21] T.R. Smith *et al, Requirements and principles for the implementation and construction of large-scale geographic information systems,* International Journal of Geographical Information Systems, 1: 13-31; quoted in Burrough 1998.

[22] Burrough, 12.

If large databases are to be kept and used constantly, computers with enough storage capacity will be needed; otherwise desktop computers may be used to support GIS application software.

The GIS may be subdivided into several different specialized programs provided by different companies (i.e. ESRI®, AutoDesk, ERDAS, etc.) in order to accomplish final products such as maps. Nevertheless, the modern trends are pushing GIS developers to include several or all of the required functions into one program. These functions may be: (1) data input and verification; (2) data storage and database management; (3) data output and presentation; (4) data transformation; and (5) interaction with the user.[23]

An example of the complexity of modern GIS software is ArcGIS™ 8.3 by the Environmental Systems Research Institute (ESRI®) which accomplishes all the above mentioned functions to some extent. The author of this work will use ArcGIS™ 8.3 software in order to design a geodatabase schema for cadastral use. Some of the tools available in this software that allow such design will be described in following sections.

ArcGIS™ 8.3

As one of leading companies in the GIS software industry, ESRI® puts special emphasis in incorporating the tools that modern GIS users (whether they are highly skilled or not) need the most to accomplish their work. On an everyday basis, GIS users learn that they need to address more and more difficult tasks in order to build maps and perform several different types of spatial analysis. The development of better tools, functions, and data models seem to be continuously addressed by ESRI®.

[23] Ibid., 13.

The ArcINFO™ Workstation is a command based GIS that is previous to the development of the ArcView™ and the ArcGIS™ programs. The data format supported by ArcINFO™ was the Coverage Model. This model has the capability to implement topology but is limited compared to the latest version of ArcGIS™ that uses the Geodatabase Model. That version is ArcGIS™ 8.3 and is used as the main tool to accomplish the goals of this work.

The Geodatabase model was introduced by ESRI® in ArcGIS™ 8 as a data model that allows the user to create "intelligent features" that behave more like the real objects they represent through the use of topology rules and field subtypes. The geodatabase model is based in object oriented programming.

The next section of this work is an overview on the data models commonly available to the GIS user including the geodatabase.

Reality Representation

A data model is "a formalized description of real world phenomena." For example, the vector data model represents space as a series of discrete entity-defined point, line, or polygon (common term for "area" in the GIS environment) units that are geographically referenced by Cartesian coordinates.[24]

Conceptual Models of Geographic Phenomena

A conceptual model is "the abstraction, representation, and ordering of phenomena using the mind." A conceptual model is the first step needed in order to simplify reality into a data model. The human perspective of the reality is to be represented and is important in order to develop a successful representation of real life phenomena.

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[24] Burrough, 14-22.

There are two descriptors required in order to represent the real world: what is present and where it is. For example, reality is represented using objects such as a town or a river. These objects are subject to be affected by elements such as the map scale and therefore the resolution that is used to represent the object. The location (addressing where objects are) can be defined in terms of geometrically exact coordinate systems (i.e. geographic coordinates, local, or national grids), or relative methods of location where no measurements or distances are used.[25]

Conceptual Models of Space

The representation of space and spatial properties is formalized using the perceptions of "entities" and "fields." In the former, space is perceived as being occupied by objects that are described by their attributes or properties and whose position can be mapped using a geometric coordinates system. Defining and recognizing the entity is the first step; listing its attributes, defining its boundaries and its location is the second. In the field conceptualization, an attribute of interest varies over space as some continuous mathematical function or "field."[26] For example, in a map showing average temperatures over an area, the variable "temperature" is considered to be continuous over the geographic space being represented.

The choice of the conceptual model determines how information can be later derived. The representation of real-life phenomena using either the entity or the field perception is up to the modeler and the needs of a particular organization.

Usually, the scientific or technical discipline of the observer determines the conceptual model to use. Disciplines that focus on the understanding of spatial processes

[25] Ibid., 19, 299.
[26] Ibid., 20

in the natural environment may be more likely to use the continuous field approach while those that work entirely in the administrative context will view an area as a series of distinct units.[27]

Geographic Data Models and Geographical Data Primitives

Geographical data models are "the formalized equivalents of the conceptual models used by people to perceive geographical phenomena." They formalize how space is discretized into parts for analysis and communication, and assume that phenomena can be uniquely identified, that attributes can be measured or specified, and that geographical coordinates can be registered.

Most anthropogenic phenomena (such as houses or countries) are best handled using the entity model. This model works really well when representing objects that need to be individually recognizable. The simplest data model of reality is a basic spatial entity that is further specified by attributes and geographical location. This can be further subdivided using one of the three geographical data primitives: the point, the line, or the area (polygon) in the vector data model.

In the field model, the variation of attributes (variables) such as elevation or temperature is assumed to be continuous in 2D or 3D space and also in time, but this variation is too complex to be captured by a simple mathematical function such as a polynomial equation. Geographical space is either represented using regression equations (i.e. trend surfaces) or divided into discrete spatial units such as square pixels (grid) or triangular irregular networks (TIN).[28]

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[27] Ibid., 20-21.
[28] Ibid., 21-22.

Modeling with Objects

An object-oriented database structure is "the organization of data defined by a series of predefined objects and their properties and behavioral characteristics." In contrast, in a relational database structure, the data is structured "in the form of sets of records or tuples so that relations between different entities and attributes can be used for data access and transformation."[29]

Notice that the key difference between the two database structures relies in the fact that in the object-oriented structures the objects overcome the records. By introducing the use of objects to represent or mimic real entities, more specialized features can be created, and these may have inherent behaviors given by the characteristics of that specific type of object. Since object-oriented databases require geographical data to be defined as a series of individual units, these data structures favor the use of the entity conceptual model. In the object-oriented databases, the attribute and behavior variables are themselves object classes for which their properties and the methods used on them are defined. Also, hierarchical relationships may be set up for the various classes. Topological links between various object instances and classes are established explicitly through object pointers and operators such as direction, intersection, adjacent to, overlaps, left of, or right of.[30] Some of these topological relationships will be used by the author in this work.

The ultimate purpose of object-oriented databases is to provide the user with a dataset that is to some extent intelligent, that is, it behaves as the real objects do. By

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[29] Ibid., 303-304.
[30] Ibid., 72-73.

using this type of dataset, the modeling of the real life phenomena with GIS can be taken a step further with more specialized and customized objects.

The following are some of the advantages and disadvantages of object-oriented databases:

Advantages

The semantic gap between the real-world objects and concepts and their representation in the database is less than with the relational databases.

The storage of both the state and the methods ensures database maintenance is minimized.

Raster and vector data structures may be integrated in the same database.

The data exchange of objects is supported.

Fast querying of the database, especially when complex objects and relationships have to be dealt with fewer join operations are needed.

Requires less disk space than relational entities which need to store many more index files.

Enables user-defined functions to be used.

Disadvantages

There is no universally accepted object-oriented model so different database products have different standards and tend to be tied to one particular [object-oriented] language.

Identifying objects is often difficult, particularly in continuous spatial surfaces.

Requires the definition of functions and topology as well as objects.

Limited application of indexing because the incompatibility of it with the notion of encapsulation and object-identity.

No established standards such as Structured Query Language (SQL) and provisions for a general query language or query optimization are made difficult by the complexity of the object types in the system.

> There is less theoretical and practical experience with [object-oriented] approach than the hybrid method.[31]

As mentioned before, object-oriented databases have advantages over relational databases such as the use of objects, and the possibility to store both raster and vector datasets. These advantages help to represent the real world in a better and more detailed manner, therefore, converting GIS in a more powerful tool to collect and analyze data about the world and its phenomenon.

The latest versions of the GIS software made by ESRI® such as ArcGIS™ 8.3 allow the user to use either file-based geographic and tabular datasets (such as the Shapefile data model) or the object oriented Geodatabase model. This work uses the object-oriented geodatabase model supported by ArcGIS™ 8.3 software.

The Geodatabase Model

The Geodatabase data model is supported in ArcGIS™ 8.1 or higher versions of GIS from ESRI®. Those versions of ArcGIS™ also have the embedded capability to build geodatabases using the personal database from Microsoft® called ACCESS.

A personal database has the limitations of a maximum size of two gigabytes (2GB), and that no more than one user can edit the database simultaneously. This work will use the tools embedded in ArcGIS™ 8.3 to design and build a personal geodatabase schema.

A geodatabase is a geographic database that is hosted inside a Relational Database Management System (RDBMS) that provides services for managing geographic data.

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[31] Burrough, 73-74, quoting D. Arctur and P. Woodsford, *Introduction to Object-Oriented GIS Technology Workshop Outline* (Laser-Scan, Cambridge, 1996); I. Graham, *Object-Oriented Methods, 2nd edn.* (Wokingham: Addison-Wesley, 1994); J.R. Herring, *TIGRIS: a data model for an object-oriented geographic information system* (Computers and Geosciences, 1992), 18(4) :443-8; P. Milne *et al*, *Geographical object-oriented databases: a case study* (International Journal of Geographical Information Systems, 1993), 7: 39-55.

Those services include validation rules, relationships, and topological associations. The geodatabase model takes advantage of the management tools provided by the relational database model, and uses them to handle geographic and tabular (non-spatial) datasets. It represents the spatial entities as objects that have characteristics and behaviors.[32]

Geodatabases organize geographic data into a hierarchy of data objects. These data objects are stored in feature classes, object classes, and feature datasets. An "object class" is a table that stores nonspatial data. A "feature class" is an object class that stores features and has a field of geometry type.[33] A "field" is a column in a table and contains the values for a single attribute. A "feature dataset" is a collection of feature classes that share the same spatial reference and therefore can participate in topological relationships with each other.[34]

The "spatial reference" describes both the projection and the spatial domain (spatial extent) for a feature dataset or feature class in a geodatabase. The "spatial domain" describes the range and precision of X,Y (that usually correspond to East and North) coordinates, and Z (usually stores elevation) and M (usually used for thematic variables) values that can be stored in a feature dataset or feature class. A "projection" is a mathematical formula that transforms feature locations from the earth's curved surface into a map's flat surface.[35]

The geodatabase model allows a GIS to represent the real life entities better than other data structures such as the shapefile, because it provides the tools to create custom entities that have attributes and behavior. The author is of the opinion that the

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[32] Andrew MacDonald, *Building a Geodatabase* (United States of America: ESRI®, 1999-2001), 464.

[33] This means that the objects are geographic features.

[34] Macdonald, 56.

[35] Ibid., 466-468.

geodatabase model provides a suitable data structure for the cadastre. Among the advantages of the geodatabase model that the author considers to be useful for a cadastral database are:

- The ability to support topological relationships: topological relationships are of great help for a cadastral database since they provide rules with which the cadastral features must comply.
- The geodatabase stores all the datasets (spatial and tabular) in one database file in contrast to other file based datasets: for example, when using the shapefile model, each one of the layers consists of a set of files, and data integrity can be compromised if any is lost or corrupted.
- The geodatabase can store both vector and raster datasets: this is an useful characteristic since all the datasets can be stored in one database, and it helps to keep the integrity of the cadastral database.

Chapter Review

The concepts that spawned this work and the concepts required to pursue it have been presented in this chapter. The concept of multipurpose cadastre from the Cadastre 2014 work by the International Federation of Surveyors (FIG), and ESRI®'s geodatabase model are two very important thresholds for this work. The geodatabase model and ArcGIS™ 8.3 will be used by the author to design a geodatabase schema that implements as much as possible the characteristics of a modern multipurpose cadastre and the data needs of the Costa Rican municipalities.

The following chapter briefly describes the structure and characteristics of the Costa Rican cadastral system.

CHAPTER THREE

COSTA RICAN CADASTRAL SYSTEM

The purpose of this chapter is to review important characteristics about the cadastral system being used in Costa Rica and its cadastral unit called the *Predio*. The definition of this cadastral unit was made by the Costa Rican governmental institution that regulates and aids the municipalities in its tasks and responsibilities. That institution is the *Instituto de Asesoria y Fomento Municipal* (Institute for the Municipal Promotion and Consultantship, IFAM).

Many of the problems that the Costa Rican cadastral system is facing at this time are due to the traditional structure of separated land register and cadastre. This structure is strongly related to the analog data storage methods such as paper maps, paper plats, and data recording in slips or forms.

This chapter briefly reviews Costa Rican national cadastre system and its principal components. Some of these components are considered as they relate to the design of the cadastral geodatabase schema that will be produced in this work.

National Cadastral System

Costa Rican national cadastral system is considered a traditional system in the sense that is divided into two parts: the land registration and the cadastre. Land registration is "a process of official recording of rights to land through deeds or as titles to properties." It is an official record of rights to land or deeds concerning changes in the legal situation of defined units of land.[36] This arrangement was established by the law according to what was appropriate, suitable, and technologically feasible in the past

[36] Henssen., 13.

decades. The cadastral aspect is managed by the *Catastro Nacional* (National Cadastre), and the legal aspect or land registration is managed by the *Registro Nacional* (National Register).

The Costa Rican *Ley del Catastro Nacional* (National Cadastre Law) establishes in its tenth article that a *Certificado Catastral* (Cadastral Certificate) must be used in any attempt to register rights over a portion of land. By this means, the National Register has a proof that a cadastral map (plat) representing the parcel's shape and size has been revised and made official by the National Cadastre. Once a cadastral certificate has been generated, the National Register can proceed to create or modify rights to a portion of land. Only the National Register can create rights or modify existing ones. This procedure is established in the cadastral law for the lands where the cadastre has been finalized.[37] As of August 2003, not a single county in Costa Rica had finalized its cadastre. Some of the procedures established by law have not been fully implemented in most of the Costa Rican municipalities to date. Usually, the main reason for this is the lack of economic resources, but insufficient qualified municipal staff and the lack of appropriate implementation plans may be affecting as well.

This situation is really unfortunate since it creates serious flaws regarding the legal registration of rights based on the cadastral data that is kept by the National Cadastre. Several flaws exist because of this situation that only worsens the quality and functionality of the cadastral system. In the worst case, those flaws may be used to take advantage of the cadastral system's deficiencies, and situations such as double ownership of real estate may occur affecting the rightful owners.

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[37] Asamblea Legislativa de la Republica de Costa Rica, *Articulo Cuarto de la Ley de Catastro Nacional* (San José, Costa Rica: Editorial Investigaciones Jurídicas, 1999), 8.

The Costa Rican national cadastral system is supposed to serve as a structured national LIS to store the cadastral data for the entire country. Since the procedures established by the law have been poorly implemented or are in the process of implementation, a digital national land information system is far from being complete and functional. The municipalities attempt to cover their information needs by creating their own LIS so they have the required data concerning the land under their jurisdiction in order to perform tax assignation, land management, and planning.

This project focuses on the need of the municipalities to have their own digital cadastre and LIS to perform their activities, and not on proposing a solution to the problems of the national cadastral system. It is clear that even though the national cadastral system is present, it is not performing satisfactorily at this point. Unfortunately, the principal reason for this situation might be directly related to a lack of economic resources.

Costa Rican Cadastral Unit: The Predio

The Costa Rican governmental institution that regulates and helps the municipalities in their tasks is called *Instituto de Asesoria y Fomento Municipal* (Institute for the Municipal Promotion and Consultantship, IFAM).

In the year 2000, the IFAM developed the technical regulations that municipalities must follow in order to create local cadastres and LIS for their own counties. The name given to this document is *Especificaciones Técnicas para Catastro Municipal* (Technical Specifications for Municipal Cadastre). This document describes the steps and technical considerations to be addressed by a municipality in order to complete its "Cadastral Project" or "Census," that is, a complete description of the properties in a county.[38]

The basic cadastral unit is defined as the *predio* that may be translated into English as property or real estate. A predio is a legal land object in Costa Rica and is a unit of land for which the owner, the possessor or the usufructuary is known.[39] The *Ley del Catastro Nacional* (National Cadastre Law) defines a predio as "the portion of land that is located in only one province and belongs to one or more owners or possessors."[40]

In the Costa Rican setting, the predio matches the concept of "tax" or "fiscal" parcel, and the cadastral system is declaratory in its nature. For example, if the owner of a predio agrees to sell a portion of it, the (new) owner of the segregated portion (new predio) is not obligated to register this as a new right in the National Register. Although the new right has not been officially registered, the owner of the new predio holds all the benefits and sanctions given by the law as the legitimate owner after the legal agreement (deed) has been made.

The situation just described is very common in Costa Rica, and represents along with others the different scenarios to be described by the cadastre. The Costa Rican *Ley de Impuesto sobre los Bienes Inmuebles* (Law of the Taxes on the Real Estate) defines the *Sujeto Pasivo* (Passive Subject) as the person responsible for the taxes on a predio.[41] According to the legal situation of a predio, the passive subject might be its owner, possessor, awardee, or usufructuary.

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[38] IFAM, *Especificaciones Técnicas para Catastro Municipal* (Moravia, Costa Rica: 2000), 22.

[39] The author uses the words "parcel" and "predio" interchangeably throughout this work to refer to the Costa Rican cadastral unit.

[40] Asamblea Legislativa de la Republica de Costa Rica, *Articulo Séptimo de la Ley del Catastro Nacional* (San José, Costa Rica: Editorial Investigaciones Jurídicas, 1999), 8.

[41] Asamblea Legislativa de la Republica de Costa Rica, *Articulo Octavo de la Ley del Impuesto sobre los Bienes Inmuebles* (San José, Costa Rica: Editorial Investigaciones Jurídicas S.A., Enero 2003), 20.

