



# ANALYSIS OF THE MAIN BRAZILIAN STANDARDS FOR AUDIT OF GEOSPATIAL DATA

## Applications to practical cases

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**ABSTRACT**

As geoinformation becomes increasingly digitized and government involvement in producing geospatial data declines, the responsibility for generating maps and geographic information systems shifts largely to private-sector providers under contractual arrangements. This shift creates significant challenges for oversight bodies. The primary goal of this article is to examine the main Brazilian quality-control standards governing the acquisition and release of geospatial data and to extract objective criteria that can support contract oversight and the use of geoinformation in public-sector management. A secondary goal is to present practical applications of these standards and provide guidance to auditors and inspectors through experiments that public officials can readily replicate. The study follows a documentary, applied methodology



with an explanatory purpose and a qualitative approach. The findings reveal substantial variation in the quality and suitability of geospatial products procured by public entities and underscore the need for strict adherence to the standards to improve the quality of geospatial data used in decision-making, contract development, and oversight of specialized services that produce and disseminate geoinformation. Accordingly, the article's contribution is aimed not at technical specialists but primarily at public officials and managers engaged in oversight and audit activities.

**Keywords:** geospatial data; digital cartography, satellite imagery; geographic information, oversight; public administration auditing.

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## 1 INTRODUCTION

Historically, the production of geospatial data in Brazil was carried out largely by institutions such as the Brazilian Institute of Geography and Statistics (IBGE), the Geographic Service Directorate of the Brazilian Army (DSG), the National Institute for Colonization and Agrarian Reform (Incra), and the Northeast Development Superintendency (Sudene). Although the source data—mostly photogrammetric and geodetic—were collected by surveying companies contracted through public procurement, much of the data processing and generation of derivative products was conducted within the public institution itself, following its own production workflows and quality-control procedures.

In recent decades, however, geospatial production in Brazil has undergone significant expansion, driven by the growing number of private companies that produce, manage, and distribute geospatial information. This transformation takes place not only through government contracts but also as a response to the private sector's increasing demand for geographic intelligence. Several factors help explain this shift, including:

- Public Administration reform, especially after Constitutional Amendment No. 19 of June 4, 1998, which aimed to streamline state management, define State-exclusive functions, establish boundaries between direct and indirect administration, and foster partnerships between the public and private sectors. As a result, the production of thematic geographic information became increasingly outsourced by government agencies, with public servants responsible for contract oversight and monitoring. This shift also affected the production of foundational geographic data. With a reduced state structure, public servants now often oversee the processing of geospatial data, the development of new methodologies, and scientific research;
- The creation of the Ministry of Cities (MCID) and the resulting promotion of the Multipurpose Territorial Cadastre (CTM) as a nationwide public policy for economic and social development (Loch; Erba, 2007, pp. 137-139). Every CTM requires a “physical cadastre,” which must be integrated with legal cadastre data (property registry information), economic cadastre data (such as assessed property values), and other thematic datasets (Amorim; Pelegrina; Julião, 2018). Incentives for georeferencing urban and rural properties led municipalities



and landowners to contract topographic, geodetic, and photogrammetric services on an increasingly large scale (Erba; Oliveira; Lima Jr., 2005). The decentralization of geospatial data production often means that small agencies lacking in-house technical staff must rely on external geoinformation providers (Erba; Piumetto, 2021);

- the creation of the National Territorial Information Management System (Sinter), designed to integrate Brazil's various real estate cadastres (Breves; Peres; Cruz, 2018). Structured as a modular cloud-based system, Sinter consolidates and distributes geospatial information on property throughout the country, integrating different CTMs and enabling expanded data production, exchange, and processing;
- the implementation of the National Geospatial Data Infrastructure (INDE), established as a public policy by Presidential Decree No. 6.666 of November 27, 2008. INDE organizes and distributes integrated geospatial datasets across Brazil. The system facilitates access to cartographic, geodetic, and geospatial information, promoting interoperability across public institutions (Brazil, 2010, p. 89). INDE focuses on the standardization, storage, and collection of geospatial data (Brazil, 2010);
- advances in digital cartography and geographic information systems, particularly in web-based geoservices (Longley; Goodchild; Maguire; Rhind, 2015, p. 233), which allow visualization and analysis of geospatial datasets, thematic maps, aerial and satellite imagery mosaics, and drone imagery. These digital transformations—enabled increasingly by free and open-source software and international interoperability standards defined by the Open Geospatial Consortium (OGC) (2024)—have expanded the adoption of geotechnologies across government entities, albeit sometimes with redundancies and overlapping responsibilities.

These developments summarize the major shifts in geospatial data production over the past two decades. With public policies promoting the democratization of geoinformation, new technologies, and the proliferation of open standards, geospatial data is now produced in diverse contexts and under numerous contracts with the public sector.

This widespread proliferation, however, presents major challenges to public officials involved in contract oversight, and government auditing Geoinformation production and analysis contracts—especially those involving the production of foundational cartography such as photogrammetric restitution or customized geospatial database integration for the review and analysis by government bodies—can be costly. And although geoinformation tools are increasingly used for decision-making in oversight, as stated by Coelho and Fornelos (2012), as well as Ferraz et al. (2015), their use still tends to be restricted to specialized audit units (Mbura; Siriba; Karanja, 2023; Intosai, 2013), without broad adoption across oversight bodies.

Poor oversight or inadequate control of geospatial production workflows brings substantial risks: substandard products, restricted sharing of intermediate and final datasets, and lack of interoperability, conditioning the use and the analysis of the acquired geoinformation to specific software solutions and implementations developed by contractors, which can lock public institutions into vendor-dependent technological ecosystems. As a result, public



managers responsible for oversight, auditing, contract monitoring, and the implementation of public policies involving geoinformation in its many forms face substantial challenges.

Given these challenges, this article aims primarily to analyze the key standards governing the acquisition and dissemination of geospatial data, extracting objective criteria for use in contract oversight and in the application of geoinformation in public administration. As a secondary aim, the article presents examples of feasible, relatively simple procedures that public managers can apply in monitoring and auditing activities.

## 2 LITERATURE REVIEW

The standards governing geospatial data quality play a critical role in standardizing and evaluating the quality of the production and dissemination of geospatial information. Each standard provides guidance and structure for cartographic and related activities, supporting efficiency and consistency at the national level.

For many years, the main procedures for handling geoinformation were set out in manuals produced primarily by DSG and IBGE. Other institutions, including branches of the Armed Forces, maintained their own internal procedures.

