Revista Brasileira de Cartografia
ISSN 1808-0936 | https://doi.org/10.14393/revbrascartogr
Sociedade Brasileira de Cartografia, Geodésia, Fotogrametria e Sensoriamento Remoto

Urban Cadastre: a Proposal for Coding of Urban Parcels Nationwide

Cadastro Urbano: uma Proposta para Codificação de Parcela Territorial Urbana com Abrangência Nacional

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Received: 12.2021 | Accepted: 11.2022

Abstract: The parcel is one of the main elements in land use planning and management. Through it, it is possible to link and obtain information on land use, environmental monitoring, land assessment and taxation, especially when a Land information system (LIS) is established. It is the basis for the Multipurpose Cadastre and, for this reason, must be correctly and unequivocally identified and allowed to use in any LIS. Due to the absence of a standard for the coding of urban parcels in the national territory, this study proposes a unique geocode as an identification key within an information system, integrating the entire territory This proposal is based on a hybrid system for land parcel identification, resulting from the combination of a hierarchical coding system, given by the administrative division of Brazil, historical reference and the absolute geolocation, using as reference the parcel centroid, determined by rectangular plane coordinates of the Local Topographic System (STL), established by the Municipal Cadastral Reference Network (RRCM), according to the Brazilian Association of Technical Standards (ABNT) NBR 14,166, of 2022 and 13,133, of 2021. The final result presents the composition of a unique identifier code for the parcel that accurately guarantees the identification and geographic positioning throughout the national territory, contributing to the integration of information and enabling greater security of the municipal territorial cadastre in the country.
Keywords: Parcel. Cadastre. Geocode. Unique Identifier.

Resumo: A parcela é um dos elementos principais no ordenamento e gestão do território. Por meio dela é possível vincular e obter informações sobre o uso solo, monitoramento ambiental, avaliação e tributação de terras, principalmente quando se estabelece um Sistema de Informações Territoriais (SIT). É a base para o Cadastro Territorial Multifinalitário e, por esse motivo, deve ser identificada de forma correta, inequívoca e permitir o uso em qualquer SIT. Devido à ausência de um padrão para a codificação de parcelas urbanas no território nacional, este trabalho propõe um geocódigo único como chave de identificação dentro de um sistema de informação, integrando todo o território. O método apresentado baseia-se em um sistema híbrido para a identificação da parcela, resultado da combinação de um sistema de codificação hierárquica dado pela divisão administrativa do Brasil – referência histórica e geolocalização absoluta –, utilizando-se como referência o centroide da parcela, determinado pelas coordenadas plano-retangulares do Sistema Topográfico Local (STL), estabelecido pela Rede de Referência Cadastral Municipal (RRCM), de acordo com a Associação Brasileira de Normas Técnicas (ABNT) NBR 14.166, de 2022 e 13.133, de 2021. A proposta atende as normas técnicas e as recomendações nacionais e internacionais. O resultado final apresenta como proposição um código identificador único destinado à parcela urbana que garante, com precisão, a identificação e o posicionamento geográfico em todo o território nacional, contribuindo para a integração das informações e possibilitando maior segurança e integração dos cadastros territoriais municipais no país.
Palavras-chave: Parcela. Cadastro Territorial. Geocódigo. Identificador Único**.**

1 INTRODUCTION

In Brazil, municipalities are responsible for managing the Urban Cadastre, in addition to legislation on land use and occupation, and the Laws of Land Parcelling and Zoning; municipalities have faced numerous challenges with these activities, either due to lack of human resources and qualified technical staff, or due to limited financial resources. Thus, from a general perspective of the cadastre already implemented in several municipalities, what is observed in practice are differentiated identifiers of the parcel without standardization, a fact that hinders the positioning and the recognition of the urban parcel at the national level, preventing the integration, availability and validation of the produced cadastral information.

The basic unit of the cadastre is the parcel, and as such, it must be identified in a contiguous and unequivocal manner (BRASIL, 2022). For this, it is necessary to establish a unique identifier code, which is considered a stable, invariant and permanent element, and it becomes the switch within a Land Information System (LIS), commonly known as cadastral registration, parcel number, real estate registration, cadastral index, cadastral record, cadastral nomenclature, cartographic code, and building identifier number, among others.

Several methods are used for this encoding. Some are based on the georeferencing of the parcel, concerning cartographic projections in different reference systems, partially converting the reference into a geocode, and others are based on hierarchical relations of location of the parcel within the elements of higher category, without any relationship to its space position. That is, the identifier code can be the connection between the administrative units of the municipality and the number that identifies the parcel in the block, the geolocation of the property or just a sequential number of registration of the parcel.

Regardless of the cadastral, legal or tax system adopted, the more precise, exact and geographically defined the identifier code, the greater the possibilities of applications and the lower the margin of error in the management of the national territory, as well as the exchange of data and information between the various spheres of public administration. On the other hand, geodetic reference systems are the basis of georeferencing for all levels and, therefore, of cartography, including cadastral mapping. The association of these concepts allows locating the parcel within a stable and permanent system.

In Brazil, there is no defined standard for identifier composition, number of numeric and alphanumeric positions and coding method, and such standard may vary from one municipality to another. Just to cite a few examples: Belo Horizonte (MG) has a size of 15 alphanumeric positions; Belém (PA) has a sequence with 22 numeric digits; Natal (RN) uses the property sequence corresponding to the address of the establishment consisting of 8 numeric characters; in Vitória (ES) for establishing the indicator, the tax registration (property) with 6 digits or the complete real estate registration (without direct relationship between them) with 17 alphanumeric digits can be used; Curitiba (PR) uses the real estate registration number, which is composed of 14 numeric digits; and Salvador uses the real estate inscription consisting of 7 characters.

Through these municipal cadastres, access to territorial information is possible and, with them, the achievement of benefits - such as the accuracy of real estate evaluation for property taxes, assertive decision-making, security of real property, social and social inclusion of others – it is easy to understand why this diversity has been presented as a problem for territorial management in Brazil.

The current urban cadastre, without a reference model to standardize the common aspects of LIS, implemented in Brazilian municipalities is managed in an outdated way and is insufficient to meet territorial demands. The result is an incomplete and disaggregated structure, making it a neglected system, and is caused mainly by the absence of an organizational structure and a regulatory environment of national scope (SILVA et al., 2021).