The different legal situations for a predio are described in another document by IFAM called *Identificación Predial en el Catastro Municipal* (Property Identification in the Municipal Cadastre). In each case, the IFAM suggests a different type of identification heading for the predio number as follows:

For Registered Real Estate:

- If the property has a legally registered owner, the passive subject is its owner.
- If the total or partial ownership is being transferred, the passive subject is its registered owner until the new owner is legally registered. The consecutive ID number will have the heading "ST."
- For the predios owned by a government institution that are under the legal possession of someone else, each individual possession (award) will be considered as a predio and the passive subject will be its awardee. The consecutive ID number will have the heading "IP."
- For the predios that are occupied against the will of the legal owner, the passive subject will be the possessor, and each occupied parcel will be considered a predio. The consecutive ID number will have the heading "PR."
- In the case of registered encumbrances, these will not be considered as individual predios but a relation to the original predio will be kept. Each usufructuary will be considered as the passive subject. The consecutive ID number will have the heading "US."

For Unregistered Real Estate:

- The possessor will be considered as the passive subject, and the consecutive ID number for the predio will have the heading "SI."

- In the case that the predio is owned by the government but is under award to someone else, and located along the coast line or in international border, each awarded portion will be considered a predio and the awardee will be its passive subject. The consecutive ID number will have the heading "ZM" for the first situation mentioned, and "ZF" for the second.[42]

These legal scenarios must be considered in order to be represented by both the spatial and non-spatial components of the geodatabase schema. These standards for the identification numbers suggested by the IFAM will be used in the pilot study for this work if needed.

In another document developed by IFAM, a number structure was designed to represent each predio. The name of this document is *Director Técnico para la Ejecución del Catastro Municipal* (Technical Director for the Execution of the Municipal Cadastre). The headings previously described are to be used with this number according to the legal situation of a predio.

The need to create a predio number is that since not all the predios are legally registered, or the legal situation is such that the predio is in possession of another person or institution (as its awardee) other than its legal owner, not all predios have a registration number given by the National Register at the time that the right on the land is registered. The structure of the number[43] was designed as shown in Figure 3.

This number structure is therefore used by Costa Rican municipalities in order to identify the predios in a county. The block number corresponds to one of the blocks into which the county is divided in order to accomplish the cadastral census. The consecutive

[42] IFAM, *Identificación Predial en el Catastro Municipal* (Moravia, Costa Rica: 2000), 3-4.
[43] IFAM, *Director Técnico para la Ejecución del Catastro Municipal* (Moravia, Costa Rica: October, 1999), 31.

number is defined within each block following, for example, a clockwise order. The maintenance digits are used in the case that a predio is divided into two or more new predios, and there is a need to keep the ID number of the original predio. The number structure also helps to establish a number standard throughout the country.

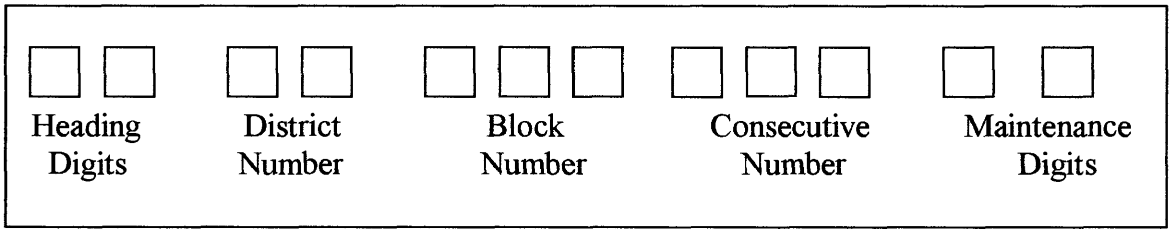

Figure 3. Structure of the predio number

The identification number structure for predios has been developed and established by IFAM as described in the preceding paragraphs. The author considers this number structure to be suitable and will use it if needed throughout this work.

Chapter Review

The most important characteristics of the Costa Rican cadastral system have been presented in this chapter. The environment and the common use throughout the past decades have defined many of these particular characteristics.

The author is of the opinion that some of the general characteristics and/or procedures of the Costa Rican cadastral system may be improved. However, that is not the purpose of this work. Some of the particularities of the cadastral system would be too difficult to modify since they have been in place for the last several decades.

Some of the developments accomplished, such as the creation of the Predio Number by IFAM must be taken into account in this work since they were created for the specific situation and characteristics of the country.

The following chapter explains the methodology that will be used in order to design the custom geodatabase schema proposed in this work.

CHAPTER FOUR

METHODOLOGY

The purpose of this chapter is to describe the steps that are used to accomplish the goals of this work. As a brief review, the main goals are to develop cadastral geodatabase schema and a maintenance model suitable for a Costa Rican municipality.

The first step in this project is the determination of the cadastral data needs of a typical Costa Rican municipality. This task is addressed by reviewing the concepts of multipurpose cadastre from the Cadastre 2014 work, and by analyzing the cadastral information needs of the municipalities in the Costa Rican setting.

The first statement of Cadastre 2014 addresses the extent of the content of the cadastre by stating that it needs "to show the complete legal situation of land, including public rights and restrictions." This statement sets the milestone for the design of a cadastral database. All the rights or restrictions that affect a portion of land should be shown for a complete description of the legal situation of the land.

The author addresses the determination of the entities needed to describe the land by interviewing the functionaries of two municipalities, by analyzing the existing cadastral datasets from these municipalities, and finally, by studying the Land Parcel Data Model from ESRI® in order to extract any useful characteristics or database structures from it.[44] The author's academic background as a surveyor in Costa Rica and experience with the cadastral system are important inputs as well.

The geodatabase schema template called Land Parcel Data Model developed by Nancy von Meyer of Fairview Industries and ESRI® will be used as a starting point in

[44] The "ArcGIS Land Parcel Data Model" is also called "Parcel Model" throughout this work.

the design of the custom geodatabase schema. This model is available at no cost through ESRI's website.[45] The development of this model and similar ones for other applications of GIS technology is being supported by ESRI® as a tool to provide standard data structures that might help GIS users to implement solutions to their data management problems and potential data sharing activities. The Parcel Model was designed to store and manage cadastral data, and is suitable to support the requirements of multipurpose cadastre.

As of November 2003, ESRI® incorporated the Cadastre 2014 work to their geodatabase templates. In these documents and geodatabase templates, some of the statements of Cadastre 2014 are incorporated into geodatabase schema. These documents were studied and are considered by the author of this work for the creation of the cadastral geodatabase schema.

The author studied and analyzed Barva County's existing cadastral datasets. These datasets include digital cadastral maps in the shapefile and DWG formats, and digital attribute tables stored using the DBF[46] format. Basically, there is one attribute table for each one of the subjects concerning the predios. These subjects are: the value assessments of the predios, the description of the buildings in the predios, the information about the owners of the predios, the information about the legal registration of the predios, and the description of the services available to the predios.

The geodatabase schema from the Parcel Model was used in two ways in this work. Regarding some subjects, entire feature classes or tables were copied from the Parcel Model into the custom geodatabase, and minor modifications were made in order

[45] Available in the Internet from http://support.esri.com/index.cfm?fa=downloads.dataModels.byLabel&dmid=11.

[46] The DBF format is a table format that can be used as part of a relational database.

to apply them to the Costa Rican setting. These subjects include the representation of encumbrances, and restrictions among others. In other instances, the results of the analysis of the Parcel Model were implemented into different tables and features classes of the custom geodatabase. This was made in order to extract from the Parcel Model all the characteristics and features that may apply to the Costa Rican cadastral reality, and that may aid towards the establishment of a multipurpose cadastre.

Once the data attributes to be recorded in the geodatabase were defined, the process of designing and building a custom geodatabase schema was addressed. This is the second step of this work. The general steps for the design of a geodatabase according to the book "Modeling our World" by Michael Zeiler are the following:

- Model the user's view.
- Define entities and their relationships.
- Identify representation of entities.
- Match to the geodatabase data model.
- Organize into geographic datasets.

The first three steps develop the conceptual model, classifying features based on an understanding of the data required to support the organization's functions, and deciding their spatial representation as point, line, area, image, surface, or non-geographic. The last two steps develop the logical data model matching the conceptual models to ArcINFO™ or ArcGIS™ geographic datasets.

The steps mentioned are required when a geodatabase has to be designed "from the ground up." That is, all the entities that are needed to represent the real world (according to the data needs of a particular organization) have to be conceptually defined and their representation determined. Entities may have a geometric, alphanumeric, or image representation among others. The next step in the design of a geodatabase is to match these representations to their correspondents in ArcINFO.[47]

In this work, the goal is the creation of a geodatabase schema to store and manage cadastral data. Since cadastral datasets were created both for Barva County and Heredia County where GIS are in use, some of the steps mentioned for the design of a geodatabase were addressed already to some extent. For example, parcels have geometric representation by means of polygons; survey landmarks (monuments) have geometric representation by means of points; the name for the owner of a predio has an alphanumeric representation by means of a field in a table. Therefore, there is no reason to redefine the representation for most of the cadastral entities since in most cases they are defined by cadastral concepts or by the Costa Rican law.

The author takes advantage of the existing datasets from the Municipality of Barva County therefore avoiding some of the steps in the design of a geodatabase. While these datasets are not built using the geodatabase model, they are in the shapefile and tabular formats, and were created for the purposes of storing cadastral data. Furthermore, the author uses his knowledge of the cadastre and the cadastral activities in Costa Rica.

The representation of any new entities is defined by the author as needed in addition to those that have been defined already by the Costa Rican cadastral law or by the cadastral theory. The tables presented in Chapter Five of this work describe all the entities, both geographic and non-geographic, that conform to the geodatabase. The author uses the geodatabase model in order to represent and model the parcels, urban blocks, political boundaries, and other objects that are involved in the cadastre.

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[47] Michael Zeiler, *Modeling our World* (Redlands California: ESRI Press, 1999), 184-190.

The author wants to emphasize that in Costa Rica it is a common situation for the cadastral department in any given municipality to be the principal source of information concerning the land. Usually, the cadastral department has the responsibilities to store and update the municipality's geographic datasets, not only the cadastral data. Even though other departments take charge of functions such as billing the taxes to the land owners, or the concession of patents, for the most part all the functions at the municipality rely on the geographic and cadastral datasets maintained by the cadastral department. The cadastral datasets are the core of the Costa Rican municipalities and usually are rigorously guarded by the municipalities.

The concept of "multipurpose cadastre" is a great development for the storage, management, and updating of the data describing the land. This is in the sense that a well designed, single depository of data, is better than several individual datasets (or even databases) for which the interconnection and integrity might be more difficult to maintain. It is the case in most Costa Rican municipalities, where different departments keep small sets of data related to their own functions. This arrangement of distributed information accounts for some of the problems that the municipality has regarding the accuracy and reliability of their datasets, both geographic and alphanumeric.

The last step of this work is the evaluation of the functionality of the custom geodatabase. This is addressed by means of reviewing the concepts learned about multipurpose cadastre and the information needs of Costa Rican municipalities. The functions that the municipalities perform or are seeking to perform provide the basis to assess the functionality of the geodatabase. The data from a pilot study area within Barva County will be used to address the evaluation process and assess if the geodatabase is functional. That is, if the geodatabase may aid in the fulfillment of the information needs of a Costa Rican municipality, and in the accomplishment of its functions.

For the purposes of this work, there is no need to have a very large pilot study area. The cadastral phenomena can be recreated using a study area of just a few city blocks since the bulk of it occurs at the predio level. This is the reason why most of the topological rules are focused in the enforcement of the behavior of the predios.

The Interviews

The information obtained from the interaction with the functionaries from the municipalities of Barva County and Heredia County is presented in this section. This information and the impressions obtained by the author about the cadastral system and the tasks performed in each one of the cadastral departments are used as inputs in the design of the geodatabase schema. The existing cadastral datasets from the Municipality of Barva County were analyzed in order to extract from them all the characteristics that might be useful to this work.

Furthermore, the author had the opportunity to experience the common tasks that the functionaries perform in an every day basis at the Municipality of Barva County. As a result of this, the author confirmed his beliefs that the geodatabase model has a great potential to aid with the tasks of a cadastral department.

The author addressed the functionaries of both municipalities with the following question: What are the functions that the municipality seeks to perform that rely on or are related to the cadastral information? Their responses are translated and summarized in the following two sections.

The Functions at Municipality of Barva County

The author interviewed the two functionaries in charge of the *Departamento de Catastro, Valoraciones y Bienes Inmuebles* (Department of Cadastre, Assessments, and Real Estate). They both hold degrees in topographic engineering, and are experienced surveyors and cartographers.

According to their comments, the functions that the Municipality is seeking to perform are mostly related to property assessment and tax assignation. The main objective is clearly the collection of taxes based on the land properties. This cadastral system is recognized as a "fiscal cadastre" by the functionaries.

The answer obtained from the functionaries can be translated as follows: "the main objective is to establish a shared dataset that is able to store all the graphic and alphanumeric information about each one of the components that generate income to the Municipality." They emphasized that the goal is to have a shared dataset that the other departments of the municipality can access in order to perform their functions properly.

Other functions mentioned are:

- The assignment of patents for commercial purposes such as mechanical workshops, liquor and grocery stores;
- The mapping, management, and improvement of the road system;
- Waste collection activities;
- Cleaning of the public ways such as roads and sidewalks;
- Organization and management of cultural activities.

These are the principal functions of the municipality other than generation of official certifications and documents. The municipality relies heavily in the cadastral datasets because they describe the predios: the main source of income through taxing.

In the year 2002, the *Censo Catastral* (Cadastral Census) was performed in Barva County. The cadastral census is the process of surveying property by property to gather all the data related to the land and the rights affecting that land. Surveying in this setting, refers to any means of getting information about the land, and not only topographic measurements. These include face-to-face interviews with the persons living or working in the properties (if there is a house or other building in place); an inspection of the property; review of the data available at the National Cadastre, the National Register, and Barva County's databases. All this data is then compared in order to build the most accurate database about all the real state in the county.[48]

The author reviewed the information tables kept by the Municipality of Barva County in order to learn what data is considered important in order to perform its functions. These tables contain the data gathered in the cadastral census. The census form included questions about the following data:

- Data about the owner: name, national identification number or passport number, address, telephone or fax numbers, etc;
- Real estate data about each predio: location (district, street, and avenue); number of co-owners (if any); number of the official cadastral plat; registration number of the corresponding deed (from the National Register); registered area; condition of the real state (if the deed was made official, is in progress, new deeds are being processed); etc.

[48] IFAM, *Cartel de Contratación Directa: Director Técnico para la Ejecución del Catastro Municipal* (Moravia, Costa Rica, October 1999), 21-35.

- Data about the topography and available services for each predio: type of road providing main access; height of the ground relative to the road; location in the city block; uniformity of the surface; services provided such as sidewalk, drinking water, electrical power, phone, etc.; current land use; and approximate dimensions of the property. If the property is located in a zone considered to be rural, the following descriptors are added: hydrographic characteristics, soil capacity, and type of topography (i.e. flat, irregular, etc.).
- Data about the buildings or any other infrastructure (if any exists): approximate years of existence; condition of the building; number of stories, rooms, and restrooms; materials of the walls, floors, roofs, etc.[49]

The cadastral census is currently the best description of the real estate and infrastructure for Barva County. Ideally, every Costa Rican municipality should have performed a similar cadastral census or it should be in process of completing it.

The product of the cadastral census for Barva County is a collection of tables and geographic datasets in the shapefile format. ArcGIS™ 8.1 was implemented to manage all the data in the most convenient way so different queries could be accomplished. The different tables and shapefiles are related by means of unique identifiers in the tables that match the predio number, or the identification number of other legal land object.

The functionaries at Municipality of Barva County had some previous knowledge about geographic databases such as the geodatabase model supported by ESRI's software. The author exposed them to some of the advantages of such models and they were clearly interested in the implementation of a geodatabase to store and manage their data.

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[49] Ibid.

The Functions at Municipality of Heredia County

The city of Heredia is the capital of the province with the same name. The author also interviewed the functionaries from the Cadastre Department at the Municipality of Heredia County.

Even though this municipality is in charge of a larger area than the Municipality of Barva County is, a GIS has not been implemented mainly because of a lack of economic resources, trained staff, and technical support on digital cartography and GIS technologies.

The data kept by Municipality of Heredia County is arranged in several digital databases form different vendors. These are not linked with each other in an automated manner. If a functionary in one department of the municipality requires data that is kept by another department, a verbal request must be made so a copy of the data can be produced, usually in hardcopy. The same situation is present in Municipality of Barva County, but there, more sophisticated databases are used with the GIS, and great effort is made to maintain good data flow between departments.

As part of the interview with the functionaries, the author explained to them some of the advantages of the geodatabases in the management of a cadastre and a local government. The functionaries expressed great interest in the potential use of the geodatabase model to manage the cadastre, mostly regarding database management tools. The possibility to use attribute domains, and the concept of "intelligent features" is definitely of interest to the functionaries.

As of December 2003, the cadastral census has not been completed for the real estate in Heredia County. This situation does not necessarily mean that the data kept is dated or incomplete, but there is less confidence about the accuracy of the data compared to Barva County's datasets. The data kept by the Municipality of Heredia County is for the most part exactly the same as in Barva County since the orientation of this cadastre is also fiscal. One of the biggest differences is that there are more commercial patents given by the Municipality of Heredia County since it is the capital of the province and is densely populated.

The Municipality of Heredia County is really interested in the fiscal aspects of the cadastre. The need for an updated database including the most accurate value for each predio in the county is the main goal according the comments given to the author. A land value map describing zones of equal value based on market values has been present for several years, and is an important source of information for the real estate business and for the general public. According to the functionaries, a map of land value zones and a map showing the current use of the land, are really important for this municipality.

A problem present in this municipality is the lack of communication and coordination between departments and their respective databases. According to the comments given to the author, the municipality keeps several different databases: one for cadastre, one for the real state, one for the urban services, one for patents, one for the graveyard and market place, and one for the management of public advertisements. Currently, there are no links between these databases so related records (for example based on the predio identification number) can not be easily inquired or used for analyses.

