Revista Brasileira de Cartografia (2012) N⁰ 64/6: 887-900
Sociedade Brasileira de Cartografia, Geodésia, Fotogrametria e Sensoriamento Remoto
ISSN: 1808-0936

3D CADASTRES IN SOUTH AMERICA

Cadastros 3D na América do Sul

Diego Alfonso Erba[1]; Andrea Flávia Tenório Carneiro[2] & Eduardo Agostinho Arruda Augusto[3]

[1]Lincoln Institute of Land Policy
113 Brattle Street, Cambridge, MA 02138-3400 USA
derba@lincolninst.edu

[2]Universidade Federal de Pernambuco – UFPE
Departamento de Engenharia Cartográfica
Av. Acadêmico Hélio Ramos, s/n - Cidade Universitária, CEP: 50740-530 Recife – PE
aftc@ufpe.br

[3]Instituto de Registro Imobiliário do Brasil – IRIB
Av. Paulista, 2073 - Horsa I - Conjuntos 1.201 e 1.202 - Bairro Cerqueira Cesar,
CEP: 01311-300 - São Paulo/SP, Brasil
geo.irib@gmail.com

Recebido em 01 Abril, 2012/ Aceito em 01 Agosto, 2012
Received on April 01, 2012/ Accepted on August 01, 2012

ABSTRACT

South American cadastral systems, in general terms, contemplate the following aspects: legal (properties and possessions), economic (land valuation and land taxation support), and geometric (surveying maps). Cadastral maps cover urban and rural areas, showing administrative and parcel boundaries, constructions and complementary improvements, as well as high-ways and streets. The multipurpose vision is present in some cadastral laws and in the intentions of several administrations, but in practice, it is not easy to find examples of its full implementation yet. One of the main shortcomings of the region's cadastres is the lack of georeferenced data; however, since most of the countries are implementing their Spatial Data Infrastructure (SDI), chances are improving for multiple institutions to work together and interchange data. According to its title, this paper aims to describe briefly the history and the current situation of the cadastres of Brazil and the Spanish-speaking countries of South America; and to present the framework that describes the territorial land objects. Based on the conceptual diversity it is possible to conclude that it too soon to define a 3D parcel and a 3D territorial land object for the entire region, however, the perspectives for the development of 3D cadastral models, is excellent.

Key words: Multipurpose Cadastre, 3D Cadastre, Land registration, Southamerican Cadastres.

RESUMO

Os sistemas cadastrais latinoamericanos, contemplam, em termos gerais, os seguintes aspectos: legais (propriedades e posse), econômicos (avaliação e apoio à tributação imobiliária) e geométricos(mapas e levantamentos). Mapas cadastrais cobrem áreas urbanas e rurais, mostram os limites das parcelas e os limites administrativos, construções e benfeitorias, bem como elementos do sistema viário, como ruas e estradas. A visão multifinalitária é apresentada em algumas legislações cadastrais e nas intenções de várias administrações, porém na prática ainda não é fácil encontrar exemplos desta

implementação completa. Uma das principais deficiências dos cadastros da região é a fala de dados georreferenciados. Entretando, uma vez que a maioria dos países está implementando suas Infraestruturas de Dados Espaciais (IDE), surge a oportunidade de aperfeiçoamento do trabalho conjunto e intercâmbio de dados entre diferentes instituições. Este artigo tem como objetivo descrever a história e a situação atual dos cadastros do Brasil e dos países da América do Sul e apresentar a estrutura que descreve os seus objetos territoriais. Com base na diversidade conceitual, é possível concluir que é muito cedo para definir uma parcela 3D e um objeto territorial 3D para a região inteira, no entanto são boas as perspectivas para o desenvolvimento de modelos cadastrais em 3D.

Palavras chave: Cadastro Multifinalitário, Cadastro 3D, Registro Territorial, Cadastros Sulamericanos.

1. INTRODUCTION

In most Latin American countries, the cadastral systems were created under the orthodox physical-economic-legal models imported from Spain and Portugal. In recent years, the multipurpose cadastral model has been gaining acceptance in the region as a new alternative, better suited to the needs of administrators and the public. The spread and gradual implementation of Spatial Data Infrastructures (SDI) in the region is a sign of the willingness to share data and investments among different institutions.

The question that inspired this paper was: is it realistic to develop spatial concepts for parcels and land objects and to propose of 3D cadastral model in South America at this time?

2. A BIT OF HISTORY OF SOUTHAMERICAN CADASTRES

It is difficult to pinpoint when it all started, particularly in a territory discovered, occupied and administered by so many different processes. However – even with this level of diversity – it is possible to find common elements that characterize the history of Latin America: for example, the presence of indigenous groups who had their own "cadastral systems" before the arrival of the conquistadors. The brief history related in this paper starts with colonization, which changed the whole system in the region, and finishes with the current cadastral situation, as well as some future perspectives.

2.1 From the Colonies to the Twentieth Century

The institutions responsible for recording real estate – cadastres and property registries – were created and gradually consolidated from the colonial period until the beginning of the twentieth century. The "countries of the River Plate" were pioneers in the development of cadastral systems. In 1826, only ten years after its independence, Argentina created the first legal cadastre in the region, considered by some as the first in the world with these characteristics. Five years later, in 1831, the Topography Commission (Comisión Topográfica) was formed in Uruguay, and the country advanced its system of real estate recording in 1879 with the creation of the Property Registry.

In 1850, Brazil created the General Public Land Administration (Repartição Geral das Terras Públicas). Years later, Paraguay, having lost all records of its territory in the War of the Triple Alliance, created the Public Land Office (Oficina de la Tierra Pública) in 1875.

In 1887, Bolivia created the Real Estate Registry Office (Oficina de Registro de Derechos Reales), in 1890 Brazil established a Registry of Transfers using the Torrens system, and at the end of the century, in 1895, Uruguay created the General Cadastre Directorate (Dirección General de Catastro).

2.2 The Twentieth Century

After the initial administrative turbulence, the need to consolidate and legalize the occupation of territory generated momentum to create recording institutions. During this period, the discussion and analysis of the benefits of centralized and decentralized systems was born, and new bodies were created, land titles were distributed and new attributions were established.

Chile created the Southern Property Ministry (Ministerio de la Propiedad Austral) in 1929, and two years later the Ministry of Land and Colonization (MInisterio de Tierras y Colonización), which ended up merging. Also at the turn of the century, Colombia argued for the creation of a real estate cadastre for the entire country. A further proposal to nationalize it and create a system of self-reporting was made in 1935.