The creation of the National Cartography Commission (Concar) fostered integration among different government entities, establishing clear responsibilities—particularly the harmonization of standards for the production, dissemination, and sharing of geospatial data (Brazil, 1997). During the 2000s, Concar meetings refined technical specifications that were later formalized, improved, and published on the Brazilian Army's Geoportal (Brazil, 2024). DSG is responsible for developing national cartographic standards at scales of 1:250,000 and larger, while IBGE is responsible for geodetic reference systems and cartography at scales larger than 1:250,000 (Brazil, 1967). DSG consolidates the standards developed by Concar and updates them based on advances in geospatial information.

Below, we summarize the main standards currently in force and highlight the aspects most relevant to public officials who oversee or audit geoinformation contracts. All Concar standards relating to geospatial data quality—binding nationwide—are included in this overview. They are: Technical Specification for the Acquisition of Vector Geospatial Data (ET-ADGV) (Brazil, 2018); Technical Specification for the Structuring of Vector Geospatial Data (ET-EDGV) (Brazil, 2017); Technical Specification for Geospatial Data Quality Control (ET-CQDG) (Brazil, 2016a); Technical Specification for Geospatial Dataset Products (ET-PCDG) (Brazil, 2016b); and a transitional standard pending replacement by the Technical Manual of Cartographic Conventions T34-700 (Brazil, 2002). Added to these standards is a broad set of directives and procedures adopted by federal entities, which fall outside the scope of this article.

### 2.1 Technical Specification for the Acquisition of Vector Geospatial Data



This standard establishes guidelines for the acquisition of vector geospatial data according to ET-EDGV's object classes definitions. ET-ADGV covers geometry and essential attributes required for identifying features.

Its adoption became necessary with the expansion of GIS and digital cartography, especially in the context of Geographic Information Systems (SIGs), as the need arose to standardize rules for acquiring geometry and related feature attributes. This is intended to ensure the standardization and guidance of the acquisition process for different types of vector geospatial data. Such harmonization covers all data-acquisition methods, including field surveys, aerial photography, and satellite-sensor imagery, given the similarities among them.

The standard addresses essential topics by providing parameters for vector acquisition and for the composition of complex objects. It also sets rules for land-cover classification and defines vector features. These guidelines aim to ensure consistency and effectiveness in the acquisition of vector geospatial data, contributing to interoperability and data quality. The first widely released version was ET-ADGV 2010 v. 2.1.3, developed in parallel with ET-EDGV 2010 v. 2.1.3. Since then, ET-ADGV has been continuously updated and is currently at version 3.0, released in 2018 (Brazil, 2024).

### 2.1.1 Feature-acquisition criteria

Below are some criteria of particular relevance for the acquisition of geospatial data.

- **Scale** - regarding the scale used, the standard establishes which features must be acquired. To determine whether a feature can be represented at the acquisition scale, a rule-of-three calculation is performed to verify whether it meets the topology-radius threshold of 0.04 mm at that scale, as defined in ET-CQDG (Brazil, 2016a). For example, a culvert with a diameter of 45 cm (450 mm) must be represented at the 1:2,000 scale, since  $450/2000 = 0.225$  mm. However, this calculation does not need to be carried out for each instance when defining the features to be acquired. Table 1 summarizes examples of features—by code and class according to ET-EDGV—the scales at which each class must be acquired, and the geometry type to be used at each scale (point, line, or polygon), based on the threshold values listed in the table in mm or mm<sup>2</sup> (for area features). For instance, a dam must always be represented at all scales using its boundary, provided that its area at map scale exceeds 12.5 mm<sup>2</sup>. If the area is smaller but its longest dimension exceeds 0.8 mm (at map scale), it must be represented as a line. In all other cases, it should be represented as a point, associated with the appropriate cell or identification symbol.

**Table 1 – Examples of features and their possible representations**



Code	Class	Scale	Area	Line	Point
1.1.9	Hydroelectric Plant	All	1	1	X
1.1.11	Thermoelectric Plant	All	1	-	X
1.1.13	Power Transmission Tower	1:1 to 1:25,000	-	-	X
1.2.2	Mineral Extraction	All	25	-	X
1.3.1	Wetland	All	25	-	-
1.3.3	Dam	All	12,5	0,8	X
1.3.9	Water Source	1:1 to 1:100,000	-	-	X
1.4.14	Municipality	All	ND*	-	-
1.4.18	Indigenous Land	All	ND*	-	-
1.4.20	Protected Area	All	ND*	-	-
1.6.3	Landfill	All	4	2	X
1.6.4	Cut Slope	All	4	2	X
1.6.6	Contour Line	All	-	ND*	-
1.8.12	Brigde	All	12,5	0,8	X
1.8.16	Tunnel	All	12,5	0,8	X
2.4.3	Structure	1:1 to 1:100,000	1	-	X
2.5.1	Access Road	1:1 to 1:25,000	12,5	5	X
2.5.2	Bike Lane	1:1 to 1:50,000	-	10	-

Source: ET-ADGV (Brazil, 2018).

- Acquisition level - to ensure consistent adoption of the standard regardless of the acquisition level, objects are collected according to each project’s specifications. Three acquisition levels are defined: *i)* basic — a preliminary cartographic product in which only the geometry and the “approximate geometry” attribute are collected; *ii)* standard — a cartographic product in which all mandatory attributes are collected, as required by the standard; and



*iii*) customized — a cartographic product in which optional attribute sets of interest to the specific project are collected.

- Land cover - the surface to be mapped must have its polygon topology validated and be fully covered, meaning no mapping gaps. These classes represent “land cover,” encompassing natural and artificial elements on the Earth’s surface, and follow the classification defined in the Technical Manual for Land Use (MTUT), published by IBGE (Brazil, 2006). The categories include built-up areas, cultivated vegetation, natural vegetation, exposed soil, and water bodies.

### 2.1.2 Acquisition of features attributes

To properly acquire geometries and classify them correctly, the operator must understand the data model (EDGV) and the acquisition rules (ADGV). The acquisition guidance for each object type is presented in tables that outline the main aspects of attribute creation, as detailed below.

- Class - feature classification according to the EDGV standard.
- Code - code assigned according to the EDGV standard.
- Geometry - possible geometric primitives, which may be defined as area (□), line (—), point (★), or complex (C) (assembled object).
- Method - description of acquisition rules, including: brief definition — introduction of the class; rules — collection rules; mandatory attributes — must be collected under the standard or when relevant in specific specializations; relationships — possible relationships relevant to object assembly (optional); specific case no. x — acquisition of a specific class, possibly with additional rows.
- Illustration - each descriptor may include one or more figures illustrating the acquisition process for the feature class.

Inconsistencies in descriptive attributes must be avoided when populating the data, as incompatible values can affect the accuracy of the final product.

Additionally, rules must be followed when naming attributes, because most formats in which geospatial data are distributed — such as the Shapefile format (ESRI) — do not allow complex representations or special characters and restrict names to ten characters.