Some municipalities even demand more conceptual modernization than technological modernization and more institutional articulation than financial resources (DANTAS, 2017). The benefits of a modern cadastre need to go beyond the governmental sphere so that the private sector also benefits from the inventory of territorial information (PAIXÃO; NICHOLS; CARNEIRO, 2012); this information needs to be based

mainly on the triad of economic, social and environmental functions. Without these functions, the cadastre often becomes a failure in its registration system, tax collection, social function, environmental management and planning actions that subsidize efficient public management in the face of the intense urban growth of recent years.

To meet the multipurpose function of the cadastre, it must be modelled to meet the needs of different users, current or future, and must be supported by a reference system and a unique and stable identifier for each parcel. The unification of registration information in a national system brings security to properties and the State, thus protecting the real estate market, in addition to facilitating and attracting investment (BRASIL, 2009).

It is worth noting that the urban cadastre in Brazil is administered and managed exclusively at the municipal level (BRASIL, 1988; COSTA 2001; BRASIL, 2022). However, the tendency to connect it to a national system through a unique identifier of the parcel that establishes its geolocation, makes it possible to identify it in the cadastral database at the national level; hence, such a connection must be considered (Bennett et al., 2012; UN-FIG, 1999). Thus, it will allow the connection between the municipal territorial databases, enabling the management of projects at all levels, without overlapping public policies, and it enhances expenditure of resources and agility in administrative, economic and social processes in public management and in the private sector.

Countries such as Germany and Switzerland already have institutional arrangements that allow approaches to territorial management at the national level. In Germany, the Federal Constitution assigns responsibility for the registration of real estate to the Federal Republic, while states create laws regarding the territorial cadastre (BENNETT et al., 2012). Interstate bodies are used to ensure that these cadastres have a standard and are uniform (HAWERK, 2001). Thus, Germany has a national database for cadastral maps and records.

In Switzerland, the constitutional authority for the cadastre lies between the federal and cantonal levels (STEUDLER; WILLIAMSON, 2005). The federal government is responsible for the strategic management of the territorial system and supervises the cadastral activities of cantonal bodies (Switzerland, 2017).

For cadastral systems to fulfil their function, an institutional structure is required at the national level. Other authors, such as Bennett et al. (2012), Bogaerts et al. (2002), Coleman and Nebert (1998), Dale and Mclaughlin (1999), Enemark; Williamson; Wallace (2005), NRC (1983), Roberge and Kjellson (2009), Silva et al. (2021) UN-FIG (1999) and Williamson (2001), also report the importance of a cadastral structure with national scope. It is clear that a national infrastructure of land information would optimize the processes of registration, monitoring and compliance, and the codification of land parcels with national coverage contributes to this integration.

There are already federal government initiatives to improve territorial management, with emphasis on the National System for the Management of Territorial Information (SINTER), established by Decree No. 8,764 of May 10, 2016. SINTER plans, based on spatial database, to become a public management tool responsible for integrating the flow of data produced by the fiscal, cadastral and geospatial public registry services of all federative entities. Decree No. 8,764 of 2016 presents the structuring for the operation of the planned database, and on June 24, 2021, the Federal Revenue Service of Brazil (RFB) published Normative Instruction (IN) no. 2,030, which established the Brazilian Real Estate Cadastre (CIB). Art. 4 of the IN giving the coding form adopted, stating that the CIB code will consist of seven alphanumeric characters and a check digit, with the structure "AAAAAAA-D". Recently, on September 26, 2022, Decree 11,208 ratified the structure of the verification code.

The solution employed is more practical than that adopted by SIGEF for rural properties (with a 32-character identifier). However, this format has no meaning, as it does not comply with the reference criteria for location, simplicity, economy and accessibility (adopted internationally), and municipalities do not have control over its creation and/or alteration. In Decree no. 11,208, there is no instruction on how this code will

be managed and maintained by the municipalities, creating a gap in the rhythm of updating the urban cadastre and not ensuring municipal autonomy.

The identifier does not need to be cryptographic and understood only by experts. According to Dale and McLaughlin (1988), "it is important not to lose sight of the fact that the cadastral world is not limited to technicians with university specialization, because it transcends the limits of the institution to enter all branches and status of public administration and citizens".

Given the relevance of the subject and the importance of the subject, this study presents a method for the composition of a unique identifier code for the entire national territory, with the ability to integrate at the municipal level and, especially, at the national level. The methodology adopted is based on a hybrid system of identification of urban parcels, resulting from the combination of a hierarchical coding system, given by the administrative division of Brazil, together with the historical reference of creation/alteration of the limits, and the absolute geolocation, using the centroid of the parcel, determined by the plano-rectangular coordinates in the STL, is used as a reference. Thus, there will be a link with the Brazilian Geodetic System (SGB) because the point of origin of the STL (X = 150,000.00 m and Y = 250,000.00 m) is established from the RRCM, and its definition is in accordance with ABNT NBR 13.133 (2021), ABNT NBR 14.166 (2022) and ABNT NBR 17.047 (2022), being able, therefore, to determine the geodetic coordinates of any point from its coordinates in the STL.

The identifier code established by this model promotes the implementation of the RRCM and the municipal STL (as recommended by ABNT NBR 13,133, of 2021, and ABNT NBR 14,166, of 2022), used in the urban cadastre, the preparation and updating of cadastral plans, monitoring and urban engineering works, maintaining georeferencing and using topographic procedures at the same time, becoming an efficient tool in optimizing processes and resources for the user and municipality, and monitoring urban territorial dynamics.

The proposal meets the desirable characteristics of the International Association of Valuation Officers (IAAO), Tax Commission of the State of Utah, United Nations Economic Commission for Africa (UNECA) and is in accordance with the standards of ABNT NBR 13.133 of 2021 and NBR 14,166 of 2022.

2 CONTEXTUALIZING THE TERRITORIAL UNIT: CHARACTERIZATION AND ORGANIZATION OF URBAN SPACE IN BRAZIL

The parcel is used mainly for land registration and planning purposes, being essential in the cadastral domain to provide information on land use and enable access to rights, duties and restrictions, in addition to being considered the central basis of administration and territorial management, becoming increasingly necessary in the management of spatial information.