In Bolivia, there were two strong, if opposing, movements during the 1930s: in 1932, the cadastres were decentralized to the level of municipalities, and

seven years later, they were all reconsolidated into the General Internal Revenue Directorate (Dirección General de la Renta Interna). During the 1940s, a large majority of the Argentine provinces started to convert the cadastral agencies that were created in the previous century to Provincial Directorates. In 1943, Paraguay issued a decree to structure a cadastre of land parcels and assessment of real estate. In 1946, Brazil completely decentralized its cadastral functions, empowering the municipalities to develop their own urban cadastres.

The second half of the century brought a polarization of two opposite trends: As one group of countries gave greater impulse to regional (provincial or state) and local (municipalities) cadastres, another increased the responsibility of national cadastres, with the main goal of unifying criteria (in the federal countries) and consolidating institutions (in centralized countries).

The decentralizing movement had its main exponents in Peru, where a 1965 Supreme Decree ordered each province to have its own independent cadastre; in Brazil, where in the 1970s the Ministry of the Treasury created the Incentive Agreement for Technical-Administrative Improvements (Convênio de Incentivo ao Aperfeiçoamento Técnico-Administrativo - CIATA) to support municipal real estate cadastres; and in Colombia, which created the District Cadastre Directorate (Dirección de Catastro Distrital) for its capital city.

The movement toward regional and municipal cadastres continued to grow and strengthen during the last two decades. In the 1980s, important events took place in central South America: the creation of the Municipal Cadastre Directorate (Dirección Municipal de Catastro) in Asunción, Paraguay, in 1983, and the Integral Municipal Cadastre Agency (Empresa Municipal de Catastro Integral) in Lima in 1987, which was converted two years later into the Lima Cadastral Institute (Instituto Catastral de Lima). In 1985, Bolivian cadastres and property taxes were transferred to the municipalities, lost them in 1986 to the National Urban Cadastre Directorate (Dirección Nacional de Catastro Urbano), and regained them once more 9 years later.

The centralizing movement also showed its strength from north to south in Latin America. In 1952, Argentina created the National Cadastre Directorate, (Dirección Nacional de Catastro) and six years later the Federal Cadastral Council (Consejo Federal de Catastro).

During the 1960s, Ecuador created the National Office of Assessments and Cadastres (Oficina Nacional de Avalúos y Catastros) (1963) which was converted into the National Directorate of Assessments and Cadastres (Dirección Nacional de Avalúos y Catastros) in 1966. In 1964, Chile created the Natural Resource Institute (Instituto de Recursos Naturales), and in 1969 Bolivia created the National Real Estate Registry (Registro Nacional de la Propiedad Inmueble) under the National Cadastre Directorate (Dirección Nacional de Catastro).

In Brazil, the National Institute of Colonization and Agrarian Reform (Instituto Nacional de Colonização e Reforma Agrária) was formed in 1970, and two years later the National System of Rural Cadastres (Sistema Nacional de Cadastro Rural).

The 1980s started with the emergence of the Ministry of National Assets in Chile (Ministerio de Bienes Nacionales), whose statutes contemplated the creation of the National Cadastre Division of State Assets (División de Catastro Nacional de los Bienes del Estado).

The last decade of the century started with the transformation of the Property Tax Directorate (Dirección de Impuesto Inmobiliario) into the National Cadastral Service (Servicio Nacional de Catastro) in Paraguay in 1991. In 1996, Uruguay formed the National Cadastral Directorate (Dirección Nacional de Catastro), and two years later, Bolivia formed the National Cadastral Institute (Instituto Nacional de Catastro) and the National Cadastral System (Sistema Nacional de Catastro).

2.3 The Twenty-First Century

Although it is just beginning, this century already has its own distinct profile, characterized by the emergence of new institutions and cadastral statutes meant to establish criteria and support national programs that attempt to merge the cadastres with the registries, and the development of information systems to define spatial data infrastructures with the participation of the cadastres.

In the first year of the century, Venezuela enacted its Geography, Cartography and National Cadastral Act (Ley de Geografía, Cartografía y Catastro Nacional), creating the Simón Bolívar Geographic Institute of Venezuela, and two years later published the Technical Standards for the Creation and Conservation of Cadastres (Normas

Técnicas para la Formación y Conservación del Catastro). Its neighbor, Brazil, created the National Rural Real Estate Cadastre (Cadastro Nacional de Imóveis Rurais) in 2001 under a new and innovative legislation that contemplates the georreferencing of parcels.

In South America, the institutional and legal ups and downs were in full display. Bolivia dissolved the National Cadastral Institute in 2003, while in 2004 Ecuador changed the authority of the cadastral administration, approving a new Municipal Statute. That same year, Peru created the National Integrated Cadastral System (Sistema Nacional Integrado de Catastro), and linked it with the Real Estate Registry. And in 2007, after a long wait, Argentine finally enacted its National Cadastral Act (Ley Nacional de Catastro).

3. SOUTH AMERICAN CENTRALIZED AND FEDERAL COUNTRIES

Of the 19 Latin American countries, only 4 adopted a federal regime. All of these have a real estate recording system based on cadastres and registries of deeds, each one with its own peculiarities. The remaining centralized countries have different forms of cadastral systems.

3.1 Cadastral Organization in Federal Countries

In Argentina there is no single system, as the provinces never delegated the cadastral function to the federal government. In fact, one interesting feature of the Argentine system is that, although the country has a National Cadastral Act and a Federal Cadastral Council that establishes general guidelines, each federative body has its own provincial cadastral act and specific regime. Therefore, the provinces organize their territorial cadastres to identify the physical, economic and legal aspects of the parcels, and use that data to define their land tax policies. In parallel, some municipalities organize their urban cadastres with the main goal of enforcing planning standards, mainly as it pertains to the subdivision of land, and use that data to define the service fees collection policies. The connection between the municipal and provincial cadastres is made at different levels around the country.

In Brazil, federalism has a particular connotation when it comes to managing territorial information. While the rural cadastre is organized by the National Institute of Colonization and Agrarian Reform, which is part of the central government, and is therefore centralized (although distributed around the country), local governments organize their municipal cadastres with ample authority and independence, focusing mainly on the cities. Given the enormous diversity of criteria, and as an alternative for the municipalities that lack the needed human, technical and financial resources, the Ministry of Cities has published National Guidelines for the Creation of a Multipurpose Cadastre which – although lacking the force of law – guide technical and administrative personnel through cadastral restructuring.

In Venezuela, the Geography, Cartography and National Cadastral Act establishes guidelines to restructure the country's cadastres. According to this law, Venezuela's Simón Bolívar Geographic Institute directs, coordinates and executes policies and plans for the creation and maintenance of cadastres throughout the country, and Municipal Cadastral Offices are obligated to organize their cadastre following these national directives. Many times, the various limitations of local governments to create and maintain a cadastre make this task impossible, so the Institute provides support, mainly by developing joint projects and collaborating to obtain resources from the pertinent public agencies, without precluding the participation of the private sector.

