Quinello, R. (2025). Facilities management strategies for public real estate portfolios in Brazil: a cluster analysis using t-SNE and K-means. *Administratie si Management Public*, 44, 150-166. https://doi.org/10.24818/amp/2025.44-09

Facilities management strategies for public real estate portfolios in Brazil: a cluster analysis using t-SNE and K-means

Robson QUINELLO[1]

***Abstract*:** Based on the results of the analysis of Brazilian federal real estate assets, conducted from the perspective of Facilities and Real Estate Management (FREM), this study sought to understand the complexity of managing this portfolio. The work begins with a historical synthesis of the discipline, addressing its applications in the private and public sectors. Next, through quantitative research, it presents the characteristics of federal assets and the possible strategic configurations to be adopted, using the life cycle of built spaces as a reference. For this, clustering techniques such as PCA, t-SNE, and K-means were used to visualize the probable groupings of properties that require specific management. This work highlights the strategic and active importance of FREM management in the optimization and sustainability of public real estate assets, reinforcing the need for effective participation in this process to ensure efficiency and effectiveness in the management of public assets.

Keywords: government, physical infrastructure, built environment life cycle, real estate assets.
JEL: M100

DOI: https://doi.org/10.24818/amp/2025.44-09

Introduction

Facility Management (FM) and Real Estate Management (REM), aim to provide operational support through the maintenance, use, and conservation of physical building infrastructures and real estate assets in both public and private spheres. In this way, they seek to meet the quality, safety, and comfort needs of users or employees in these environments. According to the report by the Brazilian Federal Court of Accounts (Tribunal de Contas da União – TCU, 2022), the Brazilian government has not adequately managed its more than 750,000 federal properties, highlighting the significant financial burden caused by the lack of integrated and professional management. In Brazil, the Brazilian Association of Facility Management, Property, and Workplace (ABRAFAC), founded in 2004, formally

[1] PhD Business; SENAI São Paulo, Brazil, Gandavo Street, n.550, Vila Mariana, São Paulo city, 04023-001, e-mail: rquinello@yahoo.com.br, https://orcid.org/0000-0002-3526-997X

introduced the discipline to the market. However, it remains relatively unknown in the national academic sphere due to the lack of theoretical contributions or formulations, emerging primarily in the practical field through the branches of multinational companies that already had a history of the scopes discussed by their headquarters, as will be addressed in the next section. Although there are no official records of the introduction of these activities, it is relevant to highlight the formation of the Service Administrators Group (GAS) and the Facility Managers Group (GRUPAS) in 1983 and 1984, respectively. These groups brought together service administration professionals, who later became the founders of ABRAFAC.

Before the 1980s, subsidiaries of American and European multinationals may have introduced tacit knowledge to their branches, especially those with industrial plants that, as in the United States, had dedicated plant engineering areas. In any case, there is still a strong influence of practices and academic studies originating from Europe and the United States, often under an ethnocentric perspective. From the 1990s onward, with the rise of environmental agendas, these activities became increasingly focused on sustainability, particularly due to the high consumption of energy and water resources, as well as the generation of waste and carbon emissions by built environments.

As a result, external influences have intensified, as will be discussed later in this article, reshaping the discipline into a model more focused on externalities and, consequently, requiring new skills from managers, such as the use of open government data. Michell (2013) argues that integrating a micro-scale of action (private sector) with a macro-scale (public sector) could benefit communities within a broader urban context, as one is intrinsically linked to the other. With the recent release of data on federal real estate assets and the public procurement of Facility and Real Estate Management (FREM) activities by a few national public agencies, a new perspective is emerging in Brazil - the potential adoption of private-sector practices in the management of public asset portfolios.