The Municipality of Heredia County is focusing efforts in the implementation of a unified database so all the information can be kept together. This new database will not be a geographic database because this model has not been introduced in the governmental institutions to date. Although a new unified database is a good solution, the municipality is not considering data models such as the geodatabase to accomplish this. Instead, a relational database will be created and later linked to the spatial datasets through the GIS. None of the advantages of the object oriented databases will be used by the municipality at least for a few years.

The author realized that the Municipality of Heredia County's Cadastre Department is mainly seeking to automate their tasks. A reform of the system looking forward to the creation of a land information system implementing a geographic database is not being considered. The municipality is basically aiming at the unified database in order to have accurate parcel values so taxes can be properly and promptly billed. No comments were made to the author regarding other major functions besides tax billing and patent assignation.

Chapter Review

The methodology used to accomplish the goals of this work and the interviews with the municipal functionaries were presented in this chapter. The determination of the entities to be stored in the geodatabase was the first step of this work. Starting with the interaction with the functionaries at the municipalities and followed by the analysis of Barva County's existing cadastral datasets, the author defines the entities needed to store all the cadastral data. The design of the custom geodatabase is the second step. All the knowledge and experience gathered from the previous step is used to address this process. The evaluation of the functionality of the geodatabase schema is the final step.

The next chapter of this work addresses the details of the design of the custom geodatabase schema and describes all the entities and objects created.

CHAPTER FIVE

GEODATABASE SCHEMA DESIGN AND CADASTRAL MAINTENANCE MODEL

This chapter addresses the design of the cadastral geodatabase schema and the cadastral maintenance model proposed as goals of this work.

The process of schema design can be accomplished using Computer-Aided Software Engineering tools (CASE). CASE tools allow the creation of custom objects and features that extend the geodatabase model. Object-oriented design tools that support the Unified Modeling Language (UML) and the Microsoft® Repository can be used to create designs for objects.[50] An example of this type of software is Visio® Enterprise from Microsoft®.

CASE tools allow the creation of blueprints of the structure of a geodatabase using the UML graphical language. Using class diagrams, the geodatabase elements such as feature datasets or geometric networks can be represented and the relationships among them can be clearly seen.[51] This type of software is really helpful when designing large and complicated databases. It allows the designer to visualize the entire database and therefore in the case of a geographic database, all feature classes, feature datasets, and object classes along with their attributes, domains (validation rules), and relationship classes can be viewed in a graphic manner.

The author acknowledges the potential of using CASE tools to design the geodatabase schema for this work. However, CASE tools were not used to accomplish

[50] Macdonald, 259.
[51] Ibid., 260.

this task because the author considers that the schema of this geodatabase is not intricate enough to require the use of CASE tools. The author considers that for this work, more time was needed to determine what data was needed to be stored, than in the process of constructing the geodatabase schema itself.

The process of construction of the geodatabase for this work was progressive, and real data (both geographic and tabular) was used throughout the design process to test its functionality. This was a strong reason to not use CASE tools since the author tested every addition and improvement to the geodatabase while it was being constructed. By using CASE tools, the process of converting the UML model to geodatabase schema each time an addition needed to be tested would have been tiresome and obstructive to the design process. The following is a description of the geodatabase schema created.[52]

Feature Datasets and Feature Classes

Five feature datasets were created in order to organize the feature classes into thematic groups. This is in order to facilitate the cadastral activities of storage, management, and update of the cadastral data.

The official coordinate projection used in Costa Rica is the Lambert Conformal Conic. This projection is used in this work since is what municipalities are required to implement. The parameters for the northern part of Costa Rica are displayed in Table 1.

The spatial extent defined for the cadastral feature datasets (excluding the Administrative Divisions and the Transportation feature datasets) encompasses all the counties of the southern part of the province, including Heredia County and Barva County.

[52] The "Land Parcel Data Model" developed by ESRI that is used as reference in the development of the geodatabase schema for this work is also referred to as "Parcel Model" throughout this document.

Since the spatial extent of the geodatabase determines its size and precision, the author decided not to define a larger spatial extent in order to maintain the precision as high as possible. These values are shown in Table 2. In order to determine these parameters, the author loaded into ArcMAP™ a layer showing the counties of the province of Heredia, and then estimated an area including all the zones of interest for this work. This makes the geodatabase schema created suitable to use by either Heredia County or Barva County.

Table 1. Parameters for Lambert Conformal Conic

Central Meridian	- 84.333333
Reference Latitude	10.4666667
First Standard Parallel	9.933333
Second Standard Parallel	11.000000
False Easting	500,000.000
False Northing	271,820.522
Spheroid	Clarcke 1866
Datum	North American Datum of 1927

The values for minimum and maximum X and Y (shown in Table 2) represent the limits in the geographic position for the features stored in the feature classes. The precision for the coordinates represent the number of system units per unit of measure. For example, a precision of one (1) means that only integer values will be stored, and a precision of one thousand (1000) means that three decimal places will be stored for each coordinate value.

The value of precision is dependent on the spatial extent of the data: if the extent is modified, the precision will change as well.[53] The precision defined for the Parcels and Survey, Interests on Land, and Value Assessments feature datasets created into the geodatabase is rather high. This is in order to allow for the stored features to be represented as accurately as they were surveyed or digitized. A lower precision is used for Administrative Divisions and the Transportation feature datasets that have a larger spatial extent that encompasses the entire country of Costa Rica.

The scope of this work is to create a geodatabase schema suitable to store the cadastre of one municipality. Therefore, only some feature datasets have a spatial extent large enough to include national datasets such as road network and administrative divisions.

Table 2. Spatial domain and precision

Minimum X (East)	510,000
Maximum X	540,000
Minimum Y (North)	210,000
Maximum Y	240,000
Precision (X,Y)	71,582.788
Maximum Z (Elevation)	4,000
Precision (Z)	10,000

The cadastral layers are considered to represent a flat surface. The predios, blocks, etc., are considered to be flat features in the cadastre. Therefore, usually the values for the elevation (Z domain) are not used for cadastral purposes.

[53] MacDonald, 56.

The feature classes within a feature dataset inherit the spatial domain that was defined for that feature dataset. This allows for any of the feature classes to participate in topological relationships.[54] The author takes advantage of this since both, feature datasets and topological relationships are used in this work.

The information that is required by the municipality to perform accurate assessments of the values of the real estate involves different subjects. Examples are the characteristics of the buildings and/or constructions (such as materials of the walls and floors) that may be located in a predio; topographic characteristics of the predio such as height of the land from the public access to it (usually a road); and the description of the services available to a predio such as electric power and drinking water. The geodatabase schema developed in this work considers all these descriptors of the real estate in order to serve as the source of the information that the municipality needs to perform its tasks.

Both attribute domains and subtypes will be incorporated into the geodatabase. An attribute domain is a named constraint in a database. It can be applied to a subtype of a field in a feature class or object class to make an attribute rule. The types of attribute domains include "range" and "coded value" domains. In the first type, the rule limits the values that can be stored in a field; the second type sets predefined values that can be numbers, codes, or words. A subtype is an attribute value that can be used to group features or objects. Subtypes differentiate objects based on their rules. Subtypes are used to implement different default values and validation rules for features or objects.[55]

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[54] Please refer to The Geodatabase Model section of Chapter Two of this work for a review of concepts of feature class and feature dataset.

[55] MacDonald, 461-468.

Parcels and Survey Feature Dataset

The purpose of this feature dataset is to accommodate the feature classes that are strongly related to the predios and to important survey monuments.

The feature classes inside this feature dataset are: Predios, Boundaries, Corners, Blocks, and Monuments. These feature classes are described in the following sections. The topology rules inside this feature dataset are: Rule 1, Rule 3, Rule 4, Rule 5, Rule 6, and Rule 7. These rules are described in the Topology Rules section of this work. The spatial domain and precision of this feature dataset were described in Table 2.

Predios Feature Class

This feature class holds the principal features of the entire cadastral model: the polygons representing the predios. The Costa Rican cadastral system is a fiscal cadastre for it is based on the concept of tax parcels. The predio is the Costa Rican tax parcel and is the most important legal land object in the cadastre. Even though a predio might not be officially registered in the National Register, the owner or possessor is responsible for paying taxes and other duties. The fields created are described in Table 3.

Table 3. Fields in the Predios feature class

Field Name	Data Type	Description	Length	Domain	Commentary
Object ID	Object ID	. . .	. . .	. . .	Default object identification field
Shape	Geometry	Polygon	. . .	. . .	Geometry type
GISPID	Text	. . .	25	. . .	Predio identification number
SHAPE_Area	Shape_Area	. . .	Double	. . .	Default area field
SHAPE_Length	Shape_Length	. . .	Double	. . .	Default length field

The GISPID is a very important field in this geodatabase schema. This number is a unique identifier for each predio and is used throughout the geodatabase schema to build relationships with other object and feature classes. Since the type of field is text, it can hold both number and letters if necessary. This would be necessary if the full predio number suggested by IFAM is to be implemented since it is composed of letters (heading) and numbers.

Blocks Feature Class

The polygons called "blocks" (*bloques* in Spanish) are stored in this feature class. These polygons represent the existing city blocks within a county.

This feature class is based on the Survey First Division Feature Class from the Parcel Model. The purpose of these polygons is to function as a type of zone that encompasses other polygons (predios in this case), and may be used to build a topological relationship. The fields created are described in Table 4.

Table 4. Fields in the Blocks feature class

Field Name	**Data Type**	**Description**	**Length**	**Domain**	**Commentary**
Object ID	Object ID	. . .	. . .	. . .	Default object identification field
Shape	Geometry	Polygon	. . .	. . .	Geometry type
NUM_BLO	Short integer	. . .	. . .	. . .	Block identification number
SHAPE_Area	Shape_Area	. . .	Double	. . .	Default area field
SHAPE_Length	Shape_Length	. . .	Double	. . .	Default length field

Boundaries Feature Class

Corners and boundaries are used to build parcel information. The corners are the ends of the boundaries, and the boundaries are the lines connecting corners. Boundaries are the exterior lines that form the parcel.[56] The purpose of this feature class is to hold the lines that are used to assembly parcel features.

The fields for this feature class are based on the fields in the Boundary Feature Class from the Parcel Model. The author considers that these fields take into account all the characteristics that features (such as lines) may have as part of a cadastral dataset. Unfortunately, they may or may not be used entirely in the Costa Rican setting because of its particular characteristics. The fields created are described in Table 5.

Subtypes are used in this feature class to implement behavior to the features. This is made using the field called "RecordBoundaryType" that holds the type of boundary feature. The subtypes are: (1) right of way, (2) subdivision, (3) parcel, (4) lot line, (5) parcel split, (6) private road, and (7) water.

The use of subtypes allows a specialized behavior of the features. Each one of the subtypes of features can have different default values (from a specified domain) for each one of the attribute fields in the feature class. For example, for a given type of boundary feature, not all the fields may be applicable and therefore, for some of these fields it might be appropriate to set a default value of "Not Applicable." The use the subtypes can be of great aid to the municipal functionary in charge of the editing and updating of the geodatabase.

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[56] von Meyer, 45-46.

Table 5. Fields in the Boundaries feature class

Field Name	Data Type	Description	Length	Commentary
Object ID	Object ID	. . .	. . .	Default object identification field
Shape	Geometry	Polygon	. . .	Describes the geometry type
RecordBoundaryID	Text	. . .	30	The primary key for the line entity.
RecordBounds	Text	. . .	30	Describes a boundary location through a call to a legal location, a related document, or a known location.
RecordBoundaryStatus	Text	. . .	30	Identifies the record boundary's status from a legal perspective.
RecordBoundaryType	Long integer	. . .	. . .	An indication of the classification of the boundary line that is used to support the definition of subtypes.
OffsetLeft	Double	. . .	. . .	The distance to the left of and perpendicular to a defined boundary line that defines the record boundary.
OffsetRight	Double	. . .	. . .	The distance to the right of and perpendicular to a defined boundary line that defines the record boundary.
RecordBoundaryComment	Text	. . .	100	Contains additional information about the record boundary that may be in public record.
Direction	Text	. . .	12	Direction is the angle between a line and an arbitrary chosen reference line.
Distance	Text	. . .	10	The quantity for the distance of a boundary. Distance is the linear measure along a line.
DirectionType	Text	. . .	10	This attribute is the "basis of bearing" or "basis of azimuth" for the direction.
DirectionUnit	Text	. . .	10	Indicates the units for a direction.
DirectionQuadrant	Text	. . .	10	Directions can be measured as either bearings or azimuth.
DistanceUnit	Text	. . .	10	Defines the units of measure and reference plane upon which distance measurements are taken.
DistanceType	Text	. . .	10	Describes the reference surface for the distance.

Table 5- Continued

Field Name	Data Type	Description	Length	Commentary
Radius	Text	. . .	10	The radius is the distance from the center of the curve to any point on the circular curve.
Delta	Text	. . .	10	The central angle of a circular curve.
Tangent	Text	. . .	10	This is a term from the Arc Cogo process and the Cogo line type.
ArcLength	Text	. . .	10	The arc length is the long chord length.
Side	Text	. . .	1	This is a term from the Arc Cogo process and the Cogo line type.
RBSourceAgent	Text	. . .	30	The source agent is the individual or organization, which determined the record boundary values.
CBSourceID	Text	. . .	30	The value assigned to a record boundary document to file or identify the source from which the record boundary originated.
SHAPE_Length	Shape_Length	. . .	Double	Default length field

The ArcEditor and ArcInfo licences of ArcGIS™ 8.3 have an advanced implementation of topology along with the ability to define, store and update COGO attributes. COGO stands for "Coordinate Geometry". The standard set of COGO attributes for line features is: Bearing/Angle, Distance, Radius, Delta, Tangent, Arc Length, and Side.[57] The COGO attributes are maintained for the lines in the Boundary feature class. ArcGIS™ 8.3 updates these fields when the appropriate tools are used to edit or create new line features.

The use of COGO attributes and tools that are based on them are examples of the inclusion in GIS of tools to process topographic survey data. ArcGIS™ 8.3 allows for surveyed data to be entered directly into the GIS without any pre-processing. Specialized

[57] Larry Young, "*Maintaining Parcels With ArcGIS™ 8.3*," ArcUser, October-December 2003.

tools are embedded to adjust and process topographic datasets. The direct input of survey data into the GIS is becoming more and more common. This is possible because the GIS are becoming really integral and powerful programs in themselves.

Corners Feature Class

The purpose of this feature class is to hold the points that represent corners of parcels. Corners are parcel point features that are usually monumented on the ground and are the physical demarcation of rights and interests in land. A corner can have multiple monuments that are attempting to identify and locate the correct legal location of the corner on the ground.[58] This feature class is based on the Corners Feature Class from the Parcel Model. The fields created are described in Table 6.

Monuments Feature Class

The purpose of this feature class is to hold the points that represent survey monuments. As mentioned before, a corner can have multiple monuments that are attempting to identify and locate the correct legal location of the corner on the ground. The Monuments feature class may also store the survey points from survey networks or other important cadastral points.

Table 6. Fields in the Corners feature class

Field Name	Data Type	Description	Length	Domain	Commentary
Object ID	Object ID	. . .	. . .	. . .	Default object identification field
Shape	Geometry	Point	. . .	. . .	Geometry type
CORNER_ID	Text	. . .	15	. . .	Corner identification number
NOMBRE	Text	. . .	25	. . .	Point name

[58] Von Meyer, 45.

The use of survey monuments as physical marks of the parcel corners is not really common in Costa Rica, at least not in the urban areas. The corners of the predios are usually demarcated using large nails but in most cases some other physical objects are located where the corners are supposed to be. Fence poles or walls of some type (usually made of bricks) are common examples of objects in the location of corners.

The author wants to mention that the lack of formal monuments to demark the location of predio corners is an important cadastral problem. Since usually there are no monuments for the corners, each time a survey is performed on a predio there is the potential for radically different coordinates to be calculated for the corners. This situation yields to a wide variety of cadastral problems that are not in the scope of this work but need to be mentioned. These problems are related to corner accuracy and demarcation that ultimately affect the GIS datasets and the production of cartography to some extent.

The Monument feature class accommodates multiple monuments for corners. That is, a corner may be marked by more than one monument. This feature class is based on the Monuments Feature Class from the Parcel Model. The fields created are described in Table 7.

The "field precision" describes the number of integer digits that can be stored in a field while the "field scale" describes the number of decimal places for float and double fields.[59] The precision and the scale are seven and six units respectively for both the east coordinate and north coordinate fields. The field for elevation has a precision of four units and a scale of six units.

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[59] MacDonald, 57.

Table 7. Fields in the Monuments feature class

Field Name	Data Type	Description	Length	Domain	Commentary
Object ID	Object ID	. . .	. . .	. . .	Default object identification field
Shape	Geometry	Point	. . .	. . .	Geometry type
CORNER_ID	Text	. . .	15	. . .	Corner identification number
MON_TYPE	Text	. . .	25	. . .	Type of monument
M_SOURCE	Text	. . .	25	. . .	Name of monument builder
ESTE	Double	. . .	. . .	. . .	East coordinate
NORTE	Double	. . .	. . .	. . .	North coordinate
ELEV	Float	-	-	-	Elevation
HZ_DATUM	Text	-	30	-	Horizontal datum's name
CO_SYS	Text	-	30	-	Coordinate system's name
VL_DATUM	Text	-	30	-	Vertical datum's name
CO_METH	Text	-	30	-	Technology used to establish coordinate value
CO_PROCE	Text	-	30	-	Procedure used to measure the coordinates
COMM	Text	-	30	-	Comments

From experience as a surveyor, the author considers that the field scale must always be large enough to hold data with many decimal places. For example, in highly accurate and precise leveling methods as those used in geodetic vertical networks, is usual to record as many as five significant decimal places. Similar precisions are used in horizontal geodetic networks. Since the cadastral network will potentially include some geodetic control points, the scale should allow the storage of these highly precise values.