3.2 Cadastral Organization in South American Centralized Countries

In Bolivia, since the dissolution of the National Cadastral Institute, the institutions involved in real estate recording no longer converge. The urban and rural cadastres have been restructured under different institutions, legislation and philosophies. The municipal governments have responsibility for managing urban cadastres and using them to organize the tax collection system and develop land planning, pursuant to the Municipal Statutes Act. The cadastral organization in Bolivian cities is still based on the National Urban Cadastral Regulation of 1991, which requires that all real estate blueprints be stored in the municipal cadastre before recording any property title as a result of a real estate transaction. In the rural realm, the National Institute of Agrarian Reform (Instituto Nacional de Reforma Agraria) issues technical guidelines to create legal cadastres of rural properties, and coordinates their implementation

with the municipalities and other public and private entities.

Chile organizes its territorial data basically in two types of cadastres: one for private assets and another for public assets, both under the responsibility of national agencies. The Internal Revenue Service (Servicio de Impuestos Internos, or SII) is responsible for an equitable administration of property taxes, enforcing compliance, reducing costs, and managing an online tax payment system. For this purpose, the SII organizes its data in databases generically called the legal cadastre and the physical cadastre; which lack any complete or modern cartographical base, as its purpose is purely financial. In parallel, the public property cadastre was designed and constructed to manage state-owned real estate, composed of all the properties recorded by the State, acquired in any form, with all their legal and physical attributes.

Colombia has a "semi-decentralized" system, although the Agustín Codazzi Geographic Institute (Instituto Geográfico Agustín Codazzi, or IGAC) is the governing body at the national level, there are also decentralized cadastres. The Institute is responsible for regulating the legal framework and its implementation, while the cadastres of the Province of Antioquia and of the cities of Bogotá, Medellín and Cali are administratively independent of the national system. However, technically, these four jurisdictions are obligated to follow the standards and procedures established by the IGAC, which is responsible for controlling, consulting and supervising the execution of the cadastral process. The country is rapidly evolving from a system of cadastres with a marked fiscal bias, to multipurpose cadastral organizations that provide the main source of information for planning and other activities that need territorial data.

In Ecuador, the cadastre has an essentially fiscal orientation, and has been structured mainly to determine the property tax base. In contrast with what happens in most of centralized countries, Ecuador does not have a specific national cadastral law, and cadastral activities are regulated by the Municipal Statute. Per current law, every two years local governments must update their overall cadastres and the assessments of urban and rural properties. This is not limited to a technical task, because once the assessments have been updated, the Municipal Council reviews them observing the principles of equality, proportionality and generality established by the national tax system.

In Paraguay, the National Cadastral Service issues a Real Estate Cadastral Certificate (Certificado Catastral de Inmuebles), which is the public instrument that describes its physical, legal and economic status. Public Notaries are obligated to obtain this document and submit it to the General Directorate of Public Registries before authorizing the transfer, modification or creation of a real estate deed. At the local level, Law 3966 of 2010 grants municipalities the power to create, maintain and update municipal cadastres, in coordination with the National Cadastral Service.

The cadastral system in Peru still has several institutions responsible for activities related to the recording of properties. However, the Integrated Cadastral System and Association with the Real Estate Registry Act (Ley del Sistema Integrado de Catastro y su Vinculación con el Registro de Predios) has broken down the barriers that existed between them, creating a convergence process, and linking these two agencies explicitly. The National Superintendence of Public Registries (Superintendencia Nacional de los Registros Públicos) has taken an important role in the Peruvian cadastral system, assuming the presidency of the National Cadastral Council and the Technical Secretariat (Secretaría Técnica) established in the aforementioned Act. In recent years, this agency has given a big impulse to cadastres around the country, contracting personnel in its main offices to perform task associated with cadastres.

In Uruguay, the cadastre is centralized in the National Cadastral Directorate, and structured in accordance with a geometric and descriptive model. The data are then distributed to branch offices located in each state (Departamentos). The geometric definition of a parcel is based on individual blueprints which are not georeferenced, as the cadastre does not have legal value and is not structured for tax purposes.

4. 3D VIRTUAL CITIES IN SOUTH AMERICA

Among the different realities and technological levels of South American countries, today it is possible to find interesting experiences indicating that development of 3D cadastral models in the region is possible. Entering the 3D world could start with

the creation of 3D virtual cities. The following section presents some visions to inspire administrators and legislators.

4.1 Formal and informal 3D virtual city

In the context of this paper, a "virtual 3D" city is the real (built) city which, represented geometrically, is useful in several types of analyses, such as vehicular traffic studies, tracking of cell phone waves, or any type of infrastructure network analysis. For other kinds of analysis the virtual 3D city it is not sufficient, as when a lawyer may need to visualize the legal 3D city as defined by urban and environmental regulations. Figure 1 shows two virtual 3D cities, one representing existing formal buildings and the other indicating the legal city according to its development potential based on the applicable urban regulations.

In Latin America, where the incidence of urban informality is practically a constant in the urban landscape, it is important to visualize and define the informal as well as the legal 3D virtual city. Every "occupied space" is a part of the city and should be considered in the urban data bases of the cadastre.

Informal settlements develop when people are unable to save money or obtain access to credit to purchase a home or are ineligible to receive government assistance through housing programs. They must find a place to settle, which is often on hazardous or protected land that is inappropriate for housing, or on vacant public or private land. The magnitude of the need for housing often surpasses the amount of land available, thus pushing informal settlers to build taller structures at higher densities that in many ways are similar to those in the formal housing market (figure 2).

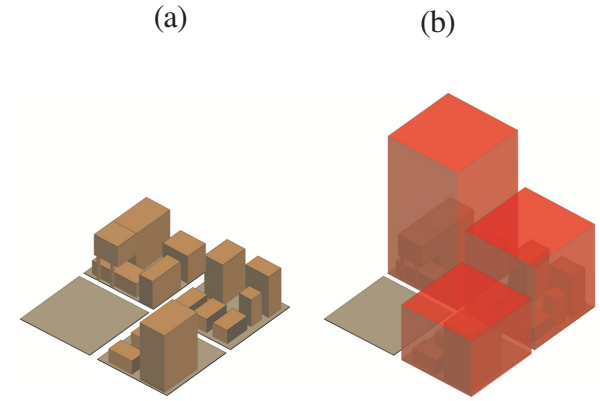

Fig. 1 – Virtual 3D formal city and virtual 3D legal city. The existing buildings (1a) are incorporated into an expanded legal city (1b).