Figure 1 presents an example of feature acquisition for a densely built-up area. Throughout the manual, examples are provided for every feature defined in the standard, making the work highly logical, though sometimes demanding.



**Figure 1 – Examples of features and their possible representations**

Class	Code	Geometry
Densely_Built-Up_Area	1.4.5	□
Method	Illustration	
<p>Area where the proximity of structures prevents their individual representation, allowing only the outline of the built-up area as a whole.</p> <p><b>Rules:</b></p> <p>1) Area-type geometric primitive as defined in Table 1;</p> <p>2) This class typically occurs at small scales.</p> <p><b>Mandatory attributes:</b></p> <p>approximateGeometry = T   F.</p>		

Source: ET-ADGV (Brazil, 2018).

## 2.2 Technical Specification for Structuring Vector Geospatial Data

ET-EDGV plays a crucial role within the context of Systematic Terrestrial Mapping, which is part of the National Cartographic System (SCN)—a standard incorporated into INDE.

Its main purpose is to establish a framework that organizes, simplifies, and promotes interoperability among vector geospatial data structures in Brazil. The goal is to enable efficient sharing of official information, particularly that used in the development of maps at scales of 1:1,000 and smaller. This ensures cohesive integration of such data into a unified spatial database.



It is a technical specification intended for GIS producers, developers, and programmers, as well as end users of geospatial data. It is also aimed at agencies and institutions involved in producing, maintaining, and using cartographic data, promoting standardization and interoperability of this information. Professionals involved in the conceptual and logical modeling of vector geospatial data also benefit from this specification. Its development occurred in parallel with ET-ADGV, and the two specifications complement each other. The essential point is that geographic information, once acquired, must already be structured according to the established interoperability standards.

### 2.2.1 Key characteristics

The characteristics of ET-EDGV that ensure quality, accuracy, consistency, and portability of vector geospatial data—and that facilitate compatibility and information sharing among public and private entities involved in producing and using these data—are listed below.

- Standardization - seeks to unify official vector geospatial data structures, particularly at scales of 1:1,000 and smaller.
- Object-oriented modeling - uses object-oriented techniques, incorporating concepts from UML 2.4.1 and OMT-G
- Interoperability and data sharing - facilitates the exchange of reference data, promoting interoperability and resource optimization.
- Updating and information aggregation - enables the efficient incorporation of new information and updates into the cartographic database.
- Adoption of international standards - increases alignment with OGC data-exchange standards.

### 2.2.2 Quality parameters

ET-EDGV defines key parameters for vector geospatial data to ensure consistency, relevance, and accuracy of cartographic information at scales of 1:1,000 and smaller. The main parameters are listed below.

- Topological consistency - ensured through attention to specific aspects of data acquisition and adherence to fundamental topological characteristics during data production.
- Updating and quality maintenance - enabled by the ability to incorporate new information and update geospatial data over time.



- File portability - guaranteed to allow use in different environments and geographic information systems.
- Metadata documentation - required under INDE specifications to ensure interoperability and data reuse.
- Standardized symbology - defined by a uniform set of symbols representing each category of geospatial features, ensuring visual consistency.
- Data accuracy - achieved through requirements established to ensure the precision of cartographic representations at scales of 1:1,000 and smaller.

### 2.3 Technical Specification for Quality Control of Geospatial Data

The primary purpose of ET-CQDG is to provide a standardized approach for assessing the quality of products that make up geospatial datasets integrated into Brazil's National Cartographic System (SCN). Standardization enables comparisons among evaluated datasets by relying on a common framework. In addition to this primary objective, the specification pursues the following secondary objectives:

- to establish definitions related to the quality assessment of geospatial products;
- to describe the measures used in quality assessment;
- to detail the procedures applied in the evaluation process;
- to define guidelines for quality reporting; and
- to present conformity parameters applicable to reference products in the Brazilian context.

Quality may be understood as compliance with a specification. At present, it is intrinsically associated with a product's or service's ability to meet user needs (Servigne; Lesage; Libourel, 2006). Even with the reduction in costs associated with the collection and processing of geographic information resulting from new technologies, assessing the quality of geographic data remains essential to enable the integration of collected information.

Broadly speaking, information about data can be classified as follows:

- non-quantitative quality information - refers to general information that is highly relevant for understanding the purpose and history of the data, as well as for supporting potential uses beyond those originally intended; and



- quantitative quality information - relates to measurable properties of geographic information (GI). These are detailed through quality elements, known as components of geospatial data quality.

### 2.3.1 Key concepts addressed

ET-CQDG establishes five main quality-control parameters: completeness, logical consistency, positional accuracy, temporal accuracy, and thematic accuracy.

Completeness of geographic information refers to the presence or absence of features and is linked to alignment with the data model (ET-EDGV) and the data acquisition specification (ET-ADGV). Data quality may be compromised by excess—when unnecessary features are present—or by omission—when required features are missing. The procedures for analyzing each type are outlined below.

- In excess analysis, the number of objects present in the sample ( $n_1$ ) that have no corresponding feature in the reference sample (size  $n$ ) is counted. The result is expressed as the ratio  $n_1/n$ , reported as a percentage from 0 to 100% (Brazil, 2016).
- In omission analysis, a similar procedure is applied, counting the number of missing objects in the sample and calculating the corresponding percentage of omissions.

As an example, consider photogrammetric restitution or vectorization over orthophotos performed to identify swimming pools for taxation purposes. An excess error occurs when non-existent pools are included in the dataset. An omission error occurs when existing pools are not recorded. In both cases, the geographic information base must accurately reflect reality; otherwise, the municipality may overtax some taxpayers (excess) or forego revenue (omission).

Logical consistency concerns compliance with logical rules governing data structure, attributes, and relationships, considering conceptual, physical, and logical aspects. The corresponding categories are described below.

- Conceptual consistency assesses the compatibility between the delivered product and its original requirements. For example, in an orthophoto mosaic, a certain spatial resolution and number of spectral bands are expected. Conceptual consistency is lacking when these minimum parameters are not met.
- Domain consistency identifies unfilled non-geospatial attributes by calculating the proportion of attributes left blank. Based on the structure defined in ET-EDGV, data acquisition (as modeled by ET-ADGV) must include attribute population for each feature. In quality control (ET-CQDG), the objective is to verify whether the rules set



forth in the two preceding standards have been followed or whether fields were created correctly but left unfilled, resulting in domain inconsistency.

- Format consistency evaluates the compatibility between the delivered product and the format defined by the standard. For example, digital map production at standard scales requires a model sheet containing specific legends, marginal information, and coordinate grids. In this case, format consistency assesses whether the delivered product adheres to the model sheet.
- Topological consistency evaluates topology rules in vector products, such as closed polygons—where the starting point coincides with the ending point; contiguity of adjacent polygons—without overlaps or gaps; and proper node creation in linear features. Examples of topological inconsistencies include contour lines of different elevations intersecting each other, adjacent parcels with overlaps or gaps, and road centerlines crossing without a defined node.