In the study conducted by the National Research Council (NRC), entitled Need for a Multipurpose Cadastre (NRC, 1980), the importance of parcel data within a LIS to support the decision-making necessary for effective territorial management was demonstrated. The study acknowledged that territorial parcel data can only be developed and maintained at the local government level but that the federal government should promote the integration of this local dataset through consolidated standards, funding programs and coordination with each state. Even after 40 years, these statements are valid to the present day.

Thus, according to the International Federation of Geometricians (FIG), for the organization of the territory and better management, the cadastre is of fundamental importance, being set up based on the survey of the limits of the existing parcels, that is, formed by parcels (FIG, 1995).

Ministerial Ordinance No. 3242 (Brasil, 2022) is the main document that governs the (CTM) Multipurpose Territorial Cadastre (CTM) in Brazilian municipalities. In its arts. 1, 4 and 7, the concept of parcel, multipurpose and the minimum elements for the urban cadastre are presented:

> Art. 1 Multipurpose Territorial Cadastre (CTM) consists of territorial cadastre data associated with thematic cadastre data. § 1 The cadastre is the official and systematic inventory of the parcels of the municipality. Art. 4th The parcel is the representation of a territorial portion of continuous extension. The elements of the parcel are I - the coordinates of the boundary vertices linked to the Brazilian

> geodetic system; II - the unique, unambiguous and stable identification code; III - the individual and collective rights that give rise to it; and IV - the identifiers that enable the relationship with the thematic records. Art. 7th The representation and characterization of parcels and territorial objects are cadastral data. § 1. Regarding the parcels, the registration data correspond to the boundary vertices, which define the positional identification, the polygon geometry and the alphanumeric attributes [...] (BRASIL, 2022).

Brazil developed legislation and guidelines related to registration and cadastre issues; however, it did not define the characteristics that met the principle of specialty[1], which requires the exclusive and exact definition of the parcel to be registered. The descriptions of the parcels have always been precarious, creating insecure rights and preventing the public administration from having overall knowledge of the territory that needs to be managed, resulting in weak land tenure governance, considering international standards (BUENO; REYDON, 2017).

ABNT NBR 17,047 (2022), which defines the procedures for the territorial cadastral survey for public registration in cases of land subdivision, adverse possession and registration rectification, started to establish the link to the Brazilian Geodetic System (SGB). The previous standard (ABNT NBR 14.645-2) that regulated the subject did not establish that the coordinates of the parcel vertices were linked to the SGB. ABNT NBR 17.047 (2022) also establishes the shapes and dimensions of urban parcels, as well as their borders, and only in this way will it be possible to comply with the principle of specialty, giving greater legal certainty to the documents that express their identification.

A geometrically defined parcel consists of a closed polygon that must be identified by its boundary vertices, with coordinates georeferenced to an official reference system, and must be adjacent to the other parcels so that they do not overlap or have gaps between them. Considered as a territorial portion of continuous extension, it needs to receive a unique identification code (which is not repeated), unambiguous (it does not raise doubts, i.e., the parcel is clearly defined) and stable (it must be permanent, or i.e., associated with the parcel in time, and if there is a change in the parcel boundaries, such as splitting up and re-memberment, a new code is assigned to it).

A group of parcels constitutes a zone, defining zoning and land use, in which only certain activities are allowed (a residential, commercial or industrial area) or where there are special restrictions of use (as in a conservation area). The parcel may have more than one use depending on the zoning, and one way to distinguish is to establish the use by the block face.

The cadastre will only be considered complete when there are no differences between the physical and legal ones; however, in Brazil, this does not occur. The land registry offices created a separate registry, seeking solutions to specialize registrations. The current descriptive memorials have coordinates that define the boundaries of the properties; however, the numbers that identify them - registration in the property registry and cadastral registration in the city hall -, in most cases, do not represent the same object (SILVA et al., 2021).

The parcel with its code should be the key for the identification of territorial rights and the administration of restrictions and responsibilities in the use of the land, integrating the LIS with the individual.

3 OVERVIEW OF THE UNIQUE IDENTIFIER OF THE URBAN TERRITORIAL PARCEL

In Brazil, it is difficult to properly identify and describe real estate properties and their rights on a national basis, as this information is presented in a dispersed manner in several databases with no common connection (for example, the data from the registry office differ from the cadastral database of the municipality,

[1] Principle of objective specialty - Every property subject to registration must be precisely described, in the manner required by law, the art. 176 of the Public Registry Law (Law No. 6015/1973) specifies the mandatory components in the individualization of properties. For urban properties: their characteristics and confrontations, location, area, street, registration number, if any (BRASIL, 1973).

which, in many cases, is different from the territorial physicist (the notary's data differ from the municipality's cadastral database and different from the territorial physicist)). This finding alone demonstrates the importance of creating an integrative cadastre system at the national level.

However, it is a plural country with a large territorial extension, which brings even more challenges. There are several records, but there is no database that includes all the parcels or data related to them; therefore, achieving this integration is an obstacle to be overcome. In addition, it is important to note that a cadastre without a standard and which is outdated can lead to wrong decisions or delay of appropriate actions to serve society, such as public land tenure regularization processes, which could benefit the population. Therefore, it is essential that the information management process access to be standardized, updated, with uniform data integrated into a single system, making it more popular (as simple as possible, to which multiple users can have access), useful (possibilities of), efficient (lower margin of error in territorial management) and less bureaucratic. The standardization of the identifier code brings greater security (it will provide the validation of cadastral information) for the integration of information at the territorial parcel (LOCH; ERBA, 2007).

Regarding standardization models, there are guidelines from the Utah (USA) *Tax Commission* (USA, 2002 and 2010) and the *International Association of Assessing Officers* (IAAO, 2015), with the proposal that the identifier code should meet a specific criteria, i.e., principles to become stable to historical changes in the management agencies and in the way of storing the information; however, in Brazil, it is often not possible to maintain them (PIMENTEL; PEREIRA; CARNEIRO, 2010).