4.2 3D Dynamic Cities

Dynamism taking place in cities can be visualized and measured in several ways, for example through studies of densification, migration, and expansion of infrastructure networks. These studies assume that social, economic, and environmental variables are dynamic, even though land is static. However, other forces that produce changes in the city can cause dislocations of different intensities that can be measured in space (3D) and time (4D). For example, the continental plates are moving South America, its cities, public and private properties, and infrastructure networks slowly toward the west at the rate of 2 centimeters (cm) per year. These movements, which seem insignificant, have consequences for urban policy if one considers that in 50 years a property could be moved as much as one meter from its current location.

Even more extreme movements are the consequence of the dynamic nature of our planet. The earthquake in February 2010 impacted Chile's southern Biobío Region at many different scales.

Fig. 2 - 3D informal city with multifamily buildings Photography: Martim Smolka, Lima, Peru.

Measurements by the Transportable Integrated Geodetic Observatory (TIGO) in the city of Concepción recorded that the entire territory moved initially toward the northwest and then ended with a displacement of 3 meters toward the southwest, all within 30 seconds. During this event, the height of land shifted by 50 cm. The telluric movement carried away properties and destroyed urban infrastructure and buildings, and the damage was compounded by the subsequent tsunami (figure 3).

The January 2010 earthquake in Haiti produced an estimated 20 million cubic meters of debris in 35 seconds, even though significant land displacements were not registered. From the point of view of the cadastre, however, these phenomena had very different impacts. If the urban information had been structured in thematic layers and integrated in a GIS platform, the earthquake in Haiti would have affected the construction layer and several representative building types would have disappeared. In Chile, the construction layer was modified mainly by the tsunami, but the land itself was most affected by the spatial displacement and shifts resulting from the telluric movement. Fast-moving natural disasters like these change the environment and people's lives radically, and have important implications for government priorities, including definitions and implementation of land policy, both before and after such events.

4.3 3D Land Market Value

One of the functions of a territorial cadastre is to provide information to determine the value of the parcels upon which taxation and urban planning policies impact. More recently, the use of spatial econometric models to determine property values with the desired statistical precision is spreading across Latin America. This is important because land values change across urban space and depend on variables such as urban regulations, environmental restrictions, scenic views, infrastructure, and what goes through the property underground and by air.

Figure 4 shows a perspective of the surface gradient of land values per square meter obtained from sample points corresponding to properties for sale. The surface has the same plan-metric referent (x, y) as the entire city, and although the spatial variable z is not related to the geographic space, it is possible to position it under the legal virtual city and analyze the spatial correlation between the land value per square meter and the urban regulation.

5. PERSPECTIVES OF A 3D CADASTRE

To identify the real perspective of 3D Cadastre model implementation in the region, and as an exercise, it is interesting to start with a more detailed analysis of the region's two biggest countries: Argentina and Brazil. They present greater diversity in terms of cadastral administration, recent cadastral laws and enormous territories to be described.

5.1 3D cadastre in Brazil

In Brazil two situations can be identified: overlapping titles of ownership on the same parcel, and different types of ownership involving more than one parcel. In the simplest case, rights may belong to the same owner, but information is distributed vertically for spatial representation. In these cases, the cadastres still record a single parcel; but buildings shown in orthogonal projection and vertical

(a) (b)

Fig. 3 – Dichato, Chile, before (3a) and after (3b) the February 27, 2010 tsunami.
Source: Geographic Information System of the Reconstruction Plan Coastal Edge, Regional government of Biobio, Chile. Credit: Sergio Baeriswyl.

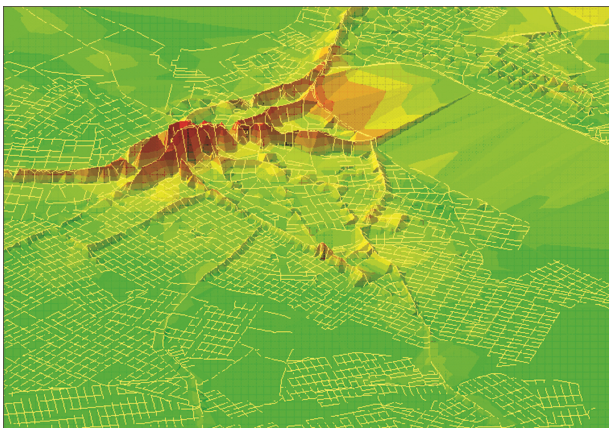

Fig. 4 – Land values per square meter on a continuous surface in Fortaleza, CE, Brazil
Source: Aeroimagem Co., Brazil. Everton da Silva

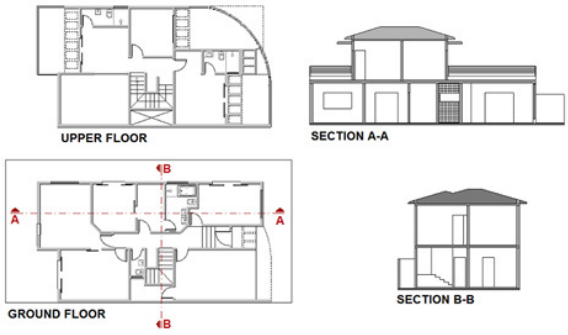

Fig. 5 – Tridimensional view shown by orthogonal and longitudinal projections.

projection (cross section) which provide a true picture in three dimensions (figure 5).

The case of two multi-use condominiums in which each apartment has a different owner is more complex because ownership changes on each floor. The vertical units are autonomous parcels and each enjoys a portion of land and common area.

The parcels are still identified in both the cadastre and property registry by unit number based on an orthogonal projection by floor. There is no tridimensional graphic information. The first digit of the ID number usually indicates the floor and gives some idea of height; however, the map does not offer a chart showing precise volume.

Besides apartment buildings, other cases of surface, subsoil and air space occupation must be addressed by the cadastre and registry. Given that, under the Civil Code, ownership covers spatially designated subsoil and air space. The owner cannot object to activities performed by a third party at a height or depth without justification for preventing such use. However, ownership of the soil does not include deposits, mines and other mineral resources, hydraulic energy potential, archaeological monuments and other property covered by special laws.

These come under Federal jurisdiction and their use depends upon concessions.

In this case, cadastral information in three dimensions would be important because it would show differences in ownership and use between surface and subsoil, since ownership of mineral resources is different from ownership of land (figure 6). The current 2D cadastre has not correlated spatial information well; therefore, it cannot prevent conflicts or define responsibilities accurately.