Brazil has a territory of approximately 8.5 million square kilometres and an estimated Gross Domestic Product (GDP) of around R$ 10.1 trillion (IBGE, 2024), making it one of the world's leading economies. The federal administration oversees more than 750,000 real estate assets, ranging from land to administrative buildings, totaling a land area of 2.23 million km², valued at approximately R$ 1.72 trillion, with annual rental expenses of approximately R$ 1.6 billion (BRASIL, 2024; TCU, 2022). Despite the growing recognition of FREM as a strategic discipline, research on its application in Brazil’s public sector remains limited. While private-sector FREM practices are well-documented, their adaptation to government real estate portfolios has not been thoroughly explored. Existing studies lack a comprehensive analysis of how data-driven asset management, clustering techniques, and sustainability principles can optimize public property portfolios.

This study addresses this gap by applying advanced data analytics (t-SNE and K-means clustering) to federal real estate assets, identifying management inefficiencies and proposing integrated, region-specific FREM strategies. By bridging private and public-sector best practices, this research contributes to a more structured, data-

oriented approach to public asset governance in Brazil. This study aims to descriptively and quantitatively analyze the data collected from official and open sources of the Ministry of Management and Innovation in Public Services, specifically focusing on federal real estate assets from the perspective of FREM, highlighting the challenges and opportunities of professional management in the public sector.

1. Literature review

Facilities and Real Estate Management (FREM) has undergone significant transformations over the past century, evolving from basic industrial asset maintenance to a strategic discipline integrating real estate portfolios and facility operations. The origins of Facilities Management (FM) can be traced back to the early 20th century, when industrial operations required systematic asset maintenance to ensure operational efficiency. This led to the formation of several plant engineering associations, including the Association of Physical Plant Administrators (APPA, 1914) and the Association for Facilities Engineering (AFE, 1915) in the United States (Alexander & Brown, 2006).

Simultaneously, Real Estate Management (REM) developed in the United Kingdom, where landowners sought professional asset management services to optimize property transactions and revenue generation (Danivska & Appel-Meulenbroek, 2022). Over time, FM and REM evolved into distinct but complementary disciplines—FM focusing on short-term operational efficiency and REM emphasizing long-term strategic asset allocation (van der Voordt, 2017).

In Brazil, the adoption of FREM followed a delayed trajectory, largely influenced by the presence of multinational corporations. Before the formal establishment of ABRAFAC in 2004, professional networks such as the Grupo de Administradores de Serviços (GAS, 1983) and the Grupo de Gestores de Facilities (GRUPAS, 1984) played a crucial role in shaping the practical application of FREM principles. However, despite its growth in the private sector, the discipline remains underdeveloped in public asset management, particularly regarding federal real estate portfolios.

While private-sector FREM primarily aims to optimize operational costs and maximize asset efficiency, public-sector asset management must balance operational effectiveness with broader economic, social, and regulatory objectives (Michell, 2013). Government-owned real estate portfolios face complex challenges, including bureaucratic procurement processes, regulatory constraints, budget limitations, and outdated asset management strategies (UK GOV, 2020). Unlike the United States General Services Administration (GSA) or the UK's Central Government Estate Strategy, which provide standardized governance frameworks, Brazil lacks an integrated model for managing public real estate assets efficiently (TCU, 2022).

A major limitation in Brazil's public real estate management is the absence of a centralized, data-driven asset management system. While some open data initiatives

(e.g., SPIUNet) aim to improve transparency and governance, their impact on real estate optimization remains minimal (Brasil, 2024). In contrast, international best practices involve digital twins, AI-driven predictive maintenance, and lifecycle cost analysis, which have led to greater efficiency in public asset portfolios (Bjørberg et al., 2017).

A key issue in Brazil's federal real estate strategy is the lack of integration between FM and REM in the public sector, resulting in fragmented decision-making, high maintenance costs, and underutilized assets. As a result, many federal properties remain vacant, inefficiently allocated, or face high operational expenses, reinforcing the need for a structured FREM framework that aligns with global best practices.

The global transition toward sustainability has significantly reshaped FREM strategies, as real estate assets account for a substantial portion of energy consumption and carbon emissions (ISO 41001, 2017). In response, organizations worldwide are integrating digital tools, smart building technologies, and data-driven decision-making to optimize resource efficiency (Mordor Intelligence, 2021).