Value Assessments Feature Dataset

This feature dataset stores the feature classes that are related to the value assessment activities. Some of the information regarding values is stored in different object classes such as Assessments and Buildings. The feature classes stored inside the Value Assessments feature dataset are Buildings and Land Value Zones feature classes. The latter stores the polygon features representing the areas of homogeneous land value.

Buildings Feature Class

This feature class holds the polygons representing the buildings or constructions that are located in the predios. The information describing the buildings is stored in the fields of this feature class. Buildings or constructions are included in the Costa Rican plats and are described in deeds. This data may be important for many reasons. One of those reasons is when a disagreement about the value of a predio exists between the owner and the municipality's records. The fields created are described in Table 8.

In Costa Rica, there is a catalog for the type of materials used in a construction and the expected value of the finished building. The name of this document is *Tipología Constructiva* (Constructive Typology) and also gives codes for the buildings made with a given set of materials. This code may be very useful for the municipality regarding the assessment of buildings in a predio.

The description of buildings stored in this feature class is very important in order to perform accurate assessments of the value of the buildings on a property. This value must be added to the value of the land in order to calculate the total taxable value of a predio and its infrastructure.

Land Value Zones Feature Class

This feature class stores the polygons that represent the land value zones. These zones are areas where the value per square meter of land is homogeneous according to the market.

Table 8. Fields in the Buildings feature class

Field Name	Data Type	Length	Domain	Default value	Commentary
Object ID	Object ID	. . .	. . .	. . .	Default object identification field
GISPID	Text	25	. . .	. . .	Predio or condominium identification number
TIPOLO	Text	25	. . .	. . .	Constructive typology code
EDAD	Short integer	3	. . .	1	Number of years since construction
CONDI	Text	15	. . .	Good	Condition of the building
V_UTIL	Short integer	2	. . .	1	Estimated useful life of the building
PAREDES	Text	50	. . .	. . .	Materials of the walls
ESTRUC	Text	50	. . .	. . .	Materials of the building's body
PISO	Text	50	. . .	. . .	Materials of the floors
CIELO	Text	50	. . .	. . .	Materials of the ceilings
TECHO	Text	50	. . .	. . .	Materials of the roofs
N_BAN	Short integer	2	. . .	1	Number of bathrooms
N_APOS	Short integer	2	. . .	1	Number of rooms
N_PLANTAS	Short integer	2	. . .	1	Number of stories
AREA_T	Double	7 / 3*	. . .	. . .	Total area of the building in square meters
VALOR_T	Double	7 / 3*	. . .	. . .	Assessed or declared value
VALOR_M	Double	7 / 3*	. . .	. . .	Value per square meter = (VALOR_T / AREA_T)
SHAPE	Geometry	Polygon	. . .	. . .	Feature Geometry
SHAPE_Area	Shape_Area	. . .	Double	. . .	Default area field
SHAPE_Length	Shape_Length	. . .	Double	. . .	Default length field

* The first number indicates the precision (or number of integer digits) and the second number indicates the scale (or number of decimal digits) of the field.

Examples of land value zones are commercial areas within a city, a subdivision, and a public park. Maps showing land value zones are important for the real estate market and the general public. The fields created are described in Table 9.

Table 9. Fields in the Land Value Zones feature class

Field Name	Data Type	Description	Length	Domain	Commentary
Object ID	Object ID	. . .	. . .	. . .	Default object identification field
SHAPE	Geometry	Polygon	. . .	. . .	Feature Geometry
COD_ZONA	Text	. . .	10	. . .	Value zone code
NAME_Z	Text	. . .	25	. . .	Name of the value zone
SHAPE_Area	Shape_Area	. . .	Double	. . .	Default area field
SHAPE_Length	Shape_Length	. . .	Double	. . .	Default length field

Interests on Land Feature Dataset

This feature dataset stores the feature classes that are related to restrictions, encumbrances, and other rights that affect the land. These may be governmental restrictions such as zoning, or separated rights such as mineral rights that are not part of the ownership of the surface land ("fee simple").

The feature classes stored inside the Interests on Land feature dataset are: Encumbrances, Restrictions, Zones, and Separated Rights. A topology rule called Topology Rule 2 is stored inside this feature dataset, and its purpose is to assess for any overlapping zone polygons. This topology rule is described in the Topology Rules section of this work.

Zones Feature Class

Simultaneous conveyances occur when several parcels are created at the same moment such as lots in a subdivision, units in a condominium, or plots in a cemetery.[60]

The author embraces the concept of simultaneous conveyance since is useful to describe cadastral situations in Costa Rica. However, the author defines them as "zones" (or *zonas* in Spanish) for this work. Simultaneous conveyances can have a hierarchical structure such as the exterior boundary is senior to interior lines, or lots may be nested inside blocks.

The purpose of the Zones feature class is to represent with polygons, zones where predios have common characteristics. The predios in a zone are usually created at the same time, such as the case of an urban development (subdivision) where all the predios are created at the same time. The fields created are described in Table 10.

This feature class is based on the Simultaneous Conveyance Feature Class from the Parcel Model. The domain for the type of zone holds the following options: (1) Urban Development, (2) Cemetery; (3) Condominium.

Encumbrances Feature Class

This feature class holds the polygons representing the encumbrances. These are limitations on the rights and use of the land, usually represented as non-continuous and overlapping polygons.[61] For example, an "easement" is a right or interest that one party has in the land of another, and it may diminish its value but does not prevent its sale.[62] Most encumbrances run with the land consistent with the passing of the ownership.

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[60] von Meyer, 25-26.

[61] Ibid., 16.

[62] Friedman, 103-110.

Table 10. Fields in the Zones feature class

Field Name	Data Type	Description	Length	Domain	Commentary
Object ID	Object ID	...	...	...	Default object identification field
Shape	Geometry	Polygon	...	...	Geometry type
NUM_ZONA	Short integer	...	...	...	Zone identification number
TIPO_ZONA	Text	...	25	TIPO_ZONA	Zone type descriptor
SHAPE_Area	Shape_Area	...	Double	...	Default area field
SHAPE_Length	Shape_Length	...	Double	...	Default length field

Encumbrances are an important part of the legal situation of a parcel since they record some limitations on the rights and the use of the land. The fields for this feature class are based on the fields in the Encumbrances Feature Class from the Parcel Model. The fields created are described in Table 11.

The domain created for the type of encumbrance has the following options: (1) Easement, (2) Utility, (3) Conservation, (4) Ingress-Egress, (5) Flood, (6) Right of way, (7) Lease, and (8) Other.

Separated Rights Feature Class

The separated rights are rights and interests in land ownership that can be disconnected from the primary or fee simple surface ownership. For example, mineral and oil rights are often separated from the surface ownership. There are also above ground separated rights, and include things like solar easements that can potentially be overlapping and non-continuous polygons. Overhead or above ground separated rights tend to be three dimensional "envelopes" although they can be expressed with a flat or two dimensional representation. As with the vertical parcels (i.e. condominiums in a building with more than one level), there could be a series of polygons on top of each other based on mineral type.[63] The separated rights are modeled as polygons.

Table 11. Fields in the Encumbrances feature class

Field Name	Data Type	Description	Length	Domain	Commentary
Object ID	Object ID	...	...	...	Default object identification field
SHAPE	Geometry	Polygon	...	...	Feature Geometry
GISPID	Text	...	25	...	Predio or condominium identification number
EncumbranceID	Text	...	30	...	Encumbrance ID Number
Encumbrance Type	Date	...	30	EncumbranceType	Type
Encumbrance Owner	Text	...	100	...	Name of the Owner
Encumbrance Area	Double	...	...	...	Encumbrance area
AreaType	Text	...	20	...	Area type
SHAPE_Area	Shape_Area	...	Double	...	Default area field
SHAPE_Length	Shape_Length	...	Double	...	Default length field

Separated rights are very common in Costa Rica especially the ones related to minerals. The fields for this feature class are based on the fields in the Separated Rights Feature Class from the Parcel Model. The fields created are described in Table 12.

[63] von Meyer, 19-20.

Table 12. Fields in the Separated Rights feature class

Field Name	Data Type	Description	Length	Domain	Commentary
Object ID	Object ID	. . .	. . .	. . .	Default object identification field
SHAPE	Geometry	Polygon	. . .	. . .	Feature Geometry
GISPID	Text	. . .	25	. . .	Predio or condominium identification number
SeparatedRightID	Text	-	30	-	ID number
RightOwner	Text	-	30	-	Right owner's name
RightType	Text	-	30	Separated RightsType	Type of right
RightMineral	Text	-	30	-	Type of mineral
RightArea	Double	-	-	-	Area involved
AreaType	Text	-	30	-	Type of area
SHAPE_Area	Shape_Area	-	Double	-	Default area field
SHAPE_Length	Shape_Length	-	Double	-	Default length field

The domain for the type of separated right holds the following options: (1) Tree cutting, (2) Non-Metallic, (3) Metallic, (4) Coal, (5) Mineral, (6), Oil, (7) Gas, (8) Solar, and (9) Other.

Restrictions Feature Class

Regulated uses and restrictions are controls by a public body or institution that limit the uses of land for the purposes of controlling development, maintaining property values, and implementing master plans or other plans. The most common form of regulated uses is zoning.[64]

The fields for this feature class are based on the fields in the Restrictions Feature Class from the Parcel Model. The fields created are described in Table 13.

[64] von Meyer, 40.

Table 13. Fields in the Restrictions feature class

Field Name	Data Type	Description	Length	Domain	Commentary
Object ID	Object ID	. . .	. . .	. . .	Default object identification field
SHAPE	Geometry	Polygon	. . .	. . .	Feature Geometry
GISPID	Text	. . .	25	. . .	Predio or condominium identification number
RestrictionID	Text	. . .	30	. . .	ID number
RestrictionType	Text	. . .	20	RestrictionType	Type of Restriction
RestrictionDescription	Text	. . .	30	. . .	Description
RestrictionAgency	Text	. . .	30	. . .	Agency imposing the restriction
RestrictionArea	Double	. . .	. . .	. . .	Area involved
SHAPE_Area	Shape_Area	. . .	Double	. . .	Default area field
SHAPE_Length	Shape_Length	. . .	Double	. . .	Default length field

The domain for the type of restriction holds the following options: (1) Restrictive Covenant, (2) Governmental Authority, (3) Land Use, (4) Zoning, and (5) Other.

Administrative Divisions Feature Dataset

This feature dataset stores the feature classes that describe the administrative division of the country into provinces, counties, and districts. Since the geodatabase schema created in this work is for the use of one municipality, there is no need to store the features for counties and districts for the entire country. However, it is usual for municipalities to maintain a copy of the national datasets in order to produce small scale maps.

The spatial domain of the Administrative Divisions feature dataset is large enough to store the national datasets. The parameters used are displayed in Table 14.

Table 14. Spatial domain and precision for the Administrative Divisions feature dataset

Minimum X (East)	310,000
Maximum X	710,000
Minimum Y (North)	1,000
Maximum Y	401,000
Precision (X,Y)	5,368.7
Maximum Z (Elevation)	4,000
Precision (Z)	100,000

Since the official Costa Rican projection is based on a cone, in the extremes of the developed projection the distortions are considerable. The author wants to mention that actually, there are two official projections in Costa Rica: one for the northern part and one for the southern part of the country in order to minimize distortions.

A new, more suitable projection based on the Universal Transversal Mercator projection was developed in order to cover the entire country with minimum distortions using only one projection. This projection is called "Costa Rica Transversal Mercator," and unfortunately is not the official projection for the country at this moment.

The projection used for this work is the one for the northern part of Costa Rica and is not suitable to display the entire country with acceptable distortions. The author uses this projection since is what municipalities are required to use for their cadastre. The Costa Rican hardcopy cartography is produced using the official Lambert Conformal Conic projection as well.

The feature classes created inside the Administrative Divisions feature dataset are Provinces, Counties, and Districts feature datasets. These features classes are described in the following sections.

Provinces Feature Class

This feature class holds the polygons representing the provinces of Costa Rica. The fields created are described in Table 15.

Counties Feature Class

This feature class holds the polygons representing the counties of Costa Rica. The fields created are described in Table 16.

Districts Feature Class

This feature class holds the polygons representing the districts. The fields created are described in Table 17.

Transportation Feature Dataset

This feature dataset stores the feature classes that represent the center lines for the street network. The spatial domain of the Administrative Divisions feature dataset is large enough to store the national datasets. The spatial domain parameters used are the same as for the Administrative Divisions feature dataset shown in Table 14.

The feature class created inside the Transportation feature dataset is called Street Network. This feature class is described in the next section.

Table 15. Fields in the Provinces feature class

Field Name	Data Type	Description	Length	Domain	Commentary
Object ID	Object ID	. . .	. . .	. . .	Default object identification field
Shape	Geometry	Polygon	. . .	. . .	Geometry type
PROV	Short integer	. . .	2	. . .	Province identification number
N_PROV	Text	. . .	25	. . .	Province name
POBL	Long integer	. . .	6	. . .	Province's population
SHAPE_Area	Shape_Area	. . .	Double	. . .	Default area field
SHAPE_Length	Shape_Length	. . .	Double	. . .	Default length field

Table 16. Fields in the Counties feature class

Field Name	Data Type	Description	Length	Domain	Commentary
Object ID	Object ID	. . .	. . .	. . .	Default object identification field
Shape	Geometry	Polygon	. . .	. . .	Geometry type
PROV	Short integer	. . .	2	. . .	Province identification number
N_PROV	Text	. . .	25	. . .	Province name
CANTON	Short integer	. . .	2	. . .	County identification number
N_CANT	Text	. . .	25	. . .	County's name
POBL	Long integer	. . .	6	. . .	County's population
SHAPE_Area	Shape_Area	. . .	Double	. . .	Default area field
SHAPE_Length	Shape_Length	. . .	Double	. . .	Default length field

Street Network Feature Class

This feature class stores the lines that represent the street network for the country. Even though a geocoding system can be implemented using this feature class, this system has not been created for Costa Rica. The fields created are described in Table 18.

Table 17. Fields in the Districts feature class

Field Name	Data Type	Description	Length	Domain	Commentary
Object ID	Object ID	. . .	. . .	. . .	Default object identification field
Shape	Geometry	Polygon	. . .	. . .	Geometry type
PROV	Short integer	. . .	2	. . .	Province identification number
CANTON	Short integer	. . .	2	. . .	County identification number
DISTRITO	Short integer	. . .	3	. . .	District identification number
N_PROV	Text	. . .	25	. . .	Province name
N_CANT	Text	. . .	25	. . .	County name
N_DISTR	Text	. . .	25	. . .	District name
POBL	Long integer	. . .	6	. . .	District's population
SHAPE_Area	Shape_Area	. . .	Double	. . .	Default area field
SHAPE_Length	Shape_Length	. . .	Double	. . .	Default length field

Table 18. Fields in the Street Network feature class

Field Name	Data Type	Description	Length	Domain	Commentary
Object ID	Object ID	. . .	. . .	. . .	Default object identification field
SHAPE	Geometry	Line	. . .	. . .	Feature Geometry
F_NAME	Text	. . .	50	. . .	Street's full name
SHAPE_Length	Double	. . .	Double	. . .	Default length field

The feature datasets and feature classes described in the previous sections store the geographic features that represent the geographic elements of the cadastre in the geodatabase. The feature classes are organized according to their thematic contents in order to facilitate the cadastral activities and to provide a form of logical arrangement of cadastral layers.

Object Classes

The object classes (tables) hold the bulk of the numeric and alphanumeric data that will be stored in the cadastral geodatabase. Each table was created in order to store data about a topic such as building's materials, or the information about the rights to the predios.

Most of the time and effort of this work were invested in the determination of the data to be stored in the geodatabase, and in finding the most suitable way to organize this data. The author interviewed the functionaries in charge of the cadastral departments from two municipalities (Municipality of Barva County and Municipality of Heredia County) in order to get acquainted with the point of view of a municipal functionary: the user's point of view. Additionally, the author analyzed the cadastral databases that are kept by the Municipality of Barva County in order to determine what data is needed for a digital cadastral system, and for a potential land information system.

The author has previous experience with the tasks involved in the creation and management of a cadastral system since that is involved in the education to obtain a degree as a surveyor engineer in Costa Rica. Jobs related to the cadastre represent the bulk of the market available for surveyor engineers in Costa Rica.

The purpose of getting involved with functionaries from the municipalities was to get in touch with the current needs and tasks of a typical cadastral department in a Costa Rican municipality. The suggestions about multipurpose cadastre made in the Cadastre 2014 work were also considered in order to build a functional and complete geodatabase schema to store and manage the cadastral data. The object classes created are described in the following sections.

Assessments Object Class

This table stores the value assessments for the predios. The source of value may be an official declaration by the owner, possessor, usufructuary, awardee, or an official assessment made by the municipality. A field was created for the date of the value since this is an important issue for tax billing purposes. In addition, the municipality may want to keep both, a current value and the last value in order to analyze the evolution of the values. The fields created are described in Table 19.

Table 19. Fields in the Assessments object class

Field Name	Data Type	Length	Domain	Commentary
Object ID	Object ID	...	...	Default object identification field
GISPID	Text	25	...	Predio or condominium identification number
VALOR	Text	25	...	Total value of the predio or condominium
FECHA	Date	...	...	Date of the declaration or assessment
TIPO	Text	15	Avalúo	Type of value: whether declaration or assessment
ZONA	Text	10	...	Value zone's code

Condominiums Object Class

The purpose of this table is to establish a relationship between a predio and its condominiums if any exist. The identification number of a predio (the "GISPID" field) can be repeated as many times as needed in this table. For each one of the records in the table there will be a condominium identification number (in the "CONDO_ID" field). The fields created are described in Table 20.