Positional accuracy assesses the quality of the geographic position of geospatial coordinates and is classified into three categories: *i)* absolute — discrepancy relative to more accurate reference sources; *ii)* relative — not addressed by ET-CQDG; and *iii)* grid-based — applied to regular grids. This is one of the oldest quality metrics, originating from the Cartographic Accuracy Standard (PEC), developed in the 1980s as a tool for evaluating cartographic data quality (Brazil, 1984). In its current version, the Positional Accuracy Standard for Digital Cartographic Products (PAP-PCD) is measured as follows:

- 1) Selecionar pontos de controle com precisão pelo menos três vezes superior ao produto que será avaliado. Os pontos devem ser perfeitamente identificados no terreno e no produto. O tamanho da amostra é determinado pelo processo de avaliação.
- 2) Calcular o erro em cada componente planimétrica para o universo de pontos considerados. Os pontos do produto que serão testados são identificados pelo sufixo “t” e os pontos de referência (controle) são identificados pelo sufixo “r”.
- 3) Calcular a componente horizontal dos erros para cada ponto “i” da amostra. [...]
- 4) Calcular o erro médio quadrático (EMQH) dos erros da amostra. [...]
- 5) Comparar cada valor de eHi com o erro máximo admissível (EM) da tabela PEC para cada classe. O produto se enquadra onde tiver pelo menos 90% de pontos com erro inferior ao EM. Se nenhum valor for correspondente, o resultado será “não conforme” e encerra-se a medida.
- 6) Comparar o valor de EMQH com o erro-padrão da tabela PEC para a classe identificada no passo 5. Se for menor, o resultado é a classe



encontrada no passo 5. Se for maior, caminha-se na tabela PEC até encontrar um valor menor ou, caso não seja encontrado, a medida resulta “não conforme” (Brazil, 2016a).

It is therefore a statistical procedure designed to assess data quality at the coordinate level, allowing classification according to expected precision and accuracy. Table 2 presents a reference example with expected maximum allowable error and standard error values.

**Table 2 – Allowable error thresholds for large-scale mapping**

Tipo	PEC	1:1.000		1:2.000		1:5.000		1:10.000	
		EM	EP	EM	EP	EM	EP	EM	EP
Planimetria	A	0,28	0,17	0,56	0,34	1,40	0,85	2,80	1,70
	B	0,50	0,30	1,00	0,60	2,50	1,50	5,00	3,00
	C	0,80	0,50	1,60	1,00	4,00	2,50	8,00	5,00
	D	1,00	0,60	2,00	1,20	5,00	3,00	10,00	6,00
Altimetria	A	0,27	0,17	0,27	0,17	0,54	0,34	1,35	0,84
	B	0,50	0,33	0,50	0,33	1,00	0,67	2,50	1,67
	C	0,60	0,40	0,60	0,40	1,20	0,80	3,00	2,00
	D	0,75	0,50	0,75	0,50	1,50	1,00	3,75	2,50

Source: ET-CQDG (Brazil, 2016a).

### 2.3.2 Sampling criteria

Sample sizing in the inspection of a geospatial product must take into account several criteria, including the number of items (features) and their spatial distribution. CQDG establishes that combining criteria increases sample representativeness. The procedure adopted by CQDG follows the sampling plans defined in ISO standards 2859-1 and 2859-2 and incorporates a cell-based item selection approach, which consists of subdividing the product’s geographic space.

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## 2.4 Technical Specification for Geospatial Dataset Products

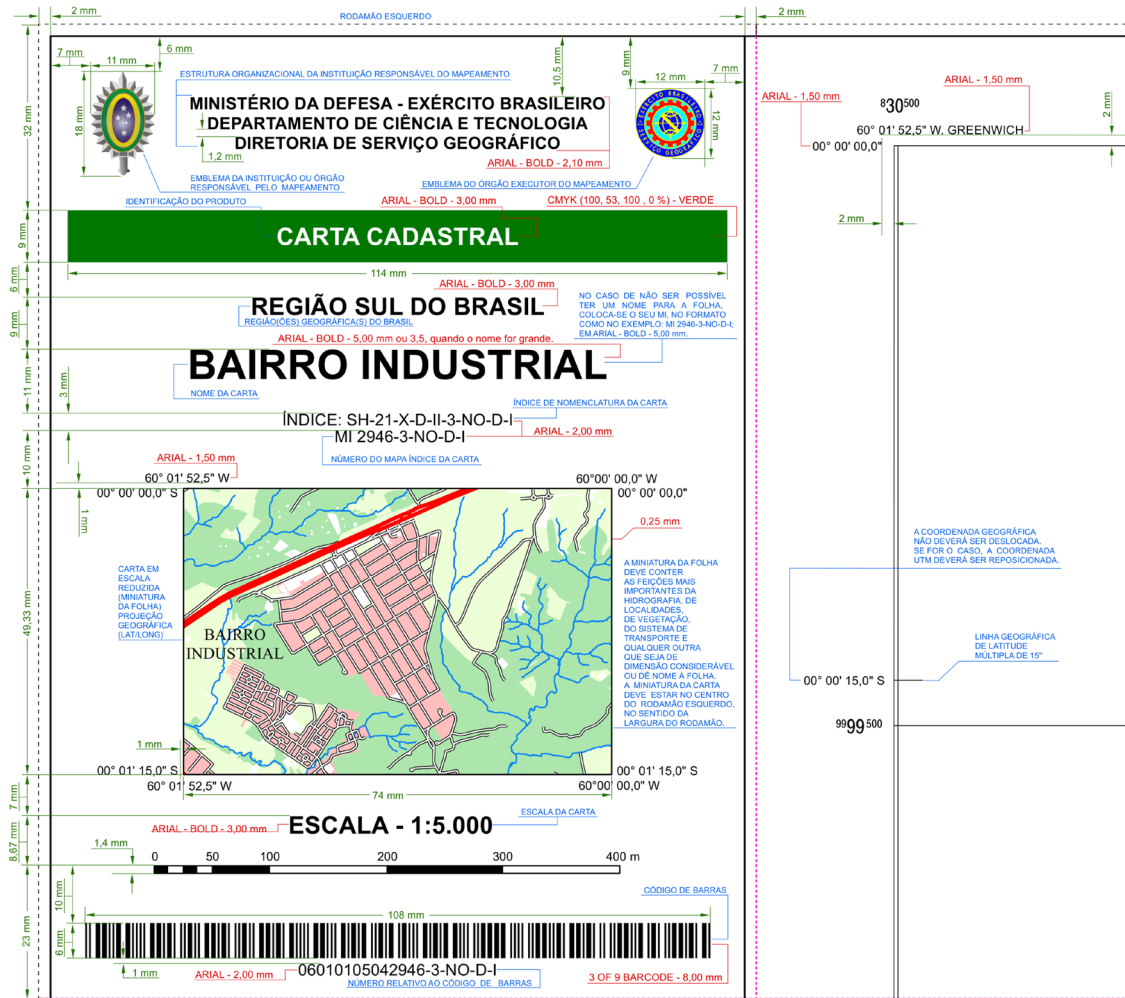


ET-PCDG constitutes a comprehensive set of guidelines established by the Brazilian Army with the purpose of standardizing products and defining criteria for geospatial datasets, covering both vector and raster aspects.