Another case in which the 3D Cadastre could play an important role is the control of subsoil occupation by infrastructure networks. Cadastres and laws designed specifically for this type of occupation would surely be a great advance in the areas of engineering and geology. They could rely on subsidies encouraging regulated use and occupation of soil, subsoil and air space. In general, the growing demand for urban underground work is hampered by the lack of an updated cadastre for all existing facilities. In urban centers, as figure 7 shows, there are several overlaps both below the surface (water, sewer and gas pipes; electric, phone and cable TV network cables; rain water reservoirs; tunnels) and in the air space (power and phone grids, viaducts, overpasses), making it difficult to plan and focus a cadastral survey on all these cases.

The situation is complicated and calls for attention, especially because spatial data for the land exists; however, there is still no institutional coordination for adopting unified reference systems and exchanging information.

Due to the popularity of geo-technology throughout the country and the gradual development of the data sharing concept, Brazil is certainly at an appropriate point for reflecting and defining strategies to construct a 3D Cadastre. The law would assign responsibility for implementing tridimensional graphical information to the companies responsible for installing, operating and maintaining urban facilities. This would facilitate performance in their specialty areas and the necessary state control. Most importantly, it would provide greater security to the population living in this complex web of networks,

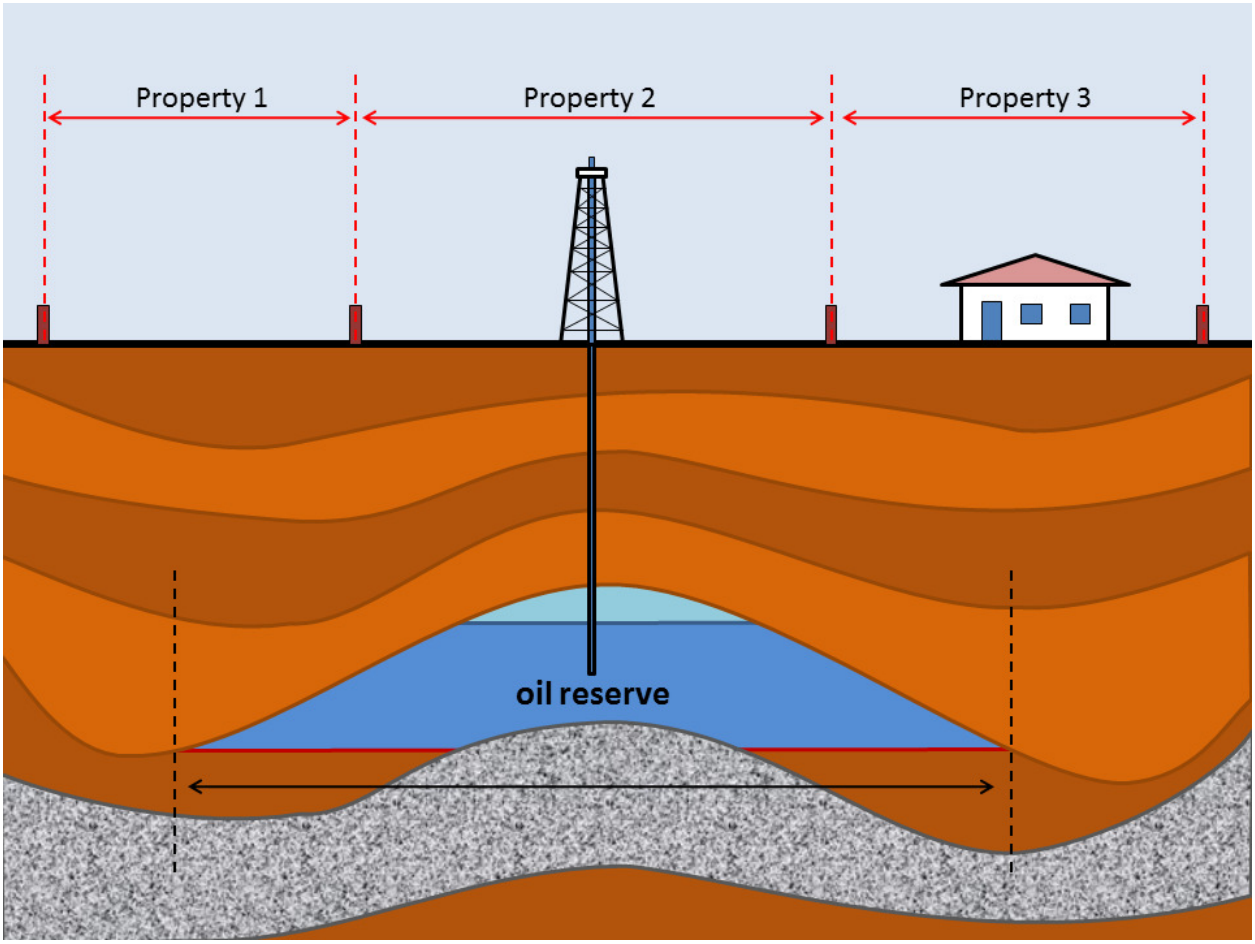

Fig. 6 - Demarcation of parcels on the soil surface and demarcation of concession area for extracting oil from a larger portion of the subsoil.

pathways and other devices typical of the modern world.

5.2 3D cadastre in Argentina

In Argentina, buildings or constructions are represented in 2D with specific height of each floor and referencing all vertical distances to the ground. In accordance with Article 2 of the Horizontal Property Law No. 13.512, "each proprietor shall be the exclusive owner of his/her flat or apartment, and co-owner of the land and all other objects of common use or essential for maintaining security in the building. For that reason, the following are considered common ownership:

a. Foundations, load bearing walls, roofs, solar patios, portals, galleries and common lobbies, stairs, entrance doors, gardens;

b. Central service rooms and facilities, such as heating, hot or cold water, air conditioning, etc.;

c. Rooms for the caretaker and superintendent's apartment;

d. Walls or partitions between apartments;

e. Elevators, freight elevators, incinerators, and in general, all artifacts or other facilities for common benefit services. This list is not exhaustive.

Basements and roof terraces are considered common areas unless otherwise noted. From the lowest floor downwards, and from the building rooftop upwards, the property is also common. Thus, all new construction that affects the common areas cannot be realized without authorization given by all the owners.

From this it is possible to conclude that walls, floors, structures and roofs are common areas in the 2D representation and common spaces in the 3D concept. The phrase "that which is common limits the extent of exclusive ownership" is valid for the 2D concept of the current cadastre, but can be extended to the 3D vision.

Different jurisdictions propose alternatives for representation of the parcels. In the province of Santa Fe, for example, the different uses of the building are represented with visual patterns in black and white(figure 8).