3.1 Criteria for establishing an identification system

The parcel identifier code must be considered within the development plan of a cadastral system. There is a consensus of desirable characteristics for the parcel identifier (NRC, 1983; DALE and MCLAUGHLIN, 1988; NICHOLS, 1993; EUA, 2002; UNECA, 2007; IAAO; 2015), such as exclusivity, simplicity, flexibility, permanence, economy and accessibility. In addition to these, the *Utah Tax Commission* (USA, 2002 and 2010) adds another principle, the **reference for the location** of the parcel.

The requirement of a unique code for each parcel is the fundamental criterion and a necessary condition for the development and maintenance of any LIS. Simplicity suggests that the identifier is easily understandable and usable, reasonably flexible, capable of adapting to changes in the parcel, as a criterion for permanence, and that it does not change over time. The savings, in this case, are related to both the initial implementation costs and the ongoing operating costs of the cadastral system, and accessibility refers to the ease with which the code can be obtained. The reference for the location establishes the possibility of locating the parcel using its respective geocode.

3.2 Identifier systems

The identifier must be assigned to all instalments, whether taxable or not. It must recognize, select, identify, organize, retrieve and facilitate the storage of information about the parcel, in addition to being used to reference data and spatial information.

There are several classes or systems of parcel identification; however, in Brazil, they are based mainly on three systems: sequential, hierarchical and geolocation.

3.2.1 SEQUENTIAL SYSTEM

The sequential system is the simplest identification pattern. It is generated by algorithms and assigned to a record by a Database Management System (DBMS). The numbers can be assigned to any unit identified as a parcel. Because the value is assigned by the DBMS, no user intervention or input is needed. This can facilitate synchronous digital workflows, supporting a large number of users and large data flows.

However, despite its simplicity as an advantage, in places with dense territorial dynamics - the case of urban areas - this system is not considered efficient. In such a system, there is no indication of location, and it becomes impractical when the number of units and subdivisions of parcels registered in the cadastral database grows (PIMENTEL; PEREIRA; CARNEIRO, 2010; LOCH; ERBA, 2007).

3.2.2 HIERARCHICAL SYSTEM

The hierarchical system uses a main unit, following the administrative division of the jurisdiction (state, municipality or district), in which the parcel identifier follows a consecutive order of identification of the hierarchy of the macro unit with the smaller units.

Generally, the divisions are systematized into the existing subunits, such as administrative boundaries, district, sector, neighbourhood, block and lot, and an alphanumeric description may be used; however, it is commonly represented by a series of numbers, especially to facilitate data processing. This system is still used in some Brazilian municipalities because it is a legacy of the Incentive Agreement for the Technical-Administrative Improvement of Municipalities (CIATA), implemented in Brazil in 1977. In this case, the identification of the parcel is given by the administrative units of the municipality together with the numbering of this block.

The hierarchical system is more appropriate for coding in urban areas; however, its graphic base must be compatible with urban cartography (PIMENTEL; PEREIRA; CARNEIRO, 2010).

The disadvantage presented in this system is the duality in the identification of the parcel in terms of procedures of splitting or division (dismemberment or splitting). It does not include an element that individualizes it in a cadastral database when there is a change in the geometry of the parcel, ignoring the principle of flexibility and proving to be adequate for regions with urban planning rules that prohibit the division of parcels.

3.2.3 ABSOLUTE GEOLOCATION

The absolute geolocation system is based on the coordinates of a point of the territorial parcel, which is usually the centroid, calculated as the centroid of the polygon. Its coordinates define the parcel code as geocode. The value is usually based on the projection used for parcel mapping or is converted to a nonprojected coordinate system (e.g., geographic coordinates).

Automated routines are developed to generate the identifier code, ensure that the point is located within the parcel and collect the coordinate values. Another variation of the parcel identifier in geolocation is to merge coordinate values to generate the code (for example, NNNEEENNEENE). These values cannot be used directly for a location but are useful for creating a unique identifier.

4 THE MUNICIPAL REGISTRATION REFERENCE NETWORK AND THE LOCAL TOPOGRAPHIC SYSTEM

The RRCM is the basic support network at the municipal level for all services that are intended for projects, territorial and multipurpose cadastre or implementation and management of works. It consists of points with planialtimetric coordinates, materialized on the ground, referenced to a single origin (SGB) and to the same cartographic representation system, allowing the linking and incorporation of all topography and geodesy works in the preparation, maintenance and updating of municipal cadastral plans and the cartographic base, referencing the topographic services of demarcation, preliminary projects, projects, subdivision, implementation and monitoring of engineering works in general, urbanization, survey of works as built and providing support to the aerial survey services (ABNT, 2022).

The RRCM must be instituted by a specific municipal decree, which is recommended as a unique and mandatory spatial reference for all cartography, geodesy and topography works for the purposes of study, projects, implementation and monitoring of works and undertaking until the phase of survey of as *built*, performed by public or private bodies, entities and companies that make wide dissemination to provide data access to the most diverse users.

The process of initial structuring of the RRCM should be the responsibility of the municipality, including the determination of the STL, at a point of origin (preferably in the centre of the urban area), with known geodetic coordinates linked to the SGB.

However, the municipality does not always have its network fully implemented, and its densification can be an expensive process. Thus, it is essential that professionals working in measurement adopt the standards and criteria established by ABNT NBR 14,166, of 2022, and 13,133, of 2021, in addition to procedures and recommendations determined by the municipal administration (e.g., technical manuals containing methods of survey, standardized procedures, way of adjusting the network, among other relevant information on the structuring of the RRCM), to thus allow a future incorporation of the implemented references.

The implementation or densification can also be done during the municipality's cadastral surveys, if it is the subject of a contract in bidding, through specific contracting or even through agreements with public and private companies and universities, and the municipality must establish compliance with the aforementioned NBRs.

A successful example of an agreement is that of the municipality of Campinas, a pioneer in the state of São Paulo, by implementing the RRCM. In 1996, the Campinas Municipal Government (PMC), through its Planning Department, established an agreement with the Department of Transport Engineering of the Polytechnic School of the University of São Paulo (EPUSP-PTR) for support and technical guidance in which the objective was to implement the RRCM. At the time, it was composed of 12 pairs of vertices materialized by stable columns (COSTA, 2001).