This technical specification encompasses a wide range of elements, from product descriptions to the characterization of their properties and distribution formats. In addition, ET-PCDG is interconnected with other essential technical specifications, such as ET-ADGV, ET-EDGV, and the future Technical Specification for the Representation of Geospatial Data (ET-RDG). This interconnection provides an integrated and holistic approach to the management and production of geospatial datasets, ensuring consistency, accuracy, and efficiency throughout the process.

As a complement to PCDG, and more specifically for dataset products of the “map” type, template sheets were defined for systematic mapping at scales of 1:1,000, 1:2,000, 1:5,000 (Figure 2), and 1:10,000 (aimed at the cadastral level), in addition to the traditional scales of systematic mapping, such as 1:25,000, 1:50,000, 1:100,000, and 1:250,000.

Figure 2 – Detail of the template sheet for the 1:5,000 scale



Source: ET-PCDG (Brazil, 2016b).



### 2.4.1 Main characteristics

ET-PCDG defines guidelines for the technical specification of geospatial dataset products, encompassing both vector and raster formats. The key characteristics of this standard include the following:

- Definition of geospatial dataset products - ET-PCDG establishes criteria and specifications for various types of geospatial products, including vector and raster data, as well as products such as topographic maps and orthophotos.
- Standardization of object class instance representation - the specification defines guidelines for representing object classes at different scales, ensuring consistency and standardization in data presentation.
- Establishment of geospatial data quality control procedures - the document describes procedures and parameters for quality control of geospatial data, ensuring the accuracy and reliability of the generated products.
- Guidance on vector data geometry acquisition - ET-PCDG refers to other standards, such as ET-ADGV, which defines general rules for acquiring feature attributes, including their geometry.
- Supplementation through annexes - the technical specification includes annexes with supplementary information, such as metadata, map templates, and a glossary of terms and definitions, which complement and further detail the guidance set out in the main body of the document.

### 2.4.2 Additional definitions

ET-PCDG also defines certain parameters to be addressed by datasets, whether raster or vector. The main parameters are described below:

- Positional accuracy - refers to the accuracy of the geographic location of the elements represented in geospatial data. The standard defines criteria for the absolute positional accuracy of cell centers in orthophotos, as well as the relative positional accuracy of features with respect to the orthophoto.
- Completeness - concerns the integrity and presence of the information required in geospatial data. Quality elements related to completeness include the amount of clouds and shadows that obscure information; omission of mandatory product metadata; omission of metadata attribute values; and radiometric and spatial resolution.
- Logical consistency - refers to the conformity of geospatial data with established standards and formats. Quality elements related to logical consistency include file format consistency and layout consistency (framing only).



- Thematic accuracy - relates to the accuracy in representing thematic characteristics or attributes of geospatial elements. This includes accuracy in feature interpretation; accuracy in the interpretation and completion of feature attributes; accuracy in the interpretation and completion of metadata; and correctness of printed toponymic information.
- Vertical reference system - establishes the vertical reference system to be used for geospatial data, including the applicable vertical datum and its specifications.

## 2.5 Technical Manual of Cartographic Conventions T-34 700




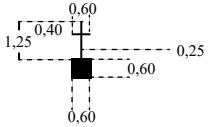




This is an older standard that remains in force, given that ET-RDG is still under development. The manual, whose most recent edition was published in 2002, aims to establish guidelines for the cartographic representation of natural and artificial features intended for the production of topographic maps and similar products at scales of 1:25,000, 1:50,000, 1:100,000, and 1:250,000. It is divided into two parts: the first defines concepts, procedures, and standards for the use of conventional symbols; the second establishes the formats and dimensions of these symbols, as well as the types and sizes of lettering to be used in map legends.

The manual addresses a wide range of topics, including transportation systems, vegetation, buildings, boundaries, infrastructure, elevation, settlements, hydrography, and reference points. It also covers fundamental elements for the construction and standardization of representations, including generalization and cartographic conventions, legends, and map templates. Figure 3 presents examples of conventions covered by this document.

In 2009, the Brazilian Association of Technical Standards (ABNT) published Brazilian Technical Standard NBR 15777, which establishes procedures for cadastral-scale mapping, such as 1:10,000, 1:5,000, 1:2,000, and 1:1,000 (ABNT, 2009), scales not covered by Manual T-34 700. This standard defines procedures for spatial representation at these scales, standardizes several semiological conventions for use in cartographic documents, and groups features into five main themes, namely: hydrography, vegetation, contour lines, road networks, and hypsometry. In addition, it establishes standards for symbol construction, as well as line thickness and text size to be used in products generated at the aforementioned scales.



**Figure 3 – Examples of cartographic conventions**

No	BUILDINGS	DATA ACQUISITION		
		Symbols	Specifications	
308	Church or temple not representable at scale with any number of towers (provided it does not exceed 0.60 mm × 0.60 mm)	 Church of Senhor Bom Jesus	SSNR - 1,50 mm 	
GEOMETRIC REPRESENTATION		FINAL REPRESENTATION		T 34-700 (PART 2)
		Symbol	Specifications	
POINT	 Church of Senhor Bom Jesus			CHAPTER 4 PARAGRAPH 4 - LETTERS a and c
No	BUILDINGS	DATA ACQUISITION		
		Symbol	Specifications	
306	Soccer field or sports court (Legend as appropriate)	 Sports Court	SSNR - 1,50 mm  DRAW TO SCALE	
GEOMETRIC REPRESENTATION		FINAL REPRESENTATION		T 34-700 (PART 2)
		Symbol	Specifications	
Sports Court	 Sports Court	SSNR - 1,50 mm 0,13  DRAW TO SCALE	CHAPTER 4 PARAGRAPH 4 - LETTER d	

Source: T-34 700 (Brazil, 2002), adapted for easier reading

## 2.6 Final remarks

This section primarily sought to summarize and present the standards currently in force to a broader audience of public sector managers. It is important to emphasize that these standards, in addition to being aligned with international regulations, follow a longstanding



tradition of geospatial data quality that dates back to Decree No. 89,817 of June 20, 1984 (Brazil, 1984). Over time, they have been progressively adapted to the digital revolution, which has invariably transformed the way maps and other cartographic products are produced, generated, and shared.