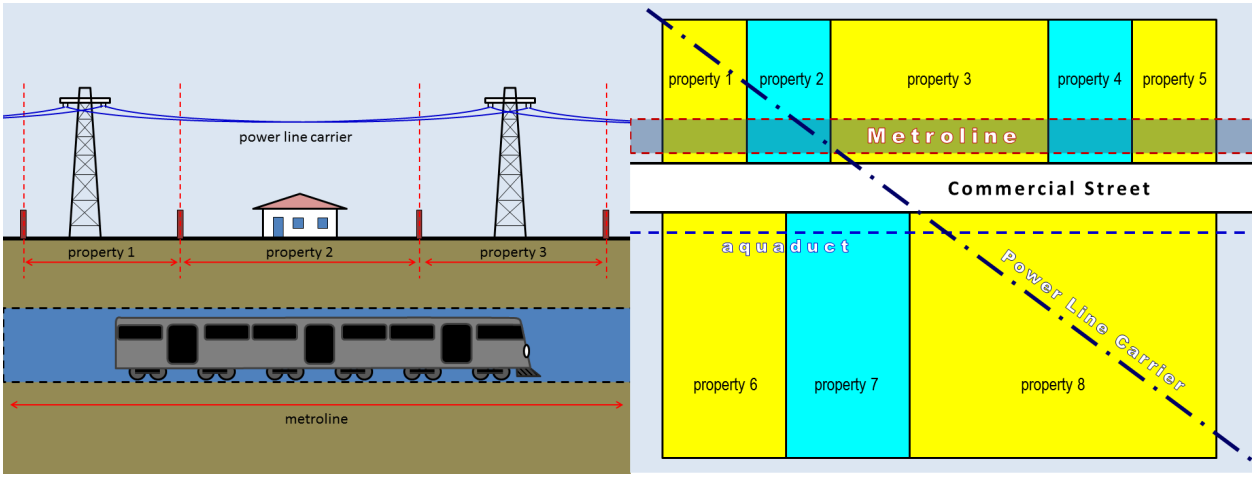

Fig. 7 - Integration of spatial data from different 2D sources.

In Argentina, parcels are generally referenced to urban elements, such as the corner of a city block, determined by the intersection of the building setback lines (line that separates the public from the private domain), fence posts, etc. However, some jurisdictions have started to implement absolute coordinates, such as the Province of Santa Fe, for example, where the survey blueprints of certain rural parcels larger than a given area must be georeferenced, and therefore have geodesic and two dimensional coordinates.

There is a strong tendency to adopt the POSGAR 2007 reference framework, as much for the cartography as for the geodesic network, in order to standardize land information not only for the provincial cadastres but also the federal system.

In practically all Argentine cadastres, the vertical distances of elevated objects are measured to the floor on which they are supported, and not identified with absolute heights or altitudes.

These representations basically follow two strategies:

1. Inclusion of a circular black and white symbol (figure 9), and at its side the vertical distance from the floor to a street level reference.

2. Representation of the height of the apartments (Z) in a horizontal property building using cross-sections and representation of the building façade (figure 10). In this case, it is possible to say that the drawing is a proto-3D representation, at least in buildings whose dimensions do not always coincide precisely with those of the parcel.

The official cadastral documents and survey blueprints are based on standards that are strictly limited to 2D representations on paper (although CAD applications are now popular, most of the professionals and institutions still conceive surveys blueprints as analog documents).

Fig. 8 - Visual black and white patterns used to represent different uses.

6. LEGAL LAND OBJECTS IN SOUTH AMERICA

The conceptualization of a 3D cadastre model requires, in addition to analyzing how the plots are recorded at present, identification of objects that restrict land (Carneiro et. al,2012). In this analysis, Peru, the third largest country, was incorporated in our analysis.

In Argentina, the National Cadastral Law No. 26.209 defines "legal object" as any portion of the territory that by nature and means of access is finite and homogeneous. A "legal land object" (objeto territorial legal, or OTL) is one that is generated by a legal cause. This legal cause may be a property title (as is the case in real estate transactions), an ordinance or law (as is the case in ownership restrictions, the creation of reservation areas, or the demarcation of an urban area), or even an international treaty (such as those that establish borders between countries). The law stipulates that all OTLs, and their public records, must be managed by the provincial cadastres.

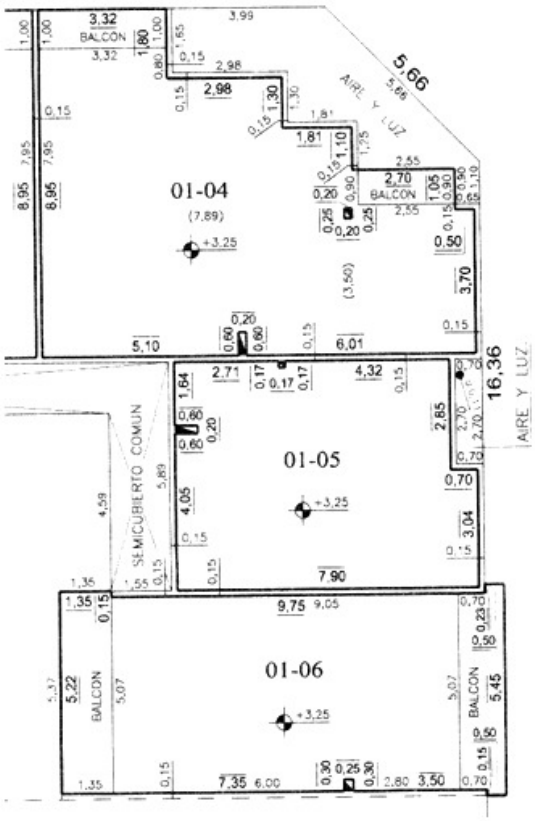

Fig. 9 - Example of survey blueprint of horizontal property.

In the rest of the South American countries, the definition of OTLs is not as explicit as in Argentina, but proof of their existence can be seen in substantive and ancillary legislation.

• Towpaths (figure 11)

In Argentina this is a restriction to private ownership established in Article 2639 of the Civil Code, and is defined as a 35 meter strip measured from the shore of navigable waterways toward the interior of adjoining properties. No compensation can be claimed for this area, and it implies a hands-off or non-interference obligation.

In Brazil, marginal or reserved plots are "those which possess navigable currents out of the reach of tides, which reach a 15 (fifteen) meters distance, measured horizontally towards the land from the median line of ordinary floods," (Decree-Law 9,760/46, article 4). Generally, the reserved lands on the shores of e lakes and navigable rivers belong to the states (Water Code – Decree 24,643/34, article 31).

In Peru, Article 74 of Act #29338 (Water Resources Act) reserves a marginal strip of land on territories abutting artificial or natural waterways, to provide for the primary use of water, free traffic, fishing, roads for monitoring and other services.