In Brazil, the federal real estate portfolio faces significant sustainability challenges, including inefficient energy consumption, outdated infrastructure, and high environmental impact. The adoption of smart buildings, predictive maintenance systems, and renewable energy sources remains limited, primarily due to budgetary constraints and slow regulatory adaptation (Santander & Sanchez-Silva, 2008). The impact of the COVID-19 pandemic further highlighted the need for flexible work, implement safety protocols, and reassess facility usage strategies (Gomez et al., 2020).

The integration of IoT (Internet of Things), artificial intelligence, and real-time monitoring has become essential in public-sector real estate management, enabling governments to enhance transparency, efficiency, and sustainability (Dhalmahatra et al., 2019). However, Brazil's current asset management framework lacks the necessary digital transformation, reinforcing the urgency for reform and modernization.

Portfolio management in the public sector refers to systematic selection, prioritization, and administration of assets to align with government objectives and maximize public value (Roberts & Edwards, 2023). Unlike private-sector portfolio management, which focuses on maximizing financial returns, public-sector asset management must balance risk, cost efficiency, and long-term societal benefits.

In Brazil, public procurement plays a crucial role in real estate portfolio management yet remains largely fragmented and inefficient. While government procurement frameworks (e.g., Decree No. 9.745) define standardized procedures for managing public assets, their implementation is inconsistent, leading to waste, inefficiencies, and increased operational costs (Brasil, 2019), internationally, countries such as the UK and the US have centralized procurement units that streamline acquisition, maintenance, and disposal processes, ensuring greater transparency and cost savings (e.g. UK GOV, 2020).

Brazil has made some progress in aligning public procurement with FREM best practices, as demonstrated by initiatives from SABESP (2017), the Ministry of

Economy (2019), ENAP (2021), and SPGG (2023). However, these efforts remain isolated and lack nationwide standardization, reinforcing the need for a unified, long-term strategy.

A well-structured public-sector FREM model should integrate portfolio management principles, lifecycle cost analysis, and digital transformation strategies to ensure efficient asset utilization, financial sustainability, and improved service delivery. The centralization of procurement processes, combined with data-driven decision-making, is essential for achieving cost-effective and sustainable public asset management.

Summarizing, over the past six decades, FREM has evolved from a purely operational function to a strategic discipline that integrates real estate management, sustainability, and digital transformation. However, in Brazil's public sector, FREM remains underdeveloped, with significant gaps in data integration, procurement efficiency, and lifecycle asset management.

While international best practices demonstrate the potential for optimized government real estate management, Brazil still lacks a comprehensive FREM framework. The absence of centralized decision-making, standardized procurement models, and sustainable asset strategies has resulted in fragmented governance and high operational costs. Addressing these gaps requires a data-driven, portfolio-based approach, incorporating the best global practices, smart technologies, and long-term asset planning.

The next section will discuss the methodological approach used in this study, including the application of clustering techniques to analyze Brazil's federal real estate portfolio.

2. Research methodology

For the descriptive and quantitative analysis of this study, open data from the Brazilian government (BRASIL, 2024) were used, with a specific focus on federal real estate assets (Union-owned properties), excluding state and municipal properties, which are not fully available. According to Bjørberg et al. (2017), data usage can be a powerful tool for improving the maintenance and operation of cities, providing governments with greater accuracy in their actions and consequently enhancing services for citizens.

According to Ramírez-Alujas (2012) and Wirtz and Birkmeyer (2015), open government can be defined as a governance model focused on the inclusion of citizens and other non-governmental actors in all phases of the public policy cycle and decision-making spaces. It is based on three principles: (a) Transparency: The public should have easy and unrestricted access to information regarding public policies, activities, decisions, and government and public administration performance, enabling social oversight, accountability, and ensuring public integrity; (b) Citizen participation: This refers to the redistribution of power through the inclusion of citizens in public policy cycles and decision-making processes to strengthen citizenship, deliberative democracy, and the legitimacy of decisions and (c) Collaboration: Defined as the joint efforts of various governmental and non-

governmental agents in creating and conducting public policies aimed at the co-production of public goods and services, fostering open innovation, and increasing public value.