In 2006, to densify this network and prepare the geoid map for the municipality, a new agreement was signed between the PMC, the Water Supply and Sewerage Society (SANASA) and the Department of Geotechnics and Transport of the Faculty of Civil Engineering, Architecture and Urbanism of the State University of Campinas (FEC-DGT/UNICAMP), resulting in the implementation of another 40 new landmarks, and later, in 2008, a new densification was carried out, in which another 120 landmarks were implanted.

Currently, the RRCM of Campinas-SP has approximately 174 marks. The geometry of this network allows intervisibility between two points, allowing conventional topographic surveys with the use of total stations.

The advantages of RRCM – conserved, structured and densified in a well-distributed manner – are the simplification of operations and reduction in production and maintenance costs of georeferenced information. It is an essential tool for the topographic and cadastral work carried out in the municipal territory and is an important means to support surveys.

5 PROPOSAL OF A UNIQUE NATIONAL IDENTIFIER FOR URBAN PARCEL BASED ON A HYBRID SYSTEM

In this section, we propose a single national identifier for the urban parcel, based on a hybrid identification system, resulting from the combination of hierarchical coding, historical reference and absolute geolocation, in addition to standardizing a unique identifier and, consequently, offering possibilities of national integration of the databases produced by different municipalities.

It is important to note that before the implementation of this proposal, the municipality must comply with the planning and implementation of the RRCM, as recommended by ABNT NBR 13,133, of 2021, and ABNT NBR 14,166, of 2022, establishing the origin of the PTL, linked to the SGB.

5.1 Structuring the unique identifier of the urban parcel

We propose a method for structuring the identifier of a parcel that meets the desirable criteria presented, being prepared in compliance with the standards of the Brazilian Association of Technical Standards, in particular NBR 14,166 of 2022, NBR 17,047 of 2022 and NBR 13,133, of 2021. Thus, a unique identifier code was created that ensures, in addition to identification at the national level, the precise geographical positioning of the parcel, being unequivocal, for the entire territory, its location and identification.

The identifier code in this proposal is composed of three elements. The first element (Table 1) refers to the administrative division of jurisdiction, in this case Brazil, which establishes the hierarchical relationship between the State and the Municipality. The second element (Table 2) is the historical reference, indicating by the date of creation or alteration of the parcel. The third element (Table 3) is the centroid of the parcel, established by the plane-rectangular coordinates, referenced to the origin of the STL of the municipality.

Table 4 presents the proposed format for the urban parcel identifier code, structured in the administrative division of the jurisdiction and the centroid. Each sub-element is separated by a “dot” character to facilitate its identification.

Table 1 - First element referring to the proposed code

First element								
Administrative division								
State			Municipality					
0	0	.	0	0	0	0	0	.

Source: The authors (2021).

Table 2 - Second element referring to the proposed code

Second element							
Historical reference							
Month			Year				
0	0	.	0	0	0	0	.

Source: The authors (2021).

Table 3 - Third element referring to the proposed code

Third element												
Instalment number												
Plano-rectangular coordinates (STL)												
0	0	0	0	0	0	.	0	0	0	0	0	0

Source: The authors (2021).

Table 4 - Proposed format for the urban parcel identifier code

First element									**Second element**								**Third element**													
Administrative division									Historical reference								Instalment number													
State			Municipality						Month			Year					Topographic coordinates – Centroid													
0	0	.	0	0	0	0	0	.	0	0	.	0	0	0	0	.	0	0	0	0	0	0	.	0	0	0	0	0	0

Source: The authors (2021).

5.1.1 FIRST ELEMENT - UNITS OF THE ADMINISTRATIVE DIVISION

The administrative division of Brazil, performed by the Brazilian Institute of Geography and Statistics (IBGE), is given by the sequence of numbers that follows the hierarchical order - from the macro unit (states) to a smaller unit (municipalities) - called geocode, exclusive to the entire national territory.

According to the IBGE (2020):

> The Table of Municipalities Codes, prepared by IBGE, presents the list of Brazilian municipalities associated with a code composed of 7 digits, the first two referring to the state code. This table, which reflects the organization of the territory, is used not only by IBGE to process information from its surveys and records but also by other institutions. It is systematically updated to include changes resulting from the splitting of municipalities and, consequently, from the creation of new municipalities, changes with the name of municipalities, as well as merger processes that result in the extinction or change of the name of some municipality.

The geocode of the municipality is composed of seven digits; the first two numbers identify the state of the political-administrative division, and the next five numbers identify the municipality. The format guarantees the uniqueness of the municipality's geocode at the national level; however, it does not cover the parcel individually.

5.1.2 SECOND ELEMENT - HISTORICAL REFERENCE

Philips (2010) recommends documenting the historical development of the parcel and, in cases of splitting and remembering, indicating the "mother parcel" from which the new parcels arose.

Thus, the structure of the second element is composed of the date of registration or change in the limits of the parcel – month and year of creation/change. Thus, the identifier code will consider the evolution of the territory over time and allow actions that change the boundaries of the parcel, such as splitting, dismemberment and re-memberment, without causing dual identifications.

5.1.3 THIRD ELEMENT - PLANO-RECTANGULAR COORDINATES OF THE STL OF THE CENTROID OF THE URBAN PARCEL

The structure of the third element is composed of the centroid given by the plano-rectangular coordinates of the STL (X and Y), which represents the geometric centre of the parcel in question. This parcel must be delimited by vertices determined by plane-regular topographic coordinates linked to the origin of the STL of the municipality defined by ABNT NBR 14.166 of 2022 and NBR 13,133 of 2021.

For a better understanding, we cite, as an example, a property in the city of Campinas, in which the parcel was vectorized on the orthophoto available on the PMC *website*, with the hatched area shown in Figure 1. The flat-rectangular coordinates of the STL of its vertices, the centroid and the geodetic coordinates of the STL origin are presented in Table 5.

The centroid of this parcel was obtained by averaging the coordinates of its vertices, resulting in X and Y values equal to 158,003.433 m and 255,203.953 m, respectively. It is suggested that the coordinates be used to the nearest whole metre, approximating the values according to the rounding rules.