Table 20. Fields in the Condominiums object class

Field Name	Data Type	Length	Domain	Commentary
Object ID	Object ID	. . .	. . .	Default object identification field
GISPID	Text	25	. . .	Predio identification number
CONDO_ID	Text	25	. . .	Condominium identification number

Real Estate Object Class

This table stores the basic information for each predio. Some of the information stored in this table concerns the legal registration data that comes from the registration process at the National Register. When a predio has not been registered, this information does not exist, and the fields take a default value of "Not Registered" based in the subtype field for the legal situation of the predios. The field called "LEGAL2" is the key field for the subtype indicating whether the predio is registered or not. The fields created are described in Table 21.

The domain for the legal situation of the predio provides the following options: (1) Predio officially registered in the National Register, (2) Predio in the process of change of ownership, (3) Government owned predio awarded in adjudication, (4) Predio invaded against owner's will (trespassed), (5) Predio whose usufruct has been awarded to someone different that his/her owner, (6) Unregistered predio, (7) Predio located along an international border, and (8) Predio located along the coast line.

Table 21. Fields in the Real Estate object class

Field Name	Data Type	Length	Domain	Commentary
Object ID	Object ID	. . .	. . .	Default object identification field
GISPID	Text	25	. . .	Predio or condominium identification number
N_PLANO	Text	25	. . .	Number of the official survey plat
N_COPRO	Short integer	2	. . .	Number of co-owners or co-possessors
UBICA	Text	100	. . .	Detailed location of the predio
DISTR	Text	20	. . .	Name of the district where is located
TOMO	Text	10	. . .	Legal registration number
FOLIO	Text	10	. . .	Legal registration number
ASIENTO	Text	10	. . .	Legal registration number
AREAREG	Text	50	. . .	Official area registered in the National Register
FOLIO_REAL	Text	25	. . .	Legal registration number
AREACAT	Text	50	. . .	Area from the of the official survey plat
LEGAL2	Text	25	LEGAL	Legal situation of the predio
TIPOPREDIO	Text	25	TIPO_PREDIO	Indicates the type of predio

The domain for the type of predio (TIPO_PREDIO) allows the following options: (1) Base predio, (2) Condominium, (3) Right of way, and (4) Other. The base predio option must be used for any predio that does not fall in any of the other options. For example, all the predios that are not a condominium or an encumbrance are considered as base predios. A common residential property is a base predio.

Owners Object Class

The information about the owner, possessor, usufructuary, awardee, or trespasser of each predio is stored in this table. The name "Owners" was given to this table even though the person (or persons) with rights to a predio might not be its owner. The reason for this choice is simply the common use of the word "owner" to refer to the person that has the rights to a predio until actual ownership is determined. The fields created are described in Table 22.

The domain describing the legal situation of the person with rights to a predio is important since this information must be recorded as accurate as possible. The options that this domain allows are the following: (1) Owner, (2) Possessor, (3) Awardee, (4) Trespasser, (5) Usufructuary, (6) Co-owner, and (7) Co-possessor.

Table 22. Fields in the Owners object class

Field Name	Data Type	Length	Domain	Commentary
Object ID	Object ID	. . .	. . .	Default object identification field
GISPID	Text	25	. . .	Predio or condominium identification number
N_FINCA	Text	25	. . .	Official registration number of the right
CEDULA	Text	25	. . .	National identification of the person or institution
NAME	Text	50	. . .	Name of the person or institution
PROVINCIA	Text	25	. . .	Name of the province where the person lives
CANTON	Text	25	. . .	Name of the county where the person lives

Table 22- Continued

Field Name	Data Type	Length	Domain	Commentary
DISTRITO	Text	25	. . .	Name of the district where the person lives
DIR1	Text	50	. . .	Detailed address of the person
N_TEL	Text	25	. . .	Telephone number of the person
POBOX	Text	25	. . .	Postal address of the person
DERECHO	Short integer	3	. . .	Percentage of ownership or possession
LEGAL1	Text	25	LEGALPROP	Legal situation of the person

Services Object Class

The different services available to a predio are recorded and described in this table. This information is an important input to the assessment of real estate values. The fields created are described in Table 23.

The domain for the type of water service available allows the following options: (1) Residential, (2) Reproductive (meaning it may be used to produce goods), (3) Ordinary, (4) Government (used by government buildings). The domain for the type of main access available to the predio allows the following options: (1) Asphalt road, (2) Gravel road, (3) Dirt road, (4) Right of pass, (5) Sidewalk only (called *alameda* in Costa Rica), (6) River or lake. The Yes/No domain only allows those two options to indicate whether or not a feature or characteristic is present.

Topography Object Class

This table contains the information that describes the topography of the predio. Those characteristics are for example the length in meters of the front (or fronts if more than one) of the predio, and the average slope (in percentage) of the terrain. The fields created are described in Table 24.

Table 23. Fields in the Services object class

Field Name	Data Type	Length	Domain	Commentary
Object ID	Object ID	. . .	. . .	Default object identification field
GISPID	Text	25	. . .	Predio or condominium identification number
AGUA	Text	25	AGUA	Type of water service available
CANO	Text	5	Yes/No	Existence of Pluvial system
CORDON	Text	5	Yes/No	Existence of street delimitation on sides
ACERA	Text	5	Yes/No	Existence of a sidewalk
A_PLUV	Text	5	Yes/No	Availability of sewer system
A_SANI	Text	5	Yes/No	Availability of sanitary piping
ELEC	Text	5	Yes/No	Availability of electric power
TEL	Text	5	Yes/No	Availability of a telephone line
A_PUB	Text	5	Yes/No	Existence of public lights
VIA	Text	5	VIAS	Type of the main access to the predio

Some of the information stored this table is also required for the assessment of the value of the real estate. For example, the fields for the percentage of slope and for the height of the terrain above the main access way level, are needed in the assessment of the value of a predio.

Table 24. Fields in the Topography object class

Field Name	Data Type	Length	Domain	Commentary
Object ID	Object ID	. . .	. . .	Default object identification field
GISPID	Text	25	. . .	Predio or condominium identification number
USO	Text	25	USO	Type of use of the land
FRENTE1	Text	10	. . .	First front's length in meters
FRENTE2	Text	10	. . .	Second front's length in meters
FRENTE3	Text	10	. . .	Third front's length in meters
PEND	Float	2/3*	. . .	Average percentage of slope of the terrain
HEIGHT	Double	1/3*	. . .	Height of the terrain in meters from the main access level
AREACAT	Double	10/6*	. . .	Area from the of the official survey plat in square meters
AREACAT2	Text	50	. . .	Area from the of the official survey plat in words

* The first number indicates the precision (number of integer digits) and the second number indicates the scale (number of decimal digits) of the field

Patents Object Class

This table stores the information about the patents or commercial permits that the municipality awards. Examples of patents are: liquor sales, prepared food sales, and mechanical workshops. The fields created are described in Table 25.

The information about patents is important to the municipality since these represent a source of income through fees. Using this table, the municipality can record what patents have been granted, and in which predios are they located. Location of commercial patents is important in some cases. For example, liquor stores or bars are required by law to be located outside a minimum radius from education institutions such as primary or high schools.

Table 25. Fields in the Patents object class

Field Name	Data Type	Length	Domain	Commentary
Object ID	Object ID	. . .	. . .	Default object identification field
GISPID	Text	25	. . .	Predio or condominium identification number
NOMBRE	Text	25	. . .	Name of patent's beneficiary
CEDULA	Text	25	. . .	Beneficiary's national ID number
TIPO_PAT	Text	25	. . .	Type of patent
NUM_PAT	Text	25	. . .	Patent number
COD_PAT	Text	5	. . .	Patent type code number

Billing Object Class

The purpose of this table is to store the information related to tax billing based on land ownership. This tax is based on the total value of a real estate: the value of the land plus any buildings or constructions in it. Tax billing information is usually updated and edited by the Billing Department of the municipalities.

The author includes this table in the schema in order to provide the possibility for this information to reside in the geodatabase, and to allow the Billing Department to access it by means of a computer network. However, since the Billing Department is required to produce receipts, account balances, etc., this table may not be completely suitable for their purposes. Financial or spread sheet-like computer programs may be more suitable for the tax billing tasks. The fields created are described in Table 26.

Table 26. Fields in the Billing object class

Field Name	Data Type	Length	Domain	Commentary
Object ID	Object ID	. . .	. . .	Default object identification field
GISPID	Text	25	. . .	Predio or condominium identification number
VALUE	Text	25	. . .	Real estate's total value
TAX	Text	25	. . .	Tax amount
YEAR	Text	25	. . .	Year being billed
BAL	Text	25	. . .	Current payment balance
STATUS	Text	25	. . .	If a person is to date or not in payments

The GISPID field is used to relate this table with the Owners table and the Assessments table. The purpose of this is to avoid data duplication in the geodatabase by accessing the data stored in other tables. The information about the owner, possessor, usufructuary, or awardee can be found in the related Owners table. The information about the current value assessments can be found in the related Assessments table. The corresponding relationship classes are described in the Relationship Classes section of this work.

The object classes created into the cadastral geodatabase were described in this section. These tables store the bulk of the cadastral information that a Costa Rican municipality may use in order to perform its activities such as tax billing, public services planning, and land management.

The next section of this work describes the relationship classes created within the geodatabase schema. Relationship classes establish links between objects such as parcel features and ownership records.

Relationship Classes

A relationship is an association between two or more objects in a geodatabase. The purpose of a relationship class is to establish a link between objects. Relationships can exist between spatial objects and/or non-spatial objects.[65] These types of relationships are used in the custom geodatabase for this work.

Some basic definitions are needed to understand relationships. A relationship between two objects is maintained through attribute values for the "key fields." The "key fields" are the fields in each class that may contain the same values allowing a matching between records (tuples) in the classes.

The "cardinality" of a relationship defines how many objects of the origin class can be related to the objects in the destination class. The cardinality can be of four types: one-to-one (1-1), one-to-many (1-M), many-to-one (M-1), and many-to-many (M-N). The first cardinality descriptor defines the number of objects of the origin class, and the second one the number of objects of the destination class that can be related. Relationships can be either simple or composite. In a "simple" relationship the objects in the database exist independently of each other. In a "composite" relationship the lifetime of one object controls the lifetime of its related objects.[66]

The relationship classes created for the geodatabase designed in this work are described in the following sections. A total of twelve relationship classes were created.

Ownership Relationship Class

This relationship class establishes associations between the spatial objects of the Predios feature class and the records of the Owners table. That is, it relates the cadastral

[65] MacDonald, 466-467.
[66] Ibid., 148-149.

predios with their owners, possessors, awardees, or usufructusries. This relationship class is described in Table 27.

Table 27. Description of the Ownership relationship class

Type	Simple
Cardinality	many-to-many
Key field in origin class	GISPID
Key field in destination class	GISPID

This relationship class has a many-to-many cardinality because multiple owners can own multiple predios. While in most cases one predio would have only one owner, several owners per predio is also a common situation. A single person can own many predios as well. The field used to associate the objects is the "GISPID" field because this is the predio number. The type of relationship is simple because the removal of an owner in the destination table can not be enforced when a predio is deleted since this owner may be related to other predios.

Value Assessments Relationship Class

This relationship class establishes associations between the spatial objects of the Predios feature class and the records of the Assessments table. This relationship has a one-to-many cardinality in order to allow several assessments for each predio. In this way, a record of past assessments can be kept and the "DATE" field in the Assessments table would indicate which one is the latest. This information may be useful in the sense that the municipal functionaries can evaluate the change in the value of a predio or an area of the county over time. The type of relationship is composite since there can be no value assessment if there is no predio for it. This relationship class is described in Table 28.

Table 28. Description of the Value Assessments relationship class

Type	Composite
Cardinality	one-to-many
Key field in origin class	GISPID
Key field in destination class	GISPID

Real Estate Data Relationship Class

This relationship class establishes associations between the spatial objects of the Predios feature class and the records of the Real Estate table.

The data concerning the legal registration of a predio is stored in the Real Estate table. This information is constantly accessed by municipal functionaries in order to perform several tasks such as tax billing, patent assignments, or in order to resolve conflicts between owners. The cardinality is one-to-one since there can only be one legal registration for each predio. The type of relationship is composite since there can be no real estate data if there is no predio for it. This relationship class is described in Table 29.

Buildings Data Relationship Class

This relationship class establishes associations between the spatial objects of the Predios feature class and the spatial objects of the Buildings feature class. The information describing the building(s) located in a predio is stored in the Buildings feature class as well. This information is an important input to the value assessments performed by the municipality. This relationship class is described in Table 30.

Table 29. Description of the Real Estate Data relationship class

Type	Composite
Cardinality	one-to-one
Key field in origin class	GISPID
Key field in destination class	GISPID

Table 30. Description of the Buildings Data relationship class

Type	Composite
Cardinality	one-to-many
Key field in origin class	GISPID
Key field in destination class	GISPID

The cardinality of this relationship is one-to-many in order to allow the description of several buildings in each predio. While there is usually only one building in each predio (i.e. a house or a factory), in Costa Rica it is common that several houses are located in one predio with no subdivision into smaller predios. The type of relationship is composite since there can be no buildings if there is no predio for them.

Terrain Data Relationship Class

This relationship class establishes associations between the spatial objects of the Predios feature class and the records of the Topography table. This table stores the topographic description of the predios, and this data is also used as input for the value assessments. This relationship class is described in Table 31.

Table 31. Description of the Terrain Data relationship class

Type	Composite
Cardinality	one-to-one
Key field in origin class	GISPID
Key field in destination class	GISPID

The cardinality of this relationship is one-to-one since there can only be one topographic description for each predio. The type of relationship is composite since there can be no terrain description if there is no predio for it.

Services in a Predio Relationship Class

This relationship class establishes associations between the spatial objects of the Predios feature class and the records of the Services table. The descriptions of the services available to a predio, such as drinking water or electric power are stored in this table. This relationship class is described in Table 32.

Table 32. Description of the Services in a Predio relationship class

Type	Composite
Cardinality	one-to-one
Key field in origin class	GISPID
Key field in destination class	GISPID

The cardinality of this relationship is one-to-one since there can only be one description of the services for each predio. The type of relationship is composite since there can be no description if there is no predio for it. The existence of more than one drinking water pipe service for a predio is managed by two fields for the water service.

Predios and Condominiums Relationship Class

This relationship class establishes associations between the spatial objects of the Predios feature class and the records of the Condominiums table. This table allows for any number of related condominiums to be related to one predio by means of repetition of the GISPID number. This relationship class is described in Table 33.

Table 33. Description of the Predios and Condominiums relationship class

Type	Composite
Cardinality	one-to-many
Key field in origin class	GISPID
Key field in destination class	GISPID

The cardinality of this relationship is one-to-many in order to allow the description of several condominiums for each predio. The type of relationship is composite since there can be no condominiums if there is no predio for them.

Predios and Patents Relationship Class

This relationship class establishes associations between the spatial objects of the Predios feature class and the records of the Patents table. The cardinality is one-to-many since a predio may have several patents. The type of relationship is composite since the patents must be awarded to a predio. This relationship class is described in Table 34.

Table 34. Description of the Predios and Patents relationship class

Type	Composite
Cardinality	one-to-many
Key field in origin class	GISPID
Key field in destination class	GISPID

Owner and Bill Relationship Class

This relationship class establishes associations between the records of the Owners table and the records of the Billing table. The cardinality is one-to-many since one person (i.e. owner, possessor, or awardee) may have several pending tax bills. The type of relationship is composite since there can be no tax bill if there is no person responsible for it. This relationship class is described in Table 35.

Table 35. Description of the Owner and Bill relationship class

Type	Composite
Cardinality	One-to-many
Key field in origin class	Cedula
Key field in destination class	Cedula

Assessment and Bill Relationship Class

This relationship class establishes associations between the records of the Assessments table and the records in the Billing table. The cardinality is many-to-many since a predio may have several pending tax bills, and each one of those may be related to a different taxable value (for the real estate). The type of relationship is simple since a

M-N relationship can not be a composite relationship. This relationship class is described in Table 36.

Table 36. Description of the Assessment and Bill relationship class

Type	Simple
Cardinality	Many-to-many
Key field in origin class	GISPID
Key field in destination class	GISPID

Condominiums' Assessments Relationship Class

This relationship class establishes associations between the records of the Condominiums table and the records in the Assessments table in order to relate each condominium with its value assessment. Even though each condominium in a complex may not be located in a separate predio, it may have a value assessment of its own.

The cardinality is many-to-many since the Condominiums table holds a M-N relationship with the Predios feature class. It is allowed for each condominium to have more than one assessment as well. The type or relationship is simple since a M-N relationship can not be a composite relationship. This relationship class is described in Table 37.

Corner and Monument Relationship Class

This relationship class establishes associations between the spatial objects of the Corners feature class and the Monuments feature class. The cardinality is one-to-many since a corner may have more than one monument. The type of relationship is composite since a monument can not exist without a corner. This relationship class is described in Table 38.

Table 37. Description of the Condominiums' Assessments relationship class

Type	Simple
Cardinality	Many-to-many
Key field in origin class	Condo_ID
Key field in destination class	GISPID

Table 38. Description of the Corner and Monument relationship class

Type	Composite
Cardinality	One-to-many
Key field in origin class	CORNER_ID
Key field in destination class	CORNER_ID

The relationship classes created into the cadastral geodatabase schema were described in the previous sections. These relationship classes allow the establishment of associations between objects (features and/or records) within the cadastral geodatabase.

The following sections of this work describe the topology rules created into the geodatabase in order to aid in the cadastral activities.

Topology Rules

The creation of topology rules is greatly simplified in ArcGIS™ 8.3 version of ESRI® software. The topology in geodatabases is the relationship between connected features in a geometric network, or shared borders between features in a planar topology.[67] In the context of ArcGIS™ 8.3, a topology contains relationships between objects, and is exposed as a layer in ArcCatalog. This layer tracks feature edits during an edit session to enforce the rules created.[68]

Topology rules can be of considerable aid to the cadastral activities. For example, when a predio is divided into two or more new predios, a topology rule that enforces that the predios do not overlap can be of great help to the municipal functionary in order to perform the appropriate editions. If the new predios are overlapping each other or other predios, this rule will identify that situation and create a record of it. Furthermore, a rule enforcing that there can be no gaps between predios can inform the municipal functionary of such situations as well.