Given the high volume of data, the R programming language and its respective statistical packages were employed for data analysis, due to their open-source nature and high processing capacity. The research questions proposed in the study are:

Q1- What are the main federal real estate assets, and what are their characteristics?

Q2- What would be the best FREM strategies for managing this portfolio?

The selection of real estate assets, such as land plots, farms, buildings, houses, lots, apartments, airports, universities, embassies, among others, was based on their alignment with the types of assets commonly managed by FREM in the private sector. The data were sourced from the Special Use Property Management System (SIAPA) and the Integrated Management System of Federal Public Real Estate (SPIUNet), referencing July 2023 – 1st Semester.

Initially, 359,215 properties (BRASIL, 2024) will be processed, undergoing pre-processing and cleaning to eliminate non-applicable, empty, or inconsistent data (NA, NaN, and Inc.), stored in an Excel spreadsheet. The data will be subdivided into four categories: UF - 27 federal units plus one external category (embassies); AREA - Total land area of the property in square meters; TYPE - 63 property subtypes; YEAR - Year of property registration.

Irrelevant data will be removed, keeping only properties with an area of at least 10 m², and a construction year from 1900 onwards. The "Type" and "UF" columns will be converted into numerical factors to facilitate further analyses. This dataset will provide an initial descriptive analysis of the properties.

For cluster verification, since the subgroups contain a large volume of imbalanced data, the oversampling (up-sampling) technique from the caret statistical package will be applied to balance the number of properties across different subtypes. After balancing, the data will be normalized, followed by a Principal Component Analysis (PCA) to measure data dimensionality and identify the key variables explaining variability.

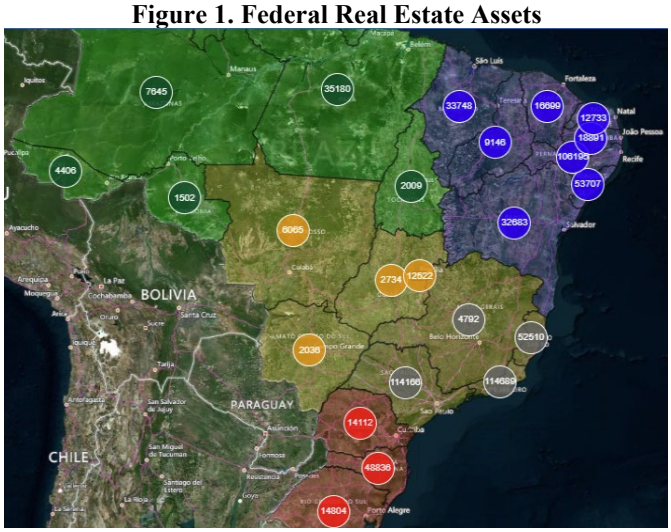
Once the principal components are confirmed using variance and standard deviation measures, the t-Distributed Stochastic Neighbor Embedding (t-SNE) technique will be applied alongside K-means clustering (Van Der Maaten and Hinton, 2008; Dhalmahapatra et al., 2019). The t-SNE method is particularly useful for visualizing high-dimensional data in two dimensions while preserving local structures. It is also a dimensionality reduction technique, maintaining neighborhood relationships between points. The process follows two main steps: (i) Computing point similarity in the original high-dimensional space by converting pairwise distances into probabilities, reflecting the likelihood that one point would choose another as a neighbor based on distance, and (ii) Defining a similar distribution in a lower-dimensional space and iteratively adjusting point positions to minimize differences between high- and low-dimensional similarity distributions. This minimization is performed using the Kullback-Leibler divergence as a discrepancy metric. The K-means algorithm is then used to further segment the data into distinct clusters by partitioning the dataset into K clusters, where each observation belongs to the cluster

with the nearest centroid. This method is widely used to identify homogeneous groups within datasets, facilitating interpretation and analysis.
To determine the optimal number of clusters, the elbow method will be applied. This technique identifies the point at which adding more clusters no longer significantly improves the variance explained by the clusters. The combination of these three techniques—PCA, t-SNE, and K-means—offers a robust approach for analyzing and managing complex and segmented real estate assets, providing valuable insights for strategic decision-making and portfolio optimization.