Table 5 - Coordinates of the topographic centroid and the defining vertices of the parcel

	X (m)	Y (m)
1	157.993,466	255.184,895
2	158.022,600	255.194,556
3	158.013,380	255.222,932
4	157.984,286	255.213,434
Centroid	158.003,433	255.203,953
Origin of STL - SIRGAS2000		
φ_o = 22°54'02,09533" X_o = 150.000,000 m		
λ_o = 47°03'26,83597" Y_o = 250.000,000 m		
Ht= 700,000 m		

Source: The authors (2021).

Figure 1 - parcel located in the municipality of Campinas-SP

Source: The authors (2021).

5.1.4 FINAL REPRESENTATION OF THE URBAN PARCEL IDENTIFIER CODE

According to the administrative division defined by IBGE, the municipal code of Campinas-SP is 35.09502.

Considering that the (fictitious) registration date of this parcel was May 1980 and that its limits did not change over time, the second element will be represented by 05.1980. Therefore, the junction of the municipal geocode, the historical reference and the centroid of the parcel will be given by geocode 35.09502.05.1980.158003.255203, as presented in Table 5.

Table 5 - Representation of the identifier code of the urban parcel located in the municipality of Campinas-SP

First element								**Second element**							**Third element**												
Administrative division								Historical reference							Parcel ID												
State			Municipality					Month			Year				Topographic coordinates – Centroid												
3	5	.	0	9	5	0	2	.	0	5	.	1	9	8	0	.	1	5	8	0	0	3	.	2	5	5	2	0	3

Source: The authors (2021).

The proposed model makes the code objective and appropriate to follow the territorial dynamics and its historical development, with enough digits 3242, of 2022, as recommended by the Ministerial Decree No. of meeting the criteria of exclusivity, simplicity, flexibility, permanence, economy, accessibility and geographical reference.

Table 6 compares some characteristics of the conventional coding systems and the proposed hybrid system.

Table 6 - Presentation of the favourable and unfavourable aspects of the conventional coding systems and the proposed hybrid system

Type	Favourable aspects	Unfavourable aspects
Sequential	- Simple identification system. - Automatically generated by a system.	- It is not efficient for dense urban territorial dynamics - the number of units and subdivisions of parcels recorded in the cadastral database grows; - The generated number does not contain derivable information; - It does not transmit information about the geographical location or other characteristics of the parcel. -Disregard of a temporal element
Hierarchical	- Location of the parcel with knowledge of the municipal administrative network.	- Duality in the identification of the parcel in procedures of division or division. - No link with geographical position. - The reconfiguration of the municipal administrative network requires the creation and assignment of new codes. -Disregard of a temporal element.
Absolute geolocation	- Link with geographical position. - Automated routines can generate the identifier code	- Use of UTM coordinates located in different time zones will have the same codes. - Duality in the identification of the parcel in procedures of division or division. - Does not meet the singularity at the national level. -Disregard of a temporal element.
Proposed hybrid system	Efficient for urban territorial dynamics. Location information. - Located within the parcel and can be used as a point representation. Automated routines generate the identifier code. It achieves the integration of cadastral databases at the national level. - Does not allow replication to another parcel. - Meets internationally required criteria (indicated by the Utah Tax Commission and IAAO).	- Depending on the geometry of the figure, the centroid may lie outside the parcel (however, the para-centroid may be used, cases treated as exceptions).

Elaboration: The authors (2022).

Each parcel will have a unique identifier code at the national level, that is, a unique and irrefutable identification in the database. Its nomenclature will be permanent, but it will be easily updated in cases of unification, dismemberment or re-memberment, that is, in the face of geometric changes in shape and/or area. This is important because the new parcel generated must have the geocode independent of the original, as it will result in a new nomenclature for the different geocode in the Property Registry.

The fundamental characteristic of the proposed geocode is exclusivity, which is sufficient for national integration into cadastral databases. Uniqueness is essential in this nomenclature, so that there is no multiplicity

among the identifiers of the parcel, and may even meet what SINTER advocates of being a public management tool and integrating the various urban cadastres existing in the country.

The rectangular plane coordinates of the STL of the centroid of the parcel, associated with the municipal geocode and its historical reference, ensure the uniqueness of the code in the database at the national level.

Its **simplicity** makes it accurate and unlikely to be erroneously transcribed, in addition to being quite **flexible**, **economical** and **accessible** to serve any municipality, regardless of its development condition (computerized or not). For its generation and maintenance, there is no need for expensive equipment, paid software or cutting-edge technology, and this is directly linked to economy and adheres to simplicity.

The creation of an identifier code must not satisfy or be content only with the number of characters established but must pay attention to the established criteria so that it is permanent or until there are relevant changes in the municipal cadastral policy, for example, in the case of a merger or emancipation of municipalities.

5.2 Considerations and advantages regarding the adoption of STL

It is worth noting that the STL has been gradually implemented in Brazilian cities, such as the cities of São Paulo, Campinas, Salto, Charqueada, Hortolândia, Catanduva, Ribeirão Preto, and Votuporanga, located in the state of São Paulo, and Campo Grande, in Mato Grosso. Grosso do Sul (Agostinho, 2007). Blitzkow et al. (2007) also cite the cities of New York, Boston, Baltimore, Cincinnati, Rochester, Atlanta, Springfield, among others, in the United States, and Tokyo, in Japan. This occurs mainly due to the simplification of calculations in topographical applications. Although the geodetic coordinate system (which is linked to a reference ellipsoid) is highly accurate and universally accepted to define positions on the Earth's surface, the associated formulations are too complex when dealing with relatively small areas. The use of geodetic coordinates as an identifier code does not allow a quick and easy reading of the position of the centroid of the parcel because it is presented in hundreds of arcseconds, which can only be evaluated by a specialist in the field, not being visual in a cadastral plan.

The flat representation of the Earth's surface allows the use of elementary geometry and avoids the use of curvature corrections. That is, the curvature of the Earth is disregarded, and the points surveyed on the physical surface are projected orthogonally onto the PTL, which is tangent to the ellipsoid at its point of origin.

Thus, the STL is a facilitator (accessible to all engineers, architects, technicians and other users) of urban engineering (subdivisions, cadastre, surveys and topographic locations, in addition to the development of basic and executive projects) because it is a system of local terrestrial coordinates (defined by the Local Topographic Plan), and its accuracy is certainly compatible with all the aforementioned purposes, thus becoming an efficient tool in optimizing resources for users and municipalities.