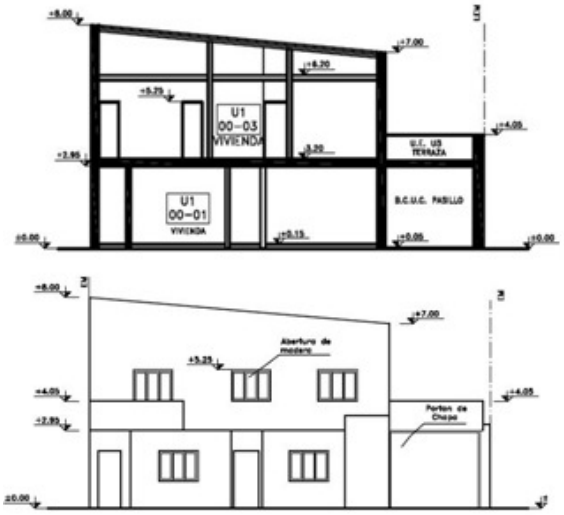

Fig. 10 - Facade and cross-sections identifying heights relative to the floor

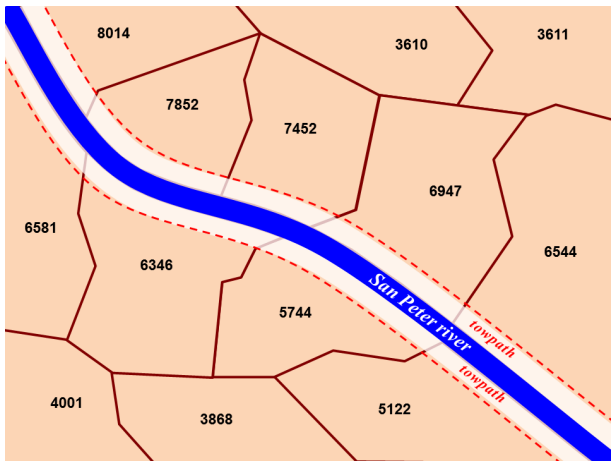

Fig. 11 - Restrictions under towpaths.

• Real Estate Right

Under National Law No. 25.509/2001, this is a real estate right to a Forested Area. It is conveyed separately from land ownership, and allows somebody to plant in another parcel, but keep ownership of what was planted. In addition, it allows for the purchase of existing plantations in parcels that belong to others. This is a temporary right, with a maximum duration of 50 years, and can be canceled if it is not used for 3 or more years. This right is granted by contract and must be recorded in the Registry of Deeds.

In Peru, Article 1030 of the Civil Code grants "surface rights" to allow the grantee the right to have

a temporary construction on a separate property above or below the land surface. This right cannot be granted for more than 99 years. After the right expires, the landowner gains ownership of the construction, but must reimburse its value. This right can be granted as a contract between living parties or by will. It is transferable.

• Active Real Estate Easements

Under Article 2970 of the Argentine Civil Code, an active easement (servidumbre) is a real estate right, permanent or temporary, exercised over a property owned by others. It is a restriction to the right of ownership by the property titleholder. An easement requires two real estate properties, a master and a slave, which must belong to different owners.

In the Brazilian Civil Code (articles 695 through 712), easements (servidões) are considered an interest in the property of another person, and there are restrictions on the potential of use imposed upon the owner of an asset in order for a third party to benefit.

Article 1035 of the Peruvian Civil Code stipulates that the state (by law) or a landowner can impose taxes or liens on another party, granting the payer the right to use the parcel, or preventing the owner from exercising certain rights.

• Rights Granted under the Mining Code (figure 12)

The Mining Code was established by Decree No. 456 of 1997. It regulates the property of mines, and the rights of exploration and operation. In Article 7, it stipulates that the mines are private assets of the Federal Government or the Provinces, depending on their location. Article 10 of the Mining Code stipulates that "independently of the original ownership by the State… the private property of the mines can be established by legal grant". This granting of mining rights can be interpreted as a mining easement to the mining company. On the other hand, Article 12 defines the mines as real estate properties. Article 20 establishes a mining cadastre to describe the physical, legal, and other useful information about mining rights. Those rights are identified with points that represent the vertices of the "area" defined in the requests for exploration permits, discovery manifests, etc. However, the Mining Code does not mandate in any of its articles the volumetric representation of the mineral to be explored.

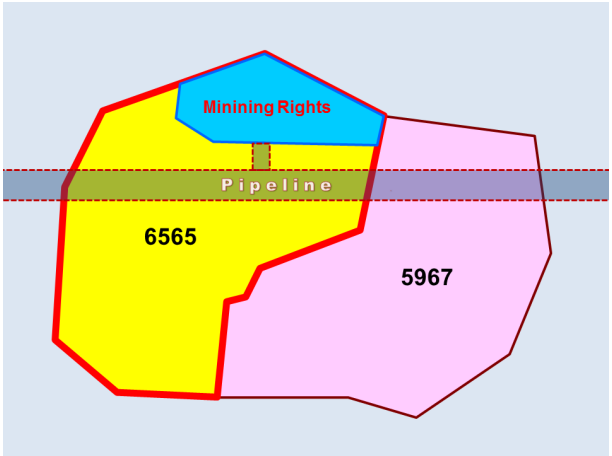

Fig. 12 - Rights Granted under the Mining Code.

According to the Brazilian Federal Constitution, Article 176, mining reserves, whether active or not, and other mineral resources and the potential for hydroelectric power, are a type of property that is different from the property of soil, for the purposes of exploitation or use, and as such they belong to Brazil. However, the grantee has a right to own the product that is mined from such area. Similar to the Argentine Code, the Brazilian legislation does not provide any information regarding volume.

In Peru, mineral rights are established by Supreme Decree #014-92-EM (Unified Text of the General Mining Act) and regulated by Supreme Decree #03-94-EM. Section II of the Preliminary Title of this legislation establishes that all mineral resources belong to the State, and that this ownership is inviolable and inalienable. Act #26615 creates the Mining Cadastre, whose unit of measure is the mineral right, a property unlike land or the right of property under or over land, and therefore is not the same as a parcel, as established in paragraphs 1 and 8 of Article 885 of the Civil Code. The General Mining Act expressly states in Article 9: "The concession of mining rights is a real estate property distinct and separate from the parcel where said rights are located."

• Restrictions under the Aeronautic Code (figure 13)

In Argentina the Aeronautic Code was established by National Law No. 17.285 of 1967, and it describes the limitations to ownership of property located close to airports. This Code defines the limits to obstacles in the airspace in airports and

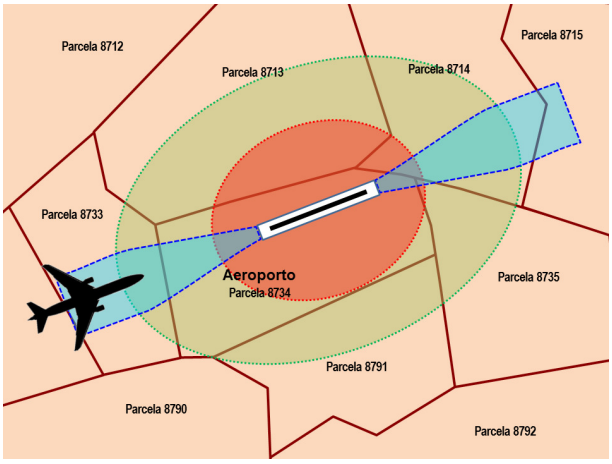

Fig. 13 - Restrictions under the Aeronautic Code.