3. Research results and discussions

From the 16th century to the present day, significant governmental real estate expansions have occurred across Brazilian territory. During the early stages of European settlement, characterized by the distribution of indigenous lands for the benefit of the Portuguese monarchy, real estate assets were primarily composed of ecclesiastical constructions, such as churches, and public buildings, such as forts and administrative offices. Over time, these federal public assets have accumulated to more than 750,000 properties, covering 2.23 million km² of land across various subtypes and characteristics, distributed throughout all regions of the country and some abroad (Figure 1), amounting to a total estimated value exceeding R$ 1.72 trillion (BRASIL, 2024).

Figure 1. Federal Real Estate Assets



Source: Quinello, 2023

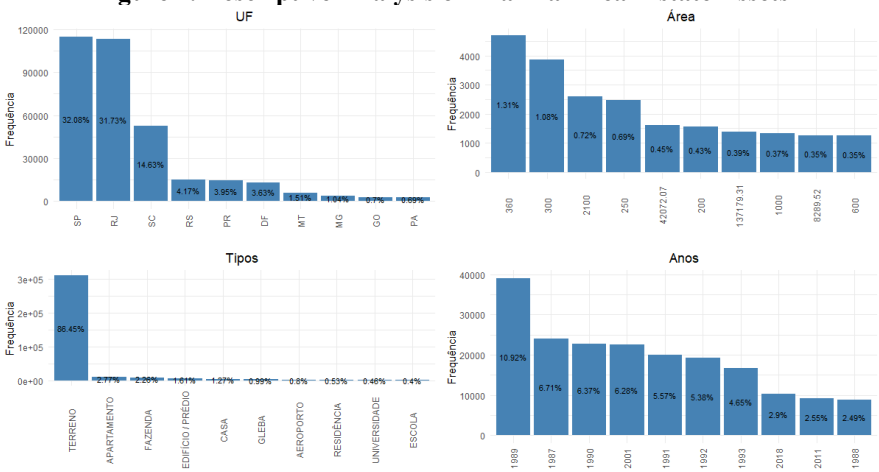
This distinction is crucial, as public assets are generally managed with the goal of serving the broader public interest rather than generating profits. Public assets include all movable and immovable properties owned by legal entities under public law (the Union, States, Federal District, Municipalities, and their respective

autonomous agencies and public foundations). According to current legal provisions, national domain properties owned by legal entities under internal public law are considered public assets, while all others are classified as private assets, regardless of ownership. Article 99 of the Brazilian Civil Code (BRASIL, 2023a) categorizes public assets into three types: (i) Public-use assets: Properties designated for collective use, meaning they are general-use assets accessible to all individuals, such as sidewalks, squares, rivers, beaches, and streets. These assets are typically inalienable by nature as they are non-transactional and cannot be sold; (ii) State-owned assets: Properties belonging to the Union that are not occupied by public administration but are granted to third parties through land regularization instruments, such as emphyteusis, real use concessions (CDRU), and special use concessions for housing purposes (CUEM). These are available assets without a predefined public purpose and can be utilized for revenue generation, provided legal conditions are met, making them subject to sale and (iii) Special-use assets: Properties used by public administration to fulfill its objectives, such as government offices, public hospitals, schools, embassies, and airports. These are inalienable patrimonial assets and cannot be sold. This study focuses exclusively on state-owned and special-use assets, as they were the only categories available in the database.