Topology rules are of great importance to the cadastre since they can help to implement the cadastral concepts and/or laws into the cadastral geodatabase. Some of the tasks under the responsibility of a municipal functionary can now be accomplished by the GIS with the aid of topology rules.

The names of the topology rules available in ArcGIS™ 8.3 are self explanatory. This is important since the purpose of a rule needs to be clear in order for the rule to be useful and practical. If more than one rule involving the same feature class has to be created, they are implemented as parts of a single topology in ArcGIS™ 8.3.

The following concepts are needed to understand the processes behind geodatabase topology. The "cluster tolerance" is a distance in which vertices of features are considered coincident. The "coordinate accuracy ranks" are defined for feature classes and they control how far the features in one class can potentially move in relation

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[67] MacDonald, 469.

[68] Ty Fitzpatrick, "*Parcel Management Using Topology in ArcGIS 8.3*," *ArcUser*, January-March 2003, 50.

to features in other classes when a topology is validated. The "validate topology" operation is used to snap feature geometry where vertices fall within the cluster tolerance, and to check for violations of the specified topology rules. This operation begins by snapping together feature vertices that fall within the cluster tolerance, taking into account the ranks of the feature classes. Features with the lowest rank of coordinate accuracy are moved to match the features with higher rank. Violations to the rules are marked and displayed in a layer for each topology.[69]

The implementation of coordinate accuracy ranks in a cadastral geodatabase is of great significance for the editing activities. The concept of ranks has been present in the cadastre for many decades but is not until now that it can be implemented within a geographic dataset or database. Is well known to surveyor engineers that each transect or survey has a different accuracy based on the measurement methods, accidental errors, etc. The geodatabase allows to make ranks inherent to the feature classes and to use these ranks in order to perform mathematical adjustments to the survey data.

The rank designation is used in the custom geodatabase as follows: Monuments feature class with the highest rank of 1 (one), Boundaries feature class with the second highest rank of 2 (two), and Predios feature class with the third highest rank of 3 (three). If any other feature class is included in a topological rule, its rank must be determined and defined considering the ranks mentioned. For example, if a highly accurate survey network is created in the county, its rank might be even higher than that of the Monuments feature class.

The cluster tolerance that is used in the custom geodatabase is the default value that is calculated by ArcGIS 8.3. This value is approximately the inverse of the spatial

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[69] ESRI®, "*ArcGIS™ 8.3 Brings Topology to the Geodatabase*," *Arc News*, Summer 2002.

resolution used for most of the feature classes in the geodatabase described in Table 2. The default cluster tolerance is 0.000028785 meters. This cluster tolerance is used to validate all the topological rules created for the cadastral features. However, a municipal functionary may define a different value for the cluster tolerance when performing editing activities such as the creation of new features into a feature class. This can be accomplished in ArcGIS™ 8.3.

The cluster tolerance should be set to the default value (calculated by ArcGIS™) if the accuracy of the datasets stored in the feature datasets is unknown. When the accuracy of datasets is known, the cluster tolerance should be set to about 1/10 (on-tenth) of the accuracy value.[70]

The following sections of this work describe the topology rules created in order to facilitate the cadastral activities of the Costa Rican municipalities.

Predios Must not Overlap (Rule 1)

This topology rule enforces that the predios do not overlap each other. This is a cadastral concept that is strongly related to the cadastral unit used. The definition of predio as a "tax parcel" does not allow for predios overlap. However, the predios are allowed to share their boundaries with their neighbors. This is the basis for what is called "coincident geometry" in the geodatabase model.

The use of this topology rule may be really important in the every-day cadastral activities of a Costa Rican municipality. Every time an editing session is performed on the Predios feature class, it can be validated and the municipal functionary is informed of

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[70] ESRI®, *ArcGIS™: Working with Geodatabase Topology*, An ESRI® White Paper, page 5 [paper on-line] (ESRI, May 2003), available from http://downloads.esri.com/support/whitepapers/-ao_/geodatabase-topology.pdf; Internet; accessed 1 April 2004.

the features that present violations to the rule. This helps to ensure quality and integrity of the cadastral dataset.

Zones Must not Overlap (Rule 2)

This topology rule enforces that the zones (simultaneous conveyances) do not overlap each other. By definition, two different zones have different characteristics, are created at different moments in time, and they can not overlap. Some exceptions may occur when for example, a condominium is created within a subdivision, or when old records and new records disagree, but this is to be resolved by the municipal functionary on a case-by-case basis. The result of the validation shows violations to the topology rule but it will not solve those violations; that must be performed by the GIS user (the municipal functionary in this case).

Blocks Must not Overlap (Rule3)

This topology rule enforces that the city blocks do not overlap each other. Usually, a road or a river will separate blocks within a county, and there is no reason for the blocks to overlap.

This rule helps to ensure that obvious errors such as two city blocks overlapping will not occur. This kind of error is usually a consequence of a drafting error, or poor editing procedures. The topology rules are used to avoid this type of error.

Corners Must be Covered by Endpoints of Boundaries (Rule 4)

The purpose of this topology rule is to ensure that there is a coincidence between the Corners feature class and the Boundaries feature class. The points of the Corners feature class must always be covered by the endpoint of a line from the Boundaries feature class. Examples of these lines are the sides of a survey (transect), or the sides of a predio feature.

Boundaries' Endpoints Must be Covered by Corners (Rule 5)

This rule complements Rule 4. Its purpose is to ensure that the creation of a line feature in the Boundaries feature class is based in the existence of a point feature in the Corners feature class. This rule and Rule 4 help to enforce the integrity of the dataset by cross-checking the existence of related features in the geodatabase.

Boundaries Must not Have Dangles (Rule 6)

The purpose of this rule is to enforce the integrity of the Boundaries feature class. The line features in this feature class have to intersect each other at vertices (nodes) in order to properly assembly polygon features.

Predios Must not Have Gaps (Rule 7)

The purpose of this rule is to check for gaps between features in the Predios feature class. Since ownership is constant (all the land has an owner) throughout Costa Rica, no gaps between parcels are allowed to exist. This rule aids to maintain the integrity and quality of the cadastral geodatabase.

The topological rules created into the custom geodatabase can be of great aid to the edition and updating processes of the cadastral datasets. In the past, cadastral concepts were checked on a feature-by-feature basis in the datasets by municipal functionaries. With the aid of the geodatabase model and topology rules, the cadastral features can be checked for inconsistencies and errors in an automated way and a record is created. This allows the municipal functionary performing the editing processes to focus on resolving any problems found by the topology rules.

Suggestions for a Maintenance Model

This section addresses the recommendation of a maintenance model for the cadastral data using the custom geodatabase schema created in this work. A cadastral maintenance model may be defined as a set of procedures or steps used to update the cadastre considering cadastral concepts and feature topology. The laws affecting the cadastre of a country may influence the maintenance as well.

The maintenance model that a municipality determines to apply to its data may depend on several variables. Among these are:

- The cartographic and topographic expertise of the municipal functionaries in charge of the updating activities
- The number of available municipal functionaries for the updating activities
- The types of datasets involved (i.e. geographic, tabular, or both)
- The geodatabase schema that was implemented
- The departmental organization of the municipality
- The internal organization of the cadastral department
- The computational resources (hardware/software) available
- The rate at which updates need to be performed in the geodatabase
- The economic resources available

The variables just mentioned usually act together in a municipality in order to accomplish the editing and updating processes in the cadastral database. Since the emphasis of this work is the cadastral database itself, no further insights are made concerning all the variables that may influence the editing and updating activities. Furthermore, those variables are strongly related to each municipality.

In most Costa Rican municipalities the editing and updating activities of the cadastral datasets are usually performed by surveyors, or other municipal functionaries under direct supervision of surveyors. In this sense, the Costa Rican municipalities are well suited since usually at least one surveyor engineer is involved in the maintenance of the cadastral datasets.

The custom cadastral database created in this work uses the geodatabase model. This model was especially designed by ESRI® to store tabular, spatial, and raster data. In addition, the geodatabase model makes possible the use of specialized tools for creation and edition of features in the database. Examples of such specialized editing tools are the topological editing tools. These tools allow the user to create and edit features by means of snapping to existing features as the base for those tasks.

Maintenance of Feature Classes

As mentioned before, the editing and updating activities of the cadastral features are greatly aided by the topological capabilities of ArcGIS™ 8.3. Actually, any feature editing or updating should be performed using the topological tools in order to enforce the topology rules that have been created in the geodatabase. After feature editing or updating has been performed, the "Validate" command should be used to check for topological errors.

The use of COGO attributes in the Boundaries feature class is important for the editing and updating tasks.[71] If the appropriate tools are used in ArcGIS™ 8.3, any edits made to the line features of the Boundaries feature class will automatically update the related COGO attributes. When new features are created in this feature class, the COGO

[71] COGO attributes for the Boundaries feature class are described in Chapter Five of this work under the heading "Boundaries Feature Class."

attributes are generated automatically as well. The edit task called "Create 2-point Line Feature" in ArcGIS™ 8.3 has to be used in order to create new line segments and their COGO attributes automatically.

Examples of common edition and update tasks for parcels are presented in following sections. These examples were adapted from the document called "Parcel Maintenance Examples Using ArcGIS™ 8.3."[72] The examples from this work are based on the Oakland County Case Study by ESRI®. The author modified these examples so they describe a generic procedure for its use with ArcGIS™ 8.3. The use a "Construction" layer is recommended when updates involving several features are to be made, and when new features are to be created. In this way all the construction work is performed in a "scratch" layer, and unnecessary topological features (i.e. edges or nodes) are not directly created in the Boundaries feature class. The Construction layer can also be used to preview any new features before these are generated in the Boundaries or the Predios feature classs of the cadastral geodatabase.

The following case studies describe suggestions of maintenance procedures for typical cadastral situations such as parcel corner resurvey, combination, and division of predios. These procedures are neither exhaustive nor describe the only way to address the maintenance of the cadastral geodatabase. In most cases, the ability and experience of the functionary in charge of the maintenance plays an important role in defining the process to update or edit the datasets.

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[72] ESRI®, *Parcel Maintenance Examples Using ArcGIS™ 8.3*, pages 1-8, [paper on line]; available from http://support.esri.com/index.cfm?fa=downloads.dataModels.byLabel&dmid=11; Internet; accessed on December 2, 2003.

Case 1: Parcel Corner Resurvey

This update is appropriate when there is not a change in direction between the old corner and the new corner and therefore, the number of vertices on the parcels remains the same. This task can be performed with the following steps:

1. With the "Topology Edit Tool" active, select the boundary where the updates are to be performed.
2. Right click to bring up the context menu and select the "Split Edge at Distance" option.
3. When the dialog appears, check the orientation of the line (arrows will be displayed on the line), update the "Orientation" radial button as necessary and type in the split distance. This does not split the line, but just adds a new topology node. A new topology node will be displayed (magenta circle by default).
4. Check the "Snapping Environment" and make sure you are snapping to "Topology nodes."
5. With the "Topology Edit Tool," select the node in the current corner location.
6. Hold the cursor over the node (the icon will change), then hold down the mouse and move the node until it snaps to the one created in step 3 (the new corner location).
7. Validate the topology and update annotation if necessary.

There are situations where it is necessary to split the line to be updated and create a new the corner, keeping the original corner vertex in the same location. This edit can be performed with the following steps:

1. Select the line along which the new corner is to be created.

2. Execute the "Proportion" command on the "Advanced Editing" toolbar. When the dialog box appears, type the splitting distance (as the first distance), and then take the default (the remaining distance) as the second distance.

3. Check the snapping environment and make sure you are snapping to the topology nodes.

4. Using the "Topology Edit Tool," select the line/edge between the two parcels. Double-click on the edge to go into the modify mode (or change your edit task to "Modify Edge"), and remove the two intermediate vertices (this is done by placing the cursor on top of the vertex, right clicking with the mouse and selecting the "Delete Vertex" option). Click on the map away from the selected edge to complete the update.

5. Using the "Topology Edit" tool select the edge and the new corner (the node created in step 2).

6. Move the cursor over the selection anchor (the X in the middle of the selected edge), hold down the "Ctrl" key (this will change cursor to something that looks like a diamond with a hole in it) and the left button on your mouse, and drag the selection anchor down so that it snaps to the selected node (the purpose is to snap the corner to the new node created with the "Proportion" command, so is necessary to move the anchor point to the selected node).

7. With the cursor over the selection anchor (which should now be on the corner to move), press and hold down the "S" key, which will cause the cursor to change. Move the mouse so that the selection anchor snaps to the node created by the "Proportion" command.

8. Validate the topology and update annotation as necessary.

The updating processes described are to be performed directly in the Boundaries feature class. In the geodatabase schema created in this work, the Predios feature class stores the parcels (or predios in the Costa Rican case). Since the Boundaries feature class and Predios feature class are topologically related, the editions in position and shape of features made to the Boundaries feature class will also be performed to the Predios feature class by means of topological relationships.

Case 2: Combine/ Merge/ Join of Parcels

This is another typical situation that requires the edition of the geodatabase. If a person buys the predio next to his/her (legally) owned predio, the appropriate way to register and legalize this is by creating a new deed describing both predios as one unit. Since the Costa Rican cadastral system is declaratory, the creation of a new deed is up to the owner's decision. This affects the cadastral geodatabase since this person may own more than one predio, or may own two adjacent predios that have not been legally merged by means of a new deed.

The process for merging two parcels can be performed with the following steps:

1. Select the two parcels to be merged. Choose the "Merge" option from the "Editor" pull down menu. When the "Merge" dialog box appears, select one parcel to indicate the attributes you want to maintain, then click on the OK button.
2. Using the "Edit Tool," select the line through the center of the combined parcel.
3. Right click to bring up the context menu for the "Edit Tool" and select the "Attributes" option to display the "Attributes" dialog box.

4. In the "Attributes" dialog box click on the word "Parcel" in the "BoundaryType" field, which should display a domain list. Select "Lot Line" from the list. Lot line represents a line that separates lots within a parcel, is not a parcel line.

5. Manually select any unwanted annotation.

6. Click on the "Delete" button after all the annotation has been selected.

7. Validate the topology and update annotation if necessary.

Case 3: Split of a Parcel Based on a COGO Line

Another common task is the splitting of a parcel. This is usually performed using survey data from an official plat or deed. The process can be performed as follows:

1. Set the target layer to the appropriate line feature class and subtype (i.e. "Boundary: Parcel").

2. Make sure the snapping environment includes "Boundary" vertices.

3. Set the "Edit Task" to "Create 2-Point Line Features."

4. Display the "Editing Options" dialog (select "Options…" from the Editor pull down), and go to the "Units" tab. Select the appropriate units according to the survey data.

5. Execute the "Traverse" command on the "Advanced editing" toolbar.

6. When the "Traverse" dialog box is displayed, set the start point of the traverse and the end point of the traverse based on the new data. These points must be endpoints of lines.

7. Enter the new transect data in the "Traverse" dialog box.

8. Click on the "Adjust" button, define a selection method and click on the "Accept" button. Dismiss the "Traverse dialog."

9. With the new lines still selected, set the "Target layer" to the destination parcel feature class and click on the "Construct Features" command (found on the "Topology" toolbar).

10. Make sure the "Consider existing features of the target layer in the current extent" option is checked, and then click on the OK button.

11. Validate the topology and update annotation as necessary.

Case 4: Split of a Parcel Based on a New Deed

In this case, the survey data (transect) for an entire new parcel has to be introduced into the feature class in order to create a new parcel feature. In the case of Costa Rica, the new data may be provided by a new deed or a new official cadastral plat. The appropriate editions and updates must be performed to any affected parcels in the geodatabase. In the custom geodatabase created, the Boundaries feature class stores the parcel lines, and the Predios feature class stores the parcel polygons. This edit can be performed with the following steps:

1. Set the target layer to the "Construction" layer.

2. Set the snapping environment to include "Boundary" vertices.

3. Set the "Edit Task" to "Create 2-Point Line Features."

4. Display the "Editing Options" dialog box (select "Options…" from the "Editor" pull down menu) and go to the "Units" tab. Select the appropriate units according to the survey data.

5. Execute the "Traverse" command on the "Advanced editing" toolbar.

6. When the "Traverse" dialog box is displayed, set the start point of the traverse. Click on the "Closed Loop" option to indicate that the traverse will end where it started.

7. Enter the new transect data in the "Traverse" dialog box.

8. Click on the "Adjust" button, select a method, and click on the "Accept" button. Dismiss the "Traverse" dialog box.

9. If the new traverse does not line up with the existing parcel fabric, rotation of the new lines may be required (this will not change the deeded dimensions typed into the "Traverse" dialog as they are now attributes of the lines). The rotation should be performed using the segments that are thought to be the most accurate for comparison.

10. Turn off snapping to "Boundary" vertices and turn on snapping to "Construction" vertices.

11. Perform the rotation using the "Rotate" tool. The following are some tips: press the "S" key to display the auxiliary (or secondary anchor); the auxiliary anchor looks like a plus sign ("+") and is about the same size as the selection anchor (which looks like an "x"); move the cursor over the auxiliary anchor, then hold down the left button on your mouse and move the anchor until it snaps to a second vertex of the transect; once the selection and auxiliary anchors are in place, change the snapping environment to include only "Boundary" edges (turning off "Construction" vertices). Rotate the new line work until the auxiliary anchor snaps to the edge of an existing parcel.

12. Depending on municipal procedures, the existing parcels may have to be snapped to the new transect. The following are some tips: the first step is to split the existing lines that are being partially replaced with new lines; select the appropriate boundary features, activate the "Split" tool, and click as close as you can to the location where the new line work intersects.

13. Validate the entire topology, which will create vertices in the parcel feature class coincident with the lines just split.