Accordingly, their use is advocated as a safe and appropriate means for analysis and auditing in the acquisition and dissemination of geospatial data, and they should be cited as quality reference documents alongside those governing procurement and contractual arrangements. Moreover, even when not explicitly referenced in bid notices, they should be applied as inspection and oversight standards, given their official and therefore binding nature, as well as their broad recognition among professionals and companies in the field.

### 3 METHODOLOGY

This study focuses on the quality of geospatial data—which encompasses accuracy but is not limited to it, as discussed in Section 2. The work was developed in two stages:

- a clear description of the main elements governing geospatial data quality, based on reliable sources that public officials and oversight bodies may rely on when assessing data produced both through contracts with the private sector and by public institutions; and
- the analysis of illustrative cases, in which selected geoinformation products contracted by the Municipality of Rio de Janeiro and made available by the Pereira Passos Municipal Institute of Urbanism (IPP), under a cooperation agreement with the Rio de Janeiro State University (UERJ), are examined. These examples are intended to illustrate a possible geoinformation audit workflow that can be replicated by public officials, regardless of their level of familiarity with geotechnologies. At the end of the analysis, discussion points and challenges faced by the Public Administration are presented, with a view to ensuring that contracts—now increasingly frequent—are monitored as efficiently as possible and without deviation from their intended purpose.

It is important to note that primary responsibility for compliance with the standards lies with the company or public body responsible for the acquisition and dissemination of geospatial data, rather than with the public official tasked with oversight or audit activities. Both the drafting of procurement procedures and the Administration's ex ante control mechanisms should explicitly link compliance with standards and technical specifications to the execution of contracts involving geoinformation.

It is equally important to use these standards as a reference for contract oversight and for the exercise of ex post control by the Public Administration, both during contract performance and after its completion. In this context, compliance with normative guidelines may be verified through sampling across different scenarios. The following sections present practical examples that illustrate simple procedures that can be carried out by officials responsible for audit and oversight activities. The examples rely on open-source software (QGIS) and free plugins, thus entailing no additional cost to the Public Administration.



The description below covers three types of geospatial products that are very common in contracts entered into by public authorities.

- Product 1 - orthoimage map (commonly referred to as an “orthophoto”), essentially composed of a mosaic of georeferenced images that have been corrected for parallax and adjusted to an orthogonal perspective. These products can be safely used as precise cartographic outputs, as distortions inherent to the camera system have been corrected. Owing to their practicality and lower cost, they have been used either as map products—with marginal elements and coordinate grids overlaid on the image—or as dynamic mosaics serving as background layers in geoservices and web-based applications. Numerous public-sector bodies rely on online geoservices or acquire their own image mosaics via drones, aircraft, or satellites. As orthoimages have increasingly been used as key inputs for public management, any positional errors they contain may pose significant risks, particularly when used to identify construction sites, verify property rights, and geolocate urban features, among other purposes.
- Product 2 - vector geospatial database, which was originally available only as topographic maps distributed sheet by sheet. Today, such datasets are commonly integrated into single files, either in Computer-Aided Design (CAD) format or as vector files prepared for Geographic Information Systems (GIS). In both cases, the transition from analog to vector data requires compliance with topological rules. For example, line features representing road segments must be fully connected so that computational algorithms can recognize route continuity. Likewise, if contour lines are not properly closed, computational models for drainage, landslides, and other analyses may fail to correctly calculate parameters such as slope and aspect. When maps were distributed exclusively in paper form, minor drafting imperfections did not lead to such issues. In the current digital context, however, all vector products must undergo cartographic validation to ensure topological consistency and to guarantee that they can be subjected to computational analyses and yield reliable results.
- Product 3 - satellite image mosaic, intended for use in multispectral classifications and as a geoservice. Major online mapping services routinely offer georeferenced imagery as background layers. However, due to atmospheric conditions, such imagery does not always provide optimal coverage, which may result in poor-quality input data caused by haze, cloud cover, or similar phenomena. For a product of this type to be suitable for target identification and for comparison with other maps, it must provide maximum coverage without any form of obstruction.

For each of the selected products, a single, easily identifiable parameter was chosen, capable of significantly influencing overall product quality. The analysis also sought to rely on simple parameters that can be readily understood by any manager—even those without technical expertise in the field—and that clearly reflect the quality of the delivered product. It should be noted that the adopted approach entails a methodological limitation, as the applicable standards encompass many additional variables that may—and should—be verified in a more comprehensive oversight process.



## 4 RESULTS AND DISCUSSION

This section presents and discusses, in thematic subsections, the results related to positional accuracy, topological consistency, and the evaluation of image-type data classification.

### 4.1 Positional accuracy

The assessment of the positional accuracy of contracted geospatial data is critical for public-sector entities, as it allows verification of compliance with the ET-CQDG standards (Section 2.3.1) for the relevant scale. This process involves comparing the location of geospatial features with known coordinates or other reference sources.

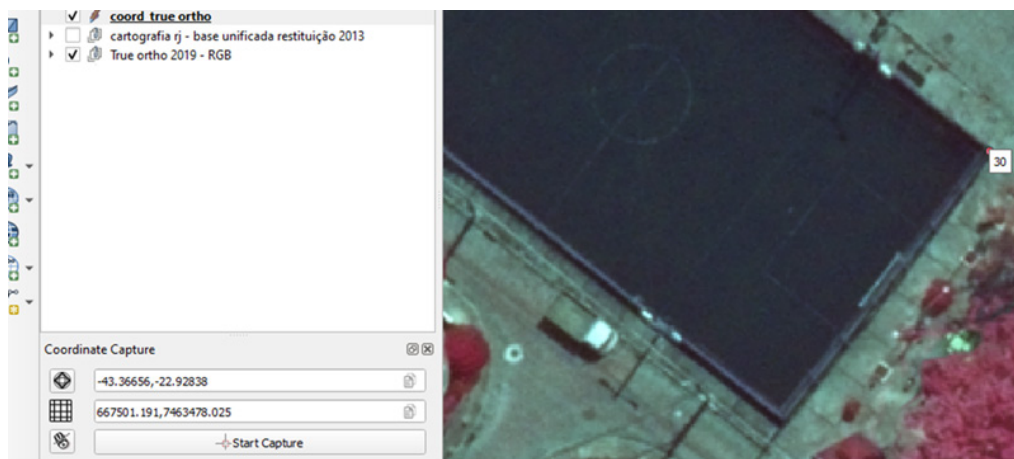
However, positional accuracy is not limited to point features. In the context of road infrastructure management, the ET-PCDG (Section 2.1.1) is used to ensure the positional accuracy of geospatial data related to public roads, including highways, arterial roads, and urban streets. Accurate positioning and geometry of road networks play a key role in planning infrastructure improvements, such as the construction of new roads, the installation of traffic signage, and the execution of maintenance activities.