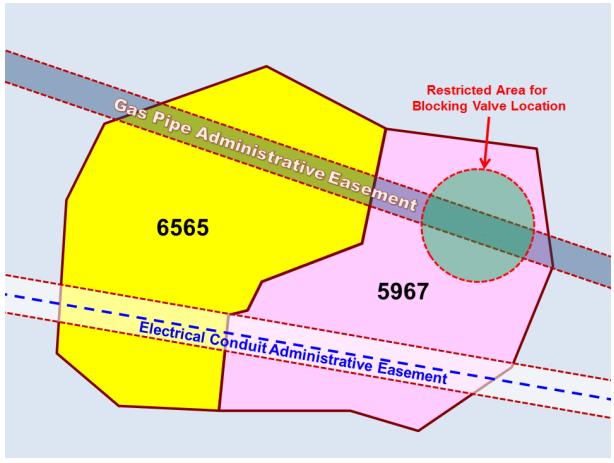

Fig. 14 - Restrictions under Administrative Easements of Utility Pipes.

their surrounding environment, to ensure the secure landing and takeoff of aircraft. Although these obstacles are by nature volumetric bodies, they are represented by their surface projections on land. However, cross-sections are also enclosed to describe the height over land over which the restriction extends.

Law 7,565 of 1986 regulates the Brazilian Air Code. The restrictions to which neighboring properties of airports are subject have to do with the use of such properties and the buildings, premises, types of crops that can be farmed, and anything that may hinder the operation of airplanes or cause interference to the radio signals used to assist air traffic or block the visibility of visual signs. These restrictions are specified based on the approval of the following plans: I – Basic Plan for Airport Protection Zone; II – Noise Zoning Plan; III – Basic Plan for Heliport Protection Zones; and IV – Plans for Protection Zones and Assistance to Air Traffic.

• Administrative Easements of Utility Pipes (figure 14)

Both the National Law No. 19.552 for electrical conduits, and the National Law No. 17.319 for hydrocarbons, stipulate that administrative easements for ducts affect ownership by imposing restrictions and limitations needed to build, maintain, repair and use a pipe or duct that is an essential component of an energy system. These administrative easements are represented graphically as areas or surfaces, with no consideration for the height (electrical conduit) or depth (gas pipe) at which they are laid.

In Peru, easements are stipulated in Act Decree #25844 (Electrical Grants Act). Article 23 of said law stipulates that a temporary grant allows the use of public assets and the right to impose easements for construction and operation of electrical plants and associated infrastructure, substations and transmission lines, as well as electrical distribution networks and substations.

• Urban Restrictions

These types of restrictions are established by municipal ordinance and have the goal of fostering coexistence among neighbors, improving the general welfare and ensuring public health. Some of the salient features of urban restrictions are the obligation of noninterference and the lack of compensation for the affected property owner. Some examples are: Chamfered corners (for visibility), building setbacks, recess of common walls between buildings, land use regulations, street extensions, etc.

In Brazil, the municipalities regulate the use of urban soil. Given that the potential for development is defined by the municipality, the air space in which buildings stand belong to the State, which then represents a clear and distinct difference between a Right to Build and a Right to Own Property. This is being discussed by scholars and by the industries that develop land policy in Latin American cities, and it is a clear example of the importance of our starting to see the city as an accumulation of 3D plots on which there is the intersection of private and public interests.

7. CONCLUSIONS

While the technologies for measuring, representing and storing properties are evolving toward 3D, cadastres in South America still look at the Earth as flat, as it was conceived since the beginning of the Classical Period.

The incipient initiatives to georeference cadastral parcels (even in 2D) and land objects under the same system of reference will be the first step to establish a 3D cadastre in the region.

The 3D representation of buildings is not yet a common practice in South America cadastres. 3D representation prototypes are generally generated in a GIS environment, showing the building as a function of the number of floors (the alphanumeric database indicates this value, which is multiplied by 3 meters to generate the real volume). Laser scanning survey techniques are gradually spreading in the region. Photogrammetric surveys are sporadic, but are nonetheless the most frequent way of generating altitude data and building heights. Most the jurisdictions have not even published guidelines for 2D georeferenced surveys, much less 3D surveys.

Given that some essential elements of a 3D cadastre model are already covered by legislation, and with the technology available in the region, it is the right time to develop theories for 3D Cadastre implementation, a model that could address situations not handled by the traditional two dimensional surveys.

The visualization of construction and property restrictions in 3D is a considerable advancement for decision making; however, there is still a long way to go in order to legally describe spatial land objects and parcels in 3D in the legislation and property titles. The intersection of these bodies in space is not a difficult task for surveyors and engineers, but it still is an arduous task for the legislator, the urban planner and the notary public.

The conceptual diversity among Latin American countries shows that it too soon to define a 3D parcel and a 3D territorial land object applicable for the entire region.

The consolidation of 3D cadastres in South America would be an effective tool for urban and environmental planning, infrastructure network distribution and the prevention of informal settlements, allowing the simulation of future land policy scenarios in the spatial domain.

REFERENCES

CARNEIRO, A., ERBA, D., AUGUSTO, E. Preliminary Analysis of the Possibilities for the Implementation of 3D Cadastre in Brazil. In: **International Workshop on 3D Cadastre**. 2., 2011, Delft, Netherlands. **Proceedings**... 2011, p. 461-478. Available at: http://3dcadastres2011.nl/.

CARNEIRO, A., ERBA, D., AUGUSTO, E. Cadastro Multifinalitário 3D: Conceitos e Perspectivas de implantação no Brasil. **Revista Brasileira de Cartografia**, 2012, n. 64/2. p. 257-271.

ERBA, D. & GRACIANI, S. 3D Cadaster in Argentina: maps and future perspectives.In: **International Workshop on 3D Cadastre**. 2., 2011, Delft, Netherlands. **Proceedings**... 2011, p.15-30. Available at: http://3dcadastres2011.nl/.

ERBA, D. A. **El catastro territorial en los países latinoamericanos.** Cleveland: Lincoln Institute of Land Policy. 2008. 450p. Available at: http://www.lincolninst.edu.