14. Select the boundary features that are being replaced by the new line work and delete them.

15. The "Topology edit" tool can be used to manually select each topology node in the vicinity of the new line work and snap it to the new line. A quicker more accurate way, though, is to use the "Zipper Task Developer Sample" (which will be part of ArcGIS™ 9.1).[73] To use the sample, first select the new construction lines. Set your "Edit Task" to the "Zipper Task," set your snapping environment to "Construction" vertices, and activate the "Trace" tool (on the "Sketch" palette). Trace the new lines in a counter-clockwise direction. In the "Zipper" dialog box enter an appropriate search distance and click on the "All Topo" button to check all of the topology layers. When you click the OK button, the "Zipper Task" will search for features from the checked feature classes that fall within the specified distance. When features are found they are aligned to the current sketch, which is a trace of the new line work.

16. After everything has been snapped together with the "Zipper Task," all the Construction features should still be selected so click on the "Copy button" ("Cut" will not work in this case, you must use "Copy" if you want to retain the attributes). Set the target layer to "Boundary: Parcel" and click on the "Paste" button.

17. Select all the "Construction" features again and click on the "Delete" button.

18. At this point all of the new line work should be in the Boundary feature class and aligned with the existing parcel data. Splitting of the original parcel follows. Select the boundary features that cut across the existing parcel. Set the target layer to the parcel

[73] Available from ESRI in the internet at http://arcobjectsonline.esri.com/.

feature class and click on the "Construct Features" button. Make sure the "Consider existing features of the target layer in the current extent" option is checked, and then click on the OK button.

19. Validate the topology and update annotation if necessary. The subtypes of some of the new boundary features may be changed according to any particular settings.

The four cases just presented are examples of edition and update processes for cadastral datasets. Usually, edition or update of the alphanumeric data is related to the edition of spatial features. For example, when a new predio is created, all the information about ownership, value assessment, legal registration, topography, etc., related to that predio must be entered.

Maintenance of Object Classes

A maintenance model may suggest the steps for the editing and updating processes of the tabular data. However, the order in which these tasks are performed may depend on several factors that affect the way in which the maintenance is accomplished.[74]

One of the key elements in updating tabular data is that all the records that need to be modified, get edited or updated at the appropriate time. For example, if two predios are merged into one, the polygons representing the predios and the records related to them need to be updated as soon as possible in order to have an accurate cadastral representation.

The geodatabase model allows the user to take advantage of object-oriented database characteristics for the editing and updating processes. Examples of these specialized options are subtypes and domains. The custom geodatabase schema created

[74] Refer to the beginning of the Suggestions for a Maintenance Model section to review some of the factors that may affect the maintenance procedure for cadastral data.

in this work offers both subtypes and domains to facilitate the edition and update of records in the object classes.[75] For example, the field describing the type of predio in the Real Estate table has a domain that offers drop-down menu options (when an edit session is in progress) such as base predio, condominium, and right of way; in the Owners table, the field for the legal situation of a person regarding a predio has a domain that allows drop-down menu options such as owner, possessor, awardee, usufructuary, and co-owner.

The use of attribute domains greatly simplifies the tasks of editing and updating cadastral data by allowing the user to choose an option from a drop-down menu. The implementation of attribute subtypes is a further step in the construction of "intelligent" features. A "subtype field" allows the user to select a type or classification for each object that makes it part of a subclass (subtype) within a table or feature class. When a new record or feature is created, the attribute fields are automatically populated with the predefined values that were defined for the selected feature subtype. An example of the use of subtypes in the geodatabase schema created is the subtype field for the legal situation of the predios in the Real Estate table. Depending on the selected subtype for a predio, some of the fields in the table are automatically populated with default values.

Attribute domains and subtypes aid in making the editing and updating tasks of the cadastral data less tiresome. It is important to mention that since the attribute domains offer the user a set of predefined options, there is less probability for the introduction of erroneous data into the geodatabase. This contributes to the quality and integrity of the information stored in the geodatabase.

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[75] All the attribute domains created into the geodatabase are described throughout Chapter Five of this work. The domains are described along with the main feature class or table where they are meant to be used.

Final Comments on Cadastral Maintenance

The author wants to emphasize that a given maintenance model should not be imposed into the workflow of any municipality. Several factors such as municipal policies, data flow, and internal departmental organization within the municipality will dictate the editing and updating procedures of cadastral data.

The suggestions presented in this work are to be used as an example for the design of a custom maintenance model for a given municipality. Even when a custom maintenance model has been created for a municipality, it should neither be considered nor used as a strict procedure. This situation has the potential to introduce inappropriate or erroneous edits to the cadastral data stored in the geodatabase.

The author suggests that the maintenance of the cadastral geodatabase should be performed by qualified municipal staff. It is recommended for the functionaries in charge of these tasks to have at least basic training in areas such as database design and management, and cartographic and surveying techniques. Finally, they must be fully acquainted with any laws affecting the cadastre and the cadastral activities.

As mentioned before in this work, it is very common in Costa Rica for a surveyor to perform the cadastral maintenance tasks. This is a favorable situation since the surveyors usually have basic training in the fields such as database design and management, as a result of using GIS. In Costa Rica, surveyors are well informed about the laws affecting the cadastre since its part of their education and professional responsibilities. Furthermore, surveyors must follow strict procedures in order to elaborate official plats.

Chapter Review

Several suggestions regarding a cadastral maintenance model were described in this chapter. The purpose of these suggestions is to provide the Costa Rican municipalities with some insights and recommendations for the editing and updating processes of cadastral data stored in a geodatabase.

A given maintenance model can not be imposed into the data flow of a given municipality since several variables such as departmental organization and data characteristics must be considered. A maintenance model can not be a strict process since the edits and updates of the cadastral datasets usually require case-by-case solutions.

The next chapter of this work addresses the evaluation of the custom geodatabase schema created, and the conclusions obtained from this work.

CHAPTER SIX

EVALUATION AND CONCLUSIONS

The evaluation of the functionality of the custom geodatabase is addressed in the following sections of this work. This is accomplished by means of reviewing the concepts learned about multipurpose cadastre and the specific information needs of Costa Rican municipalities. The suggestions of the ArcGIS™ Land Parcel Data Model geodatabase template are considered as well.

The functions that the municipalities perform or are seeking to perform along with the suggestions of Cadastre 2014 provide the basis to assess the functionality of the geodatabase. These functions were commented to the author in person by the municipal functionaries from the municipalities of Barva County and Heredia County in response to the following question: What are the functions that the municipality seeks to perform that rely on or are related to the cadastral information?

The data from a pilot study area within Barva County is used to recreate cadastral phenomena. The author was given permission by functionaries of the Municipality of Barva County to use part of the County's cadastral datasets. Spatial and attribute data is loaded into the geodatabase to asses if the geodatabase is functional, that is, if the geodatabase may aid to fulfill the information needs of a Costa Rican municipality, and therefore, to accomplish its functions.

As of this point, the following steps have already been addressed and described throughout the preceding chapters of this work:

- The determination of the cadastral data needs of a municipality according to what modern concepts of cadastre suggest: the Cadastre 2014 work and the Land Parcel Model geodatabase template were reviewed for this purpose. The author also interviewed the functionaries in charge of the cadastre departments at the Municipality of Barva County and the Municipality of Heredia County. The results of these interactions are integrated in the geodatabase schema created as well.
- Barva County's existing cadastral datasets were reviewed and analyzed: both, the existing geographic datasets and the attribute datasets were studied in order to learn their characteristics. This was made in order to study the data that was currently in use in a Costa Rican municipality. The results of this analysis are integrated in the geodatabase schema created.
- The design and creation of the custom geodatabase schema: the knowledge and expertise obtained from the previous steps about the requirements of a modern multipurpose cadastre were applied in this process. The characteristics of the existing cadastral data, and the needs for cadastral data were taken into account as well. The custom geodatabase schema was the result of this process.
- The creation of suggestions for a maintenance model of cadastral data: these suggestions may help the municipalities in the creation of custom maintenance models for their cadastral datasets. Each municipality has its own particular characteristics that may affect the way in which the maintenance of the cadastre must be accomplished.

Evaluation of the Custom Cadastral Geodatabase Schema

The evaluation of the cadastral geodatabase schema is presented in the following sections. Real cadastral data was loaded into the geodatabase in order to recreate cadastral phenomena and assess if the geodatabase is functional. Figure 4 shows a screen capture of predios loaded into the geodatabase for the pilot study as displayed in ESRI's ArcMap™ 8.3.

Figure 4. Predios loaded into the geodatabase for the pilot study

According to the interviews performed by the author, the principal functions of the Costa Rican municipalities are the collection of taxes based on the ownership of the land, and the awarding of commercial patents. In order to address the tax calculation and billing processes, the municipalities need to have an accurate value for each one of the predios in the county. This value can be declared by the legal owner, possessor, awardee, or can be assessed by municipal functionaries if necessary.[76] The predio is a Costa Rican legal land object and represents a tax parcel.

Predios feature class is used to store the basic features of the cadastre, that is, the polygons representing the predios. The predios are the cornerstone of the Costa Rican

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[76] Asamblea Legislativa de la Republica de Costa Rica, *Articulo 10, Articulo 10 bis, Articulo 11, Articulo17, de la Ley del Impuesto sobre los Bienes Inmuebles* (San José, Costa Rica: Editorial Investigaciones Jurídicas S.A., Enero 2003), 22.

cadastral system. The concept of "tax parcel" is also included in the Land Parcel Model and is implemented in its Tax Parcels Feature Class.

The custom geodatabase created in this work focuses in providing the means to store, manage, and update the cadastral data. Figure 5 shows a screen capture of the contents of the geodatabase schema created as displayed in ESRI's ArcCatalog™ 8.3, and Figure 6 shows a screen capture of the contents of the feature datasets displayed in the same program.

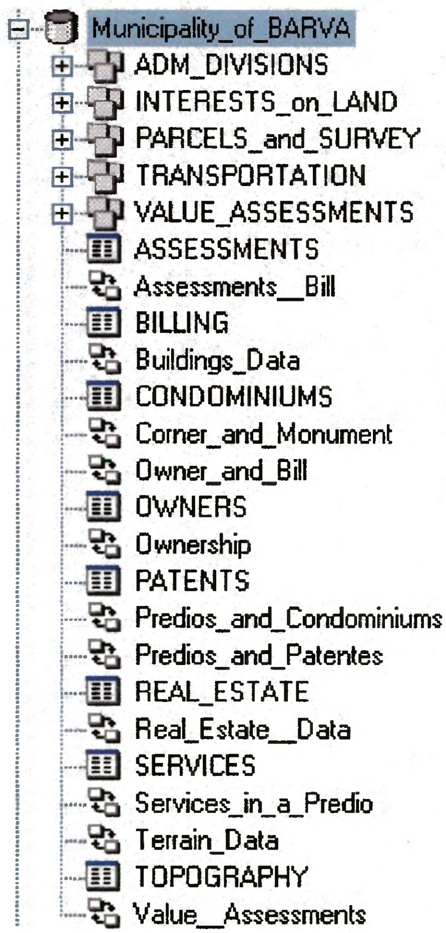


Figure 5. Contents of the custom geodatabase schema

Most of the feature classes and object classes were created into the geodatabase in order to allow the storage of information related to the predios. These datasets describe the shape and size of the predios, the buildings or constructions located in the predios, the topography of the land, the legal registration data for the predios, the holders of rights to the land properties (owners, possessors, awardees, etc), among other subjects. Figure 7 shows a screen capture of the Assessments table which stores the data about value of the predios.

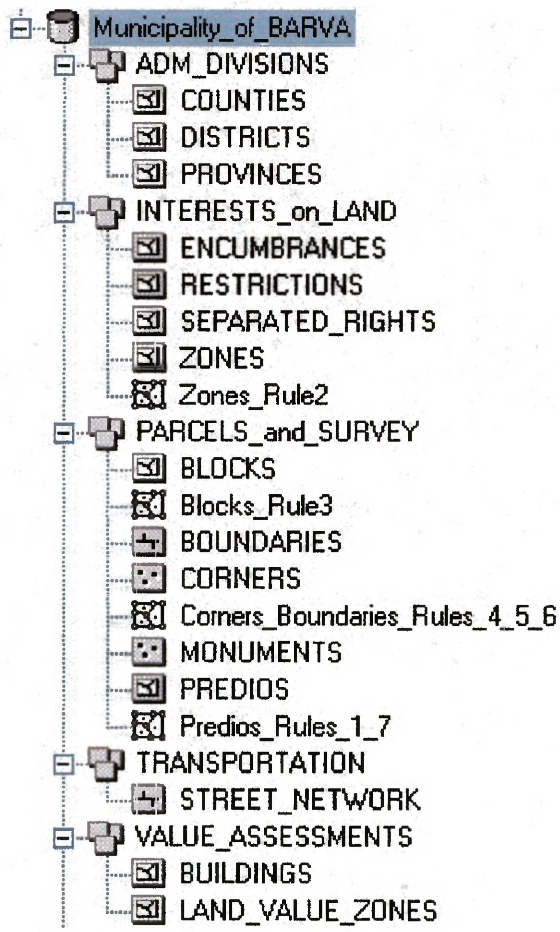
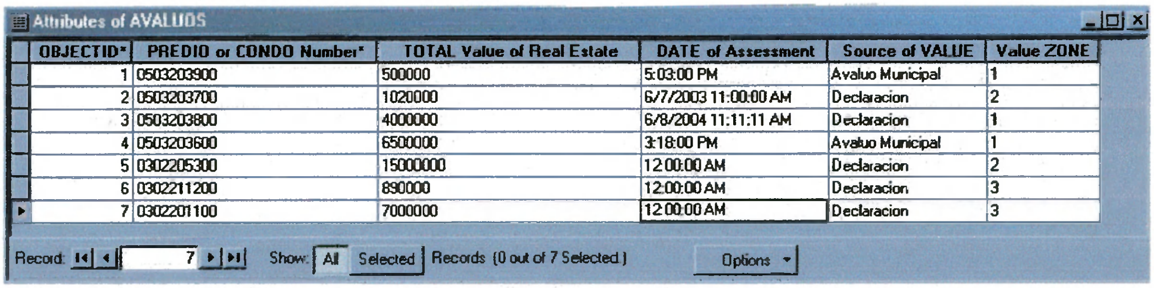


Figure 6. Contents of the feature datasets



Attributes of AVALUOS

OBJECTID*	PREDIO or CONDO Number*	TOTAL Value of Real Estate	DATE of Assessment	Source of VALUE	Value ZONE
1	0503203900	500000	5:03:00 PM	Avaluo Municipal	1
2	0503203700	1020000	6/7/2003 11:00:00 AM	Declaracion	2
3	0503203800	4000000	6/8/2004 11:11:11 AM	Declaracion	1
4	0503203600	6500000	3:18:00 PM	Avaluo Municipal	1
5	0302205300	15000000	12:00:00 AM	Declaracion	2
6	0302211200	890000	12:00:00 AM	Declaracion	3
7	0302201100	7000000	12:00:00 AM	Declaracion	3

Record: 7 Show: All Selected Records (0 out of 7 Selected) Options

Figure 7. Sample data in the Assessments table

Implementation of the Suggestions from Cadastre 2014

The first statement of Cadastre 2014 suggests that the cadastre must show the complete legal situation of the land, including public rights, and restrictions. The geodatabase schema created implements this suggestion in several ways:

- The inclusion of the Zones feature class to represent the land with homogeneous characteristics such as subdivisions. Figure 8 shows a screen capture of the pilot study area including the Predios and Zones feature classes.
- The inclusion of the Encumbrances feature class to represent limitations on the rights and use of the land. For example, "easements" are rights or interests in the land held by a person other than its legal owner, possessor, or awardee, and may diminish its value but does not prevent its sale.
- The inclusion of the Separated Rights feature class to represent the rights and interests in land ownership that can be disconnected from the surface ownership (fee simple) such as mineral rights.
- The inclusion of the Restrictions feature class to represent regulated uses and restrictions. These are controls by a public body that limit the uses of land for the

purposes of controlling development, maintaining property values, or implementing master plans, or other plans.

- Some feature classes such as Corners and Boundaries aid in the implementation of the first statement of Cadastre 2014 by functioning as construction layers or by representing important cadastral objects (such as parcel corners). Figure 9 shows a screen capture with features from the Corners and Boundaries feature classes in the pilot study area.
- The creation of suitable fields in the Real Estate table in order to record the information concerning the legal registration of the predios. This information includes the legal registration numbers, the official area, the number of the official plat, etc.

Figure 8. Features in the Predios and Zones feature classes

In addition, topology rules were created within the custom geodatabase schema in order to facilitate the maintenance activities of the cadastral data.[77] Topology rules can be of great aid to the cadastre since they can help to implement the cadastral concepts

[77] Refer to the section called Topology Rules in Chapter Five of this work for further information about the topology rules created.

and/or specific laws of a country within the cadastral geodatabase. For example, one of the rules created in the geodatabase schema checks for any overlapping predios in the Predios feature class when the "Validate" command is used. The result of the validation of this rule is a GIS layer that shows as errors any overlapping areas, that is, any predios that violate the topology rule. Figure 10 shows a screen capture of the results of that validation process for predios within the pilot study area.