The STL has a smaller spatial amplitude (Lima; Demetrio, 1997; Costa, 2001) than the UTM, RTM (*regional transverse Mercator*) and LTM (*local transverse Mercator*) projections but preserves a precise relationship with the geodetic coordinates because it has the origin of the georeferenced coordinate system, making it possible to calculate the geodetic coordinates of any local topographic coordinates. Thus, the difficult-to-solve cartographic problem, which is the transposition of time zones, is also avoided. It is also important to remember that the UTM System is intended for systematic cartography with a larger scale of 1:25,000.

Regarding the area covered by the STL, large urban areas or even informal urban centres[2] furthest away are hardly reached by the extension defined in NBR 13,133 of 2021.

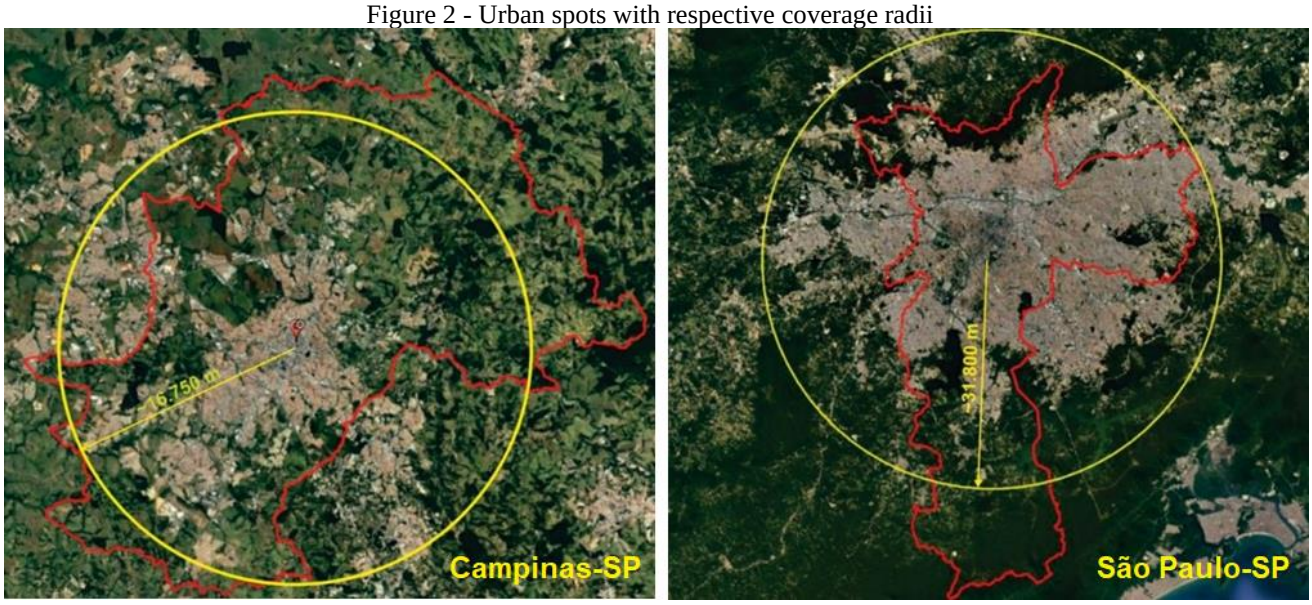
[2] Informal urban nucleus is "that clandestine, irregular or in which it was not possible to carry out, in any way, the titling of its occupants, even if the legislation in force at the time of its implementation or regularization was complied with" (BRASIL, 2017). Law No. 13,465, of 2017, art. 11, item II.

The radius of coverage of the municipalities that contain the ten largest urban centres in Brazil (São Paulo-SP, Rio de Janeiro-RJ, Brasília-DF, Goiania-GO, Curitiba-PR, Campinas-SP, Campo Grande-MS, Belo Horizonte -MG, Porto Alegre-RS, among others) does not exceed 35 km from the centre of the urban area.

In the municipality of São Paulo (the largest urbanized area in Brazil (IBGE, 2015)), for example, the urban area (Figure 2) has a radius of approximate coverage of 31.8 km. The urban area of Campinas-SP (9th municipality in the urbanized area in Brazil (IBGE, 2015)) has a radius of approximate coverage of 16.75 km, while its largest linear extension is approximately 40 km. The two mentioned municipalities have already implemented their respective STLs.

In cases such as the municipalities of Altamira-PA, Barcelos-AM, São Gabriel da Cachoeira and others, which have large territorial extensions but have relatively small radius of coverage of the urban area - approximately 12 km, 3 km, 7 km, respectively - it is possible to structure the RRCM, with the determination of the STL, only in urban areas, of urban extension and urbanizable for implantation of the identification code of the parcel using the presented methodology.

Figure 2 - Urban spots with respective coverage radii



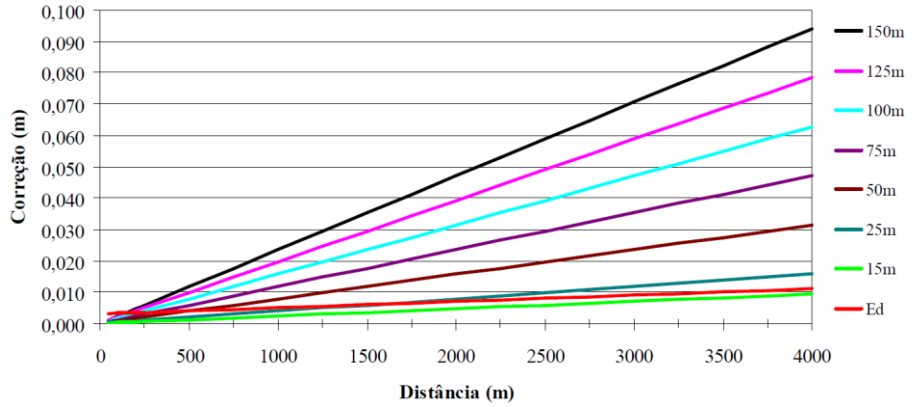
Source: Adapted from Google Earth (2021).