As an example of positional accuracy assessment, a quality analysis was conducted on an orthoimage mosaic acquired by the IPP, intended to support the production of base maps and orthophoto maps, as well as the updating of the cadastral database of the City of Rio de Janeiro. The mosaic was acquired through a contract and has a nominal acquisition scale of 1:5,000.

In this example, easily identifiable points in the imagery were selected in accordance with the sampling rules proposed by the ET-CQDG (Section 2.3.1). Figure 4 shows the selection of coordinates at a street block corner, and Table 3 presents the coordinates obtained in the Universal Transverse Mercator (UTM) system, together with their values derived from a higher-precision vector dataset, which is taken as ground truth.



**Figure 4 – Selection of a point for coordinate measurement in the image**



Source: elaborated by the authors.

**Table 3 – Points selected for positional accuracy analysis**

Point	Vector base		Orthoimage	
	E	N	E	N
01 - pool	653203,138	7467980,793	668378,211	7462110,811
02 - pool	668377,087	7462103,932	668497,522	7462418,373
03 - pool	667859,545	7462281,186	667859,545	7462281,186
04 - pool	667917,720	7463932,517	667917,836	7463932,963
05 - pool	666607,537	7463451,339	666607,669	7463451,339
06 - pool	666605,156	7463446,973	667334,347	7463561,703
07 - pool	667773,324	7464350,079	667772,993	7464350,277
08 - pool	668401,048	7464596,869	668400,717	7464596,902
09 - pool	668140,566	7464059,765	668140,169	7464059,633
10 - pool	668571,903	7464087,48	668571,969	7464088,274
11 - Lot	667933,52	7464385,182	667933,388	7464385,248
12 - Lot	667870,351	7464350,918	667869,954	7464350,72
13 - Lot	668227,67	7464059,811	668227,472	7464059,744
14 - Lot	667798,053	7464188,398	667797,789	7464188,067



Point	Vector base		Orthoimage	
	E	N	E	N
15 - Lot	667325,772	7463336,506	667325,573	743335,977
16 - Low-rise building	667742,755	7463094,941	667742,557	7463095,338
17 - Low-rise building	667142,945	7463630,524	667142,68	7463630,392
18 - Low-rise building	667345,351	7463300,456	667345,087	7463299,993
19 - Low-rise building	667424,528	7463574,631	667424,329	7463574,366
20 - Low-rise building	667997,615	7463565,172	667996,491	7463564,709
21 - blocks	668481,670	7461893,931	668482,133	7461893,799
22 - blocks	668080,959	7461768,155	668080,76	7461768,354
23 - blocks	667154,487	746340,829	667154,09	7463409,762
24 - blocks	667337,612	7463122,293	667336,686	7463121,3
25 - blocks	667886,622	7462262,661	667886,755	7462263,455

Source: elaborated by the authors.

The data were then processed using the open-source QGIS software, with the QPEC plugin developed by Elias et al. (2023), which performs positional accuracy assessments of geospatial data in accordance with the ET-CQDG standard (Section 2.3.1). The results indicate positional consistency in the sampled data, qualifying the product as Class A for the acquisition scale (1:5,000). The dataset could even be used at larger scales, albeit with reduced quality (Class B at 1:2,000 and Class D at 1:1,000).

**Table 4 – Positional accuracy standard calculation for the 25 selected points**

ID	PE	RMSE	1:1000	1:2000	1:5000	1:10000
1	0,209171	0,586	Class D	Class B	Class A	Class A
2	0,503752	0,586	Class D	Class B	Class A	Class A
3	0,533285	0,586	Class D	Class B	Class A	Class A



ID	PE	RMSE	1:1000	1:2000	1:5000	1:10000
4	0,49747	0,586	Class D	Class B	Class A	Class A
5	0,651461	0,586	Class D	Class B	Class A	Class A
6	0,238492	0,586	Class D	Class B	Class A	Class A
7	0,385693	0,586	Class D	Class B	Class A	Class A
8	0,264583	0,586	Class D	Class B	Class A	Class A
9	0,272726	0,586	Class D	Class B	Class A	Class A
10	0,796501	0,586	Class D	Class B	Class A	Class A
11	0,093544	0,586	Class D	Class B	Class A	Class A
12	0,503752	0,586	Class D	Class B	Class A	Class A
13	0,187089	0,586	Class D	Class B	Class A	Class A
14	0,516615	0,586	Class D	Class B	Class A	Class A
15	0,591626	0,586	Class D	Class B	Class A	Class A
16	0,44372	0,586	Class D	Class B	Class A	Class A
17	0,295813	0,586	Class D	Class B	Class A	Class A
18	0,481549	0,586	Class D	Class B	Class A	Class A
19	0,385693	0,586	Class D	Class B	Class A	Class A
20	1,277488	0,586	Class D	Class B	Class A	Class A
21	0,56515	0,586	Class D	Class B	Class A	Class A
22	0,295813	0,586	Class D	Class B	Class A	Class A
23	0,337279	0,586	Class D	Class B	Class A	Class A
24	1,40628	0,586	Class D	Class B	Class A	Class A
25	0,804699	0,586	Class D	Class B	Class A	Class A

Source: elaborated by the authors.

## 4.2 Topological consistency

Data contracted by the Public Administration must be assessed for topological consistency to ensure that spatial relationships among features comply with the guidelines set out in