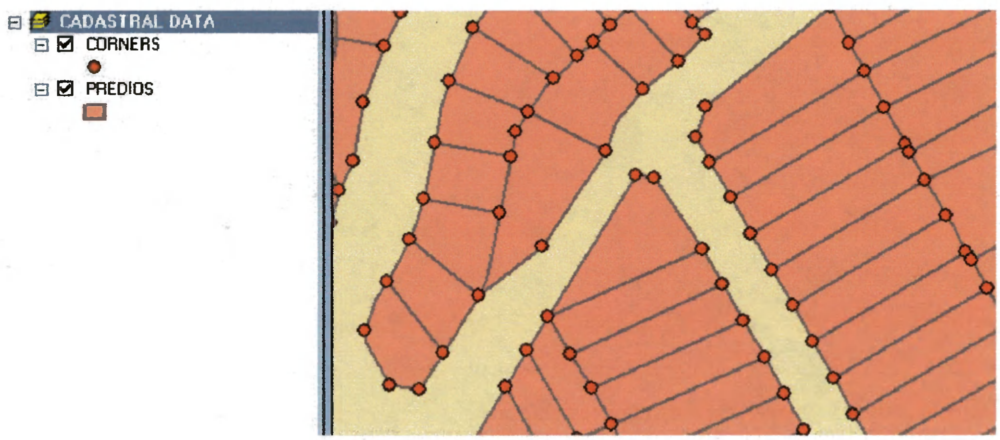


Figure 9. Features in the Corners and Boundaries feature classes

Figure 10. Violations to topology Rule 1

The topology rules can be validated for an entire feature class, or for the visible extent in the screen when working in ArcMap™ 8.3. The partial validations of a dataset are recommended when its size is considerable large (i.e. over one Gigabyte), or when the cadastral features and spatial relationships are to be closely examined by the municipal functionary. Figure 11 shows a screen capture of a larger area with predios and overlapping errors found by Rule 1.

Figure 11. Violations to topology Rule 1 on a larger portion of the study area

The remaining five statements of Cadastre 2014 suggest more characteristics of a multipurpose digital cadastre, also about the interaction of the official cadastre and the private sector, and about the financing of a modern cadastre. The second statement of Cadastre 2014 suggests that the separation between maps and registers must be abolished. The third statement suggests that the "cadastral mapping" must disappear, and "cadastral modeling" should be implemented. The fourth statement suggests that "paper and pencil" cadastre should be replaced for digital storage media such as digital databases. All these proposals are considered in the geodatabase schema designed in this work.

The geodatabase schema created allows the integration of the maps and the registers as the second statement of Cadastre 2014 suggests. Geographic features are stored in feature classes and alphanumeric data in object classes, but all this data is maintained as one database file. This represents an important development for the cadastre. Both, the graphic and the alphanumeric parts of the cadastre are integrated into one database and furthermore, into one computer file. For example, if a municipal functionary wants to display one or more predios and some of the information related to them, the appropriate feature and object classes can be loaded into ArcMap™ 8.3, and both, graphic and tabular features can be displayed simultaneously on the computer screen. This is an improvement in the cadastre as compared to the "paper and pencil" cadastre where paper maps and hardcopy records are usually kept separately, and most likely, in different offices or departments that the functionaries need to physically access.

The traditional "paper and pencil" cadastre is substituted for the geodatabase model which is a digital database. There are great advantages in a digital cadastral database over files and records kept only in hardcopy:

- Is easy to make a digital copy of the entire database so it can be stored for backup or historical purposes.
- Copies of the database can be shared with other municipalities or governmental institutions.
- A digital database can be accessed by many different users (i.e. the functionaries from different departments) if the appropriate connections and permissions exist within the municipality's computer network.

- The entire database or parts of it can be created, edited, or managed with an increasing number of computer programs such as ACCESS or EXCEL from Microsoft®. These programs can be useful to edit or manage specific elements of the database if needed.
- An important advantage of a digital database for modern cadastral applications is without a doubt, that it can be used as input for a GIS. A GIS can provide the tools to manage and analyze the cadastral data in order to answer the information needs of a municipality. Furthermore, a GIS can be used to implement a land information system (LIS) with a complete multidisciplinary description of the land.

In Costa Rica, data in hardcopy format is usually the primary source of input data for the cadastre. Usually, all the official documents and patents that municipalities deal with are stored in hardcopy. The deeds and official plats are in hardcopy as well. The documents in hardcopy format will not disappear from the cadastre, but a large share of these is being converted into digital data format for its use with computers.

The fifth statement of Cadastre 2014 suggests that the cadastre should be highly privatized, meaning that public and private sector are working closely together. The sixth statement of Cadastre 2014 proposes that the cadastre should be cost recovering. These characteristics of the cadastre are closely related to the laws of a country, and to the structure of the municipalities themselves. In Costa Rica, the public and private sector are working together to some extent. For example, contracts are usually established between the municipalities and private companies to perform the entire cadastral census or parts of it. These companies usually perform all the necessary topographic surveying and the alphanumeric data collection in the field for the cadastral census.

There is no doubt that cost recovery is an important characteristic of any cadastre or cadastral system. The municipalities have a major challenge in balancing the economic investments in the cadastral system (i.e. cadastral datasets, computer hardware and software, trained staff, etc.), with the incomes from taxing the land owners and patent awarding. Municipalities require economic input, and as expressed by the functionaries at the Municipality of Barva, "the municipalities are trying to have accurate information about each one of the components that generate income to the municipality."

Benefits from the Geodatabase Model and the Geodatabase Templates from ESRI®

The municipal functionaries at the Municipality of Barva County mentioned that an important characteristic of the cadastral database should be its suitability to be accessed and edited by different departments. This can be accomplished using the geodatabase model and multiple licenses of ArcGIS™ 8.3 since several users can access a geodatabase from different computers that are connected in using a network. The ability for several users to access a digital cadastral dataset is a great improvement over the "paper and pencil" cadastre, where hardcopy documents need to be physically accessed in order to be modified. There is a higher potential of integrity for the cadastre when a digital database is used, because all the data is stored in a single file.

The geodatabase model can be used to represent the reality. Some of the aspects of the reality regarding the cadastral phenomena and the interactions of humans with the land can be recreated using a suitable geodatabase schema. Therefore, the geodatabase schema created in this work not only can be used to digitally represent predios, but it can aid to record and analyze some of the interactions between the people and the land. These interactions are usually established in the laws of a country.

The geodatabase schema created in this work can be considered a cadastral model for the Costa Rican cadastre, and furthermore, it can act as a dynamic cadastral model. The permanent updating activities of the cadastral datasets allow them to represent reality in a more accurate way every time a new update is made. This also means that the geodatabase will never be a complete and fully updated description of reality at any given moment, because changes continuously occur in the cadastral features represented in it.

The assignment of patents for commercial purposes such as mechanical workshops and grocery stores is an important function in the municipalities. The custom geodatabase schema addresses this situation with the Patents object class that can store the information about patents. Each record of the table is related to its respective predio in the Predios feature class through the predio number. In this way the municipality can record what patents have been awarded, and where are they located.

The Municipality of Barva County is seeking to accomplish some other functions that are not directly related to the cadastre, but are common functions of a local government. Some of these functions are related to the mapping of the waste collection routes, and the maintenance of the street network. These are common activities of a local government that the Parcel Model does not address because of its emphasis on cadastre. These topics are addressed in other geodatabase templates by ESRI® like the ones called "Local Government Data Model," and "Base Map Data Model."

The Local Government Data Model is an example of the general topics and GIS layers that may be included in the geodatabase of a local government. These topics are called "thematic groups" and some examples are: administrative areas, environmental, street network, network facilities, land records, and base map. The author considers that this model is a suitable example of the geodatabase required to aid in the operation of a local government.

The author included the Street Network feature class in the geodatabase schema to store the lines that represent the center lines of the streets. It is based on the Street Network Feature Class from the Local Government Data Model. This feature class may be useful to Costa Rican municipalities in order to store the street lines, their names, and some of their characteristics. Unfortunately, a geocoding system has not been implemented using the Costa Rican street network. In a GIS, geocoding is the process of creating geometric representations for locations (usually using point features) from descriptions of locations such as addresses.[78] This is a powerful tool when one location needs to be mapped along a line network (i.e. a street network). Among the uses for such GIS capabilities may be waste collection route design, emergency response services (i.e. the 911 system in the USA), and street/road maintenance activities.

The address system in the USA is a form of geocoding. In Costa Rica such system has not been created yet, but since it has a great potential is likely that some form of it might be implemented in the future. Since street networks is not the emphasis of this work, the author only wants to further mention that a geocoding system should be considered for Costa Rica in order to allow the implementation of location mapping along the street network, and to improve the postal services, among other potential uses.

The Street Network feature class was included to store the lines representing the street network. Routes can be planned and mapped using this feature class. An

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[78] MacDonald, 464.

additional feature class might be needed in order to map the routes, but this is optional. This optional feature class would store copies of the lines from the Street Network feature class along the collection routes.

Conclusions

The proposed goals for this work are a geodatabase schema and a cadastral maintenance model, suitable for Costa Rican municipalities. These must consider the needs of a modern multipurpose cadastre for the storage, management, and maintenance of cadastral data. Both, the geodatabase schema and the maintenance model should be suitable for the cadastral characteristics of these counties and therefore, for the general Costa Rican setting.

The existing cadastral databases and GIS layers from the Municipality of Barva County were analyzed and used as input in the determination of the cadastral data needs of a typical Costa Rican municipality. The municipalities of Barva County and Heredia County are considered representative examples of Costa Rican municipalities.

The first step in this project was the determination of the cadastral data needs of Costa Rican municipalities. This task was addressed by reviewing the concepts of multipurpose cadastre from the Cadastre 2014 work, and by analyzing the cadastral information needs of municipalities in the Costa Rican setting. The first statement of Cadastre 2014 suggests that the content of the cadastre should show the complete legal situation of land, including public rights and restrictions. This statement sets the milestone for the design of a cadastral database.

The author interviewed municipal functionaries from the municipalities of Barva County and Heredia County in order to obtain their professional opinions regarding the cadastral data needs of Costa Rican municipalities.

In addition, the author had the opportunity to analyze the existing cadastral datasets from the Municipality of Barva County. Both spatial and attribute datasets were studied in order to learn the specific characteristics and the data needs of the Costa Rican cadastre.

The Land Parcel Data Model from ESRI® was used as a starting point and as the main reference for the construction of the custom cadastral geodatabase schema. In some instances, entire feature classes were copied into the custom geodatabase schema created in this work. However, in other cases the proposed feature classes or object classes from the Land Parcel Model were used as reference in the creation of custom classes suitable for the Costa Rican setting.

The attributes and spatial features to be included in the geodatabase were defined based on the concepts of cadastre from the Cadastre 2014 work, and the cadastral information needs of a municipality in the Costa Rican setting. The next step of this work was the design of the custom cadastral geodatabase schema.[79] A total of five feature datasets, fifteen feature classes, eight object classes, twelve relationship classes, and seven topology rules were created within the geodatabase schema.

The author considered the inputs from several sources in the design of the custom geodatabase schema. Those inputs were:

- The concepts of modern multipurpose cadastre suggested in the Cadastre 2014 work by the International Federation of Surveyors (FIG).

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[79] The results of this process are presented in Chapter Five of this work.

- The comments and suggestions from the municipal functionaries from the Municipality of Barva County and the Municipality of Heredia County.
- The results of the analysis of the existing cadastral datasets from the Municipality of Barva County.
- The author's high-level education on surveying engineering including courses on the theory of cadastre and the Costa Rican cadastral system.
- Professional comments and suggestions on cadastral topics from Prof. Alex Gonzalez, faculty member at the *Escuela de Topografía, Catastro y Geodesia* (School of Topography, Cadastre, and Geodesy) at the *Universidad Nacional* (UNA) in Costa Rica. Professor Gonzalez has a vast experience in the cadastre, and specifically in the Costa Rican cadastral system.

The last step of this work was the evaluation of the functionality of the custom geodatabase. This was addressed by means of reviewing the concepts learned about multipurpose cadastre and the cadastral information needs of the Costa Rican municipalities. The functions that the municipalities perform or are seeking to perform provided the basis to assess the functionality of the geodatabase. The data from a pilot study area within Barva County was used to address the evaluation process, and assess if the geodatabase is functional.

The custom cadastral geodatabase schema created in this work incorporates the inputs mentioned above in order to meet the needs for cadastral information of a typical Costa Rican municipality. Modern concepts of multipurpose cadastre from the Cadastre 2014 work were an important input to the design of the geodatabase schema. They suggest the general structure of the cadastre and the cadastral datasets, using modern concepts as well as modern database and GIS technologies.

The geodatabase schema created in this work can be used to store, manage, and update the cadastral datasets of a Costa Rican municipality. Almost all the functions mentioned to the author by the municipal functionaries from the Municipality of Barva County and the Municipality of Heredia County can be fully accomplished using the custom geodatabase schema created in this work. However, some of the functions can only be partially accomplished because of particular characteristics and/or deficiencies of the Costa Rican cadastre and/or municipalities. For example, the Street Network feature class created to store the lines representing the streets and roads can not be used to find locations along those features. The reason for this is that no geocoding system has been implemented in Costa Rica to allow the location of addresses along the street network.

The cadastral functions related to the principal legal land object, the predio, can be accomplished using the custom geodatabase schema created. Several feature datasets, feature, object, and relationship classes, as well as topology rules and attribute domains may aid to address the cadastral activities of a Costa Rican municipality.

The geodatabase schema created in this work needs to be further customized by any Costa Rican municipality that intends to implement it. There are two main reasons for this: (1) the spatial extent for most of the feature datasets was set to accommodate the Province of Heredia, and (2) the cadastral datasets from every municipality have their own particular characteristics. For example, while every municipality stores the information about the owner, possessor, usufructuary, or awardee for each predio, the field names used to refer to a particular attribute may differ between municipalities.

Furthermore, different municipalities may even store slightly different sets of attributes about a given object, based on the particular characteristics of their counties and legal land objects.

The geodatabase schema created in this work should be used as an example of geodatabase schema for a Costa Rican municipality. Every municipality is likely to have different characteristics that would affect the structure of the cadastral geodatabase schema. Some of these characteristics may be:

- Data flow within the municipality and between its departments
- Number of functionaries and their level of experience with the cadastre
- Availability of computer resources
- The county's size, and the number of legal land objects defined within it
- The type and number of sources of data that may generate edits of updates to the cadastral datasets

The author is of the opinion that a connection between the cadastral datasets and the survey (topographic) datasets may be useful for Costa Rican municipalities. This can only be accomplished if the cadastral datasets are properly structured, and appropriate COGO attributes are kept for line features (i.e. boundary lines). The relationship between the geodatabase classes and the survey datasets allows a different approach to the editing and updating processes of the cadastral data. ESRI® has created an extension for their ArcGIS™ 8.3 software that allows the integration of survey datasets directly into the GIS. This extension is called Survey Analyst, and is additional to the ArcGIS™ 8.3 software package.

The concept of "survey-aware" feature classes is used to refer to the feature classes that are related to the survey datasets within a geodatabase by means of topological rules. This allows for the cadastral features to be edited or updated based on the new or adjusted location of corners or other cadastral points using the data from topographic surveys. The purpose of using survey-aware features is to maintain the cadastral datasets as current as possible using the latest survey data available. The use of survey-aware datasets and the Survey Analyst extension may help to update the cadastral datasets considering the survey data as a constant and reliable source of input data to the cadastre. Cadastral surveys are performed by Costa Rican municipalities in an irregular basis since they rely mostly in other sources of data such as deeds or plats. The expenses from these documents are covered by the land owners, and the municipality saves money in this way. Nevertheless, the use of survey-aware features may be an excellent aid in the editing and updating activities of the cadastral features stored using the geodatabase model for ESRI's ArcGIS™ software.

The author proposes that further research and municipal efforts should be directed toward the creation of an official cadastral geodatabase schema for all of Costa Rica. This geodatabase schema would include every known aspect of the Costa Rican cadastre based on the experience of surveyors, municipal functionaries, lawyers, and any other professionals related to the cadastre. The involvement of the Institute for the Municipal Promotion and Consultantship (IFAM) would be required in order to create and establish a cadastral geodatabase schema that would be available to all the municipalities. Furthermore, the IFAM and the Costa Rican government may at some point in the future establish this national cadastral geodatabase schema as the mandatory official database schema for the storage of cadastral data in Costa Rica.

As a final remark, the author wants to mention some of the potential benefits to the cadastre from implementing the ArcSDE® (SDE stands for "Spatial Database Engine") software from ESRI®. ArcSDE® is an application server that facilitates storing and managing spatial data in a database management system (DBMS), and makes the data available to many kinds of applications. ArcSDE® allows the storage of data in one of four commercial databases: IBM® DB2®, Informix®, Microsoft® SQL Server™, and Oracle®. ArcSDE® can serve data to the ArcGIS™ Desktop products (ArcView®, ArcEditor™, and ArcInfo™) and through ArcIMS® (IMS stands for "Internet Map Server"), and is a key component in managing a multi-user GIS.

The benefits of using ArcSDE® to store and manage GIS datasets may be:

- Database portability: ArcSDE® provides a common model for spatial data. Data can be moved from one database to another without any loss of information. This is specially important in heterogeneous database environments.
- Application portability: ArcSDE® defines a single logical model for spatial data that is independent of the physical data representation in the DBMS.
- Use of ESRI®'s data models: ArcSDE® allows the use of a simple relational model of points, lines, and polygons, or the more sophisticated Geodatabase model.
- Data integrity: ArcSDE® manages the integrity of point, line, and polygon information, and does not allow the insertion of corrupted data. In addition, it allows the implementation of real-world behaviors for the features.

- Long transactions and versions: ArcSDE® supports long transaction editing as well as "what if" scenarios by creating versions. Versioning lets the users create multiple, persistent representations of the database without making copies of the data, and more than one user can modify the data.[80]

The Costa Rican cadastre may benefit from using the ArcSDE® software. The author of this work used a personal geodatabase that does not allow for simultaneous multi-user editing of the cadastral datasets. However, simultaneous multi-user editing may be implemented in Costa Rican municipalities in order to allow several functionaries from different departments to edit the cadastral data at the same time if needed. This situation is particularly true if a municipality stores and manages a large amount of cadastral data, and it is likely that several functionaries would be simultaneously accessing and editing the geodatabase.

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[80] ESRI®, *ArcSDE: The GIS application Server*, pages 1-2,[paper on line]; available from http://www.esri.com/library/whitepapers/sde_lit.html; Internet; accessed on March 1, 2004.

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