NBR 13,133 of 2021 states the need to establish the subdivision of the system into partial systems when, in relation to the LTP adopted, the differences in level are greater than ±150 m in the area to be represented. When establishing this limit, the error is maintained due to the reduction or expansion factor of the horizontal distances. The factor is due to the horizontal distances being reduced to the height of the PTL; however, one thing to note is that in Brazil, there are few places where these differences occur in urban areas. Agostinho (2007) shows that the correction relative to the altimetric reference is truly only necessary in works that demand a high degree of precision, such as in industrial locations and monitoring of structures. In this case, it is necessary to establish an arbitrary system, obtaining points by angular intersections with precision equipment in the order of 1" to 0.2".

The graph presented in Figure 3 represents the correction values that must be applied to the plane distances so that they become horizontal and vice versa, performed as a function of the difference in the altimetric reference. The line Ed (red), which represents the error of the measured distance, is the simplified form of the standard deviation of the distances measured by electronic distance metres, which are referenced to a high-precision electronic distance metre. Analysing the graph, at certain times, the distance correction value is lower than the measured distance error, thus generating uncertainty about the real need for distance correction in these cases. It is also noted that at distances less than 125 m, there is uncertainty about the use of

the correction because the possible error in the distance measurement is greater than the correction relative to the altimetric reference (AGOSTINHO, 2007).

Figure 3 - Distance x correction as a function of the altimetric difference for the PTL



Source: Agostinho (2007).

If it is necessary to avoid the influence of the level difference, the coordinates can be obtained in the PTL by applying the Rotation and Translation Matrix. In this method, as three-dimensional coordinates are used, there is no influence of the level difference; that is, the enlargement or reduction factor is eliminated, and the PTL can be adopted at any time (MORAES JUNIOR; SILVA, 2017; DAL'FORNO et al., 2010).

In Brazil, cadastral systems that employ absolute geolocation usually use the *Universal Transverse Mercator* (UTM) projection system. Absolute geolocation is one of the most accurate ways to establish the identifier; however, there is a disadvantage when using UTM coordinates in the integration of cadastral databases at the national level. For example, because the UTM zone does not inform the centroid coordinates in the code, there is a great possibility that parcels located in different UTM zones have the same codes, precisely failing the exclusivity criterion.

Although the UTM projection is one of the most used projection systems in cartography (suitable for medium to small scales) and has the property of conformity (angles without deformation), it has distortions in the measurements of areas and distances (as a function of K). which makes it incompatible with urban engineering works.

Often, professionals (technicians, engineers and architects) who work in engineering works disregard or even are unaware of technical aspects of the cartographic database they use, especially with regard to coordinate systems for the preparation and implementation of projects.

6 FINAL CONSIDERATIONS

Oliveira (2010) emphasizes that the unique identifier code of the parcel should be the component that incorporates the municipal administrative sectors into the other public or private concessionaires, in addition to ensuring the connection with government agencies at the state and federal levels.

The use of a territorial cadastral system should not be considered only to maintain information on the parcels for tax management but also used in the process of territorial evaluation and planning. For this to be possible, the territorial parcels need to be linked to data that refer to this information, and in this case, the main interconnection between them and their tabular data is the identifier code. An identifier must use a number/code rather than a full legal description to uniquely identify a parcel in a cadastral database. This means that each parcel needs to be identified by a unique and exclusive code that relates a given cadastral layer with files containing data such as ownership, market value, zoning and others. The identifier, in addition to providing a common index for all property records, will help track changes in legal descriptions in a rigorous and more manageable manner.

Among the criteria to be considered to establish an identification system for territorial parcels, the main ones are exclusivity, permanence and geographical location. The proposed method meets the determined criteria and is simple to apply since the established code is a geocode that is easily generated and managed in any GIS platform, including free *software*.

The hybrid system proposed is a hierarchy interrelated with the historical reference and a location identification system based on plane-rectangular coordinates of the STL and is easy to maintain, since the new codes are quickly assigned, choosing only the centroid of the territorial parcel. which guarantees the recommended criteria for a geocode in the database at the national level.

Another advantage can be pointed out when the parcels have a small extension and are very close or next to each other because if the geodetic coordinates are considered for the definition of the geocode, these could even be a coincident with the risk of corrupting the exclusivity criterion. This fact occurs because each identifier has to be unique for each parcel unit, which does not occur with the use of coordinates in the STL.

The choice of an identifier system should be a fundamental concern in the process of implementing an urban territorial cadastral system; however, it is recommended that attention should also be directed to its allocation, reallocation and subsequent control. The control of parcel identifiers is part of a process of managing changes in land tenure. If the configuration of the parcel is changed due to re-memberment and dismemberment, new identifiers will be assigned; however, even so, the original parcel must remain a historical entity, and its records will be kept in the old identifier code.

In exceptional situations, the centroid may be outside the parcel if it is very irregular. If this actually occurs, the technician responsible for the registration will make the necessary adjustments; for example, define the “para-centroid” (point that is guaranteed to be inside the polygon) of the parcel.

It is recommended that, for this methodology to be developed to meet a territorial management system at the municipal, state and national levels, the RRCM be implemented in all Brazilian municipalities and the STL be established in accordance with ABNT NBR 14.166 of 2022.

In addition, it is essential that the model undergoes a validation process so that it contributes to issues such as fit and overfit, where it can be refined to deal with future data - this will guide the taking of preventive and/or corrective measures.

The geocoding proposed as one of the instruments of the CTM eliminates overlapping parcels, allowing their immediate location at the national level in an unequivocal way, providing the control and governance of the territory by all agencies of the public administration and the private sector, whether this is taking place in the social, or economic field.

This proposal is not at odds with Decree No. 11,208 (2022), and the codification of the said decree may be incorporated as a complement for tax purposes.

Authors' contribution

The author D.V.S. was responsible for Conceptualization, Methodology, Visualization, Writing (initial draft, revision and editing). The authors D.C.C. and J.R. were responsible for Conceptualization, Methodology, Visualization, Writing (revision and editing). The authors J.L.A.T. and H.C.O were responsible for the Writing (revision and editing).

Conflict of interest

The authors declare no conflict of interest.

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