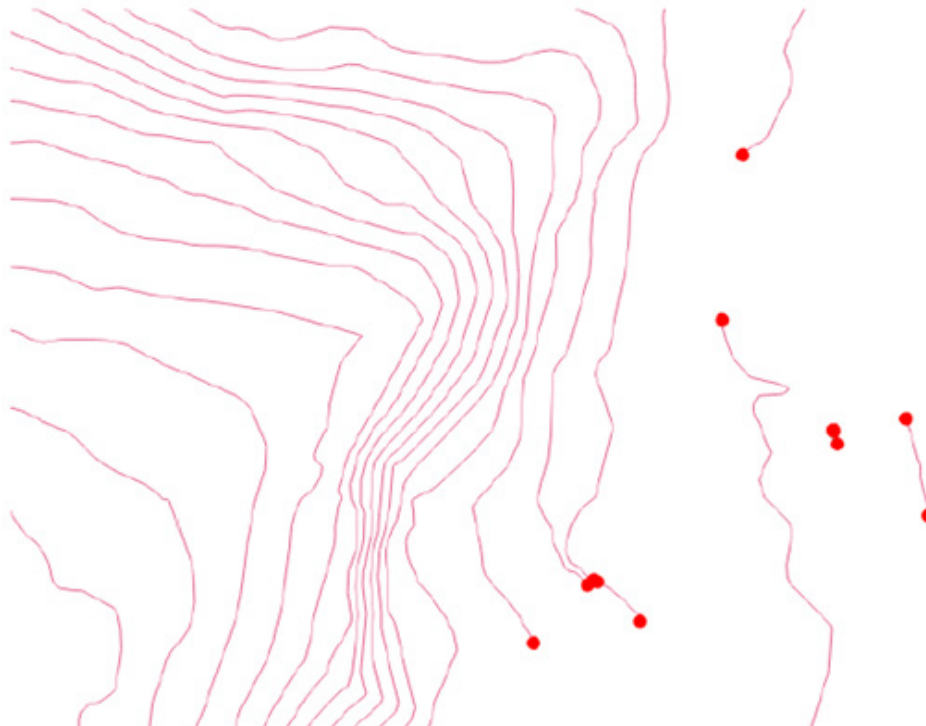
the applicable standards. This can be achieved through topological integrity analyses in geographic information systems.

In urban and regional development projects, standards may be used to ensure the logical consistency of geospatial data related to urban zoning, land use, and urban infrastructure. Compliance with established standards ensures data interoperability and facilitates integration into urban planning and municipal management systems.

The following examples illustrate topological validation analyses that can be applied in the oversight of geoinformation contracts. These checks were performed on the unified vector database contracted by the IPP and produced through stereorestitution.

In the example shown in Figure 5, contour line features from Brocoiό Island were used, totaling 334 items. When the topology checker tool in QGIS was applied, 154 errors were identified. However, since each unclosed contour line generates two error points, the total number of unclosed linear features amounted to 57. Consequently, the error rate was 57 out of 334, equivalent to 17%, a percentage considered unacceptable—exceeding the 5% acceptance threshold.

**Figure 5 – Topological analysis of contour lines with inconsistencies, represented by red points**



Source: elaborated by the authors.

In the example illustrated in Figure 6, an assessment was conducted on overlapping land parcels that should ideally be contiguous. Parcel features from Paquetá Island were used, totaling 1,981 items. The topology checker identified 26 errors. As each error involved two



features, the total amounted to 52 errors. The resulting error rate—52 out of 1,981, or 2.6%—was therefore considered acceptable.

**Figure 6 – Topological analysis of parcels with inconsistencies, represented by red areas**



Source: elaborated by the authors.

### 4.3 Evaluation of Image-Type Data Classification

A geospatial data product commonly procured by the Public Administration is satellite image mosaics, which support a wide range of applications—from land-use classification to the production of image maps. However, due to the characteristics of satellite orbits, which are tied to specific overpass schedules and revisit times, such imagery may occasionally contain cloud cover. In aerial photogrammetry, whether using aircraft or drones, flight dates can be scheduled for clear-sky conditions, whereas satellite image acquisition is constrained by orbital passes.

In this context, acceptance of a satellite-based product must be conditioned on image quality, particularly the absence of obstructions caused by haze or cloud cover. In the case of the 2022 WorldView image mosaic acquired by the IPP (Figure 7), a certain amount of cloud cover is evident, primarily over the Tijuca Forest region. As these images are used for land-use mapping and for monitoring the growth of informal settlements, cloud obstruction hampers the acquisition of accurate data for planning and management purposes.



To assess the quality and acceptability of the product, a classification study was conducted to identify areas affected by cloud cover and to quantify them relative to the total contracted area. In this context, the metric percentage of unavailable area, provided for in the ET-CQDG (Section 2.3.1), is appropriately applied. Using a supervised multispectral classification procedure in the QGIS software, it was possible to identify and delineate regions impacted by cloud cover.

By applying an area calculation tool, it was determined that approximately 29 km<sup>2</sup> were covered by clouds. Considering the total area of the municipality—1,204 km<sup>2</sup>—this corresponds to roughly 2.4% of unavailable area, a percentage that classifies the product as acceptable, despite cloud obstruction being concentrated in specific areas of the city.

**Figure 7 – Classification of cloud-covered areas in a WorldView satellite image mosaic**



Source: elaborated by the authors.

## 5 FINAL CONSIDERATIONS

Geospatial data quality standards are essential for defining requirements that ensure the accuracy and reliability of such information. When supported by an adequate geospatial database, public policies can be implemented with substantially greater confidence, encompassing applications in urban and regional planning, environmental management, defense and security, and infrastructure. As geographic information has become widely shared and increasingly used as a public management tool, it is equally necessary for those responsible for contract oversight and for ensuring the adequacy of core administrative processes to have access to such information, so that it can be used and integrated properly.

This study presented a synthesis of the main standards governing quality requirements for the acquisition and dissemination of georeferenced data, including maps, vector datasets,



and image-based products. It is important to note that these standards do not exhaust the full body of regulations on geoinformation, as there are additional local guidelines and standards implemented by subnational government entities, as well as best practices documented in a broader body of literature on cartography and geographic information systems. Nevertheless, the standards addressed herein provide a relatively comprehensive overview of the principal criteria for assessing the quality of geographic data. Within each standard, key topics were selected based on their practical applicability and their suitability for sample-based evaluation when determining the quality of a geospatial product.

Likewise, the examples presented are straightforward and can be adapted to different public-sector contexts and operational realities, as they do not require expensive equipment or proprietary software licenses. It is acknowledged that auditors or public officials responsible for overseeing contracts involving geoinformation often lack the time or resources to conduct a comprehensive review of all delivered products. However, it is argued that reliable assessments can be achieved through sampling-based analyses.

There is a reasonably well-established understanding that geographic information can be widely employed to improve the quality of services contracted by the Public Administration, as well as audit activities themselves (Ferraz *et al.*, 2015; Gevaert *et al.*, 2024). What remains less clear, however, is how to ensure the quality of the data used in decision-making processes. For a considerable period, responsibility for quality control rested solely with traditional geoinformation-producing agencies. In a context where the generation and dissemination of such data permeate all levels of public administration—and, indeed, society as a whole—it becomes increasingly necessary for a wide range of actors to be capable of ensuring the relevance of geospatial data and their suitability for the services in which they are employed.

As a development of the issues discussed in this article, it is suggested that easily accessible instructional materials be developed to guide public managers in the acceptance and oversight of specialized services that generate and disseminate geoinformation. Within audit institutions, it is further proposed that the elements and procedures discussed herein be incorporated into compliance audits, in coordination with the main stakeholders involved in the use of geographic information. The objective is to assess the legality and legitimacy of geospatial data in light of the prevailing normative standards.

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