3.1 Descriptive analysis of federal real estate assets (Q1)

Regarding the first research question (Q1), the final sample (N = 357,995) was processed by removing non-applicable, empty, or inconsistent data (NA, NaN, and Inc.). The analysis revealed that, in absolute values, the majority of properties are concentrated in São Paulo (SP) and Rio de Janeiro (RJ), totaling 63%. These properties vary in size (land area) and are primarily classified as land plots (86%), followed by apartments, farms, and buildings, with most registered in 1989.

Figure 2. Descriptive Analysis of Brazilian Real Estate Assets



Source: Quinello, 2023

Although the Southeast region leads in absolute property count, this trend does not hold when analyzing total land area. Table 1 demonstrates that the North and Midwest regions collectively hold over 75% of the total land area. These properties typically lack extensive built infrastructure but require constant surveillance and monitoring, demanding specialized workforce and technologies.

Table 1. Total Land Area by State (UF)

UF	Area_Sum (m²)	Area_SD	Perc_ Sum (%)	Perc_ Cum (%)
PA	1.337254e+11	1.254008e+08	21	21
MT	1.034851e+11	6.984609e+07	16	37
AM	7.929001e+10	1.311630e+08	12	49
RO	6.163704e+10	1.579638e+08	9	59
MA	5.370086e+10	9.123404e+07	8	67
AC	2.367743e+10	1.428213e+08	3	71
TO	2.135182e+10	4.922698e+07	3	75

Source: Quinello, 2023

The general dataset highlights the typological, spatial, and temporal diversity of real estate assets, significantly increasing the complexity of FREM. According to the Federal Court of Accounts (TCU, 2022) report, multiple issues were identified, such as vacancy and vandalism, high operational costs, difficulties in selling surplus properties, lack of revenue generation, and risks of invasion in unoccupied properties. The TCU declared that the Federal Public Administration is unable to efficiently manage these assets, contributing to the so-called "Brazil Cost". Ultimately, all these challenges fall under the scope of an integrated FREM strategy, assisting public administration in the proper handling and allocation of these assets.

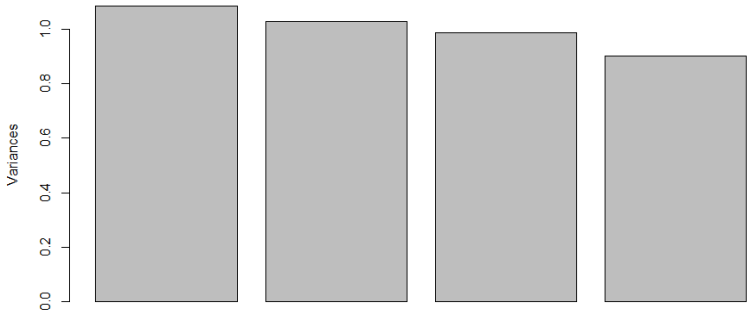
3.2 Cluster analysis and management strategies (Q2)

Regarding research question Q2, which focuses on appropriate management strategies for the identified profiles, a cluster analysis was conducted to verify convergent groups that could be managed appropriately. Given the large dataset size, which would complicate subsequent tests, a random sample was generated before applying t-Distributed Stochastic Neighbor Embedding (t-SNE) and K-means clustering. The sample consisted of 17,960 records (5% of the original dataset, with a 99% confidence level and a 1% margin of error).

Initially, Principal Component Analysis (PCA) was performed to assess variance among the main components. As shown in Figure 4, the components exhibited similar variances and standard deviations above 0.9. The total variance significance indicates that the four components—UF (State), Area, Type, and Year (PCA4)—explain 100% of the dataset variability. The variance captured by the principal components (PCs) suggests that a linear combination of these factors contains most of the information within the dataset. This implies that excluding any of these factors

could lead to a significant loss of information. PCA also revealed that these factors are interdependent in explaining data variability—they not only contribute individually but also interact through their linear combinations. In summary, the factors Year, UF, Area, and Type collectively capture the majority of variability in the dataset, demonstrating their necessity for further analysis.

Figure 3. PCA of the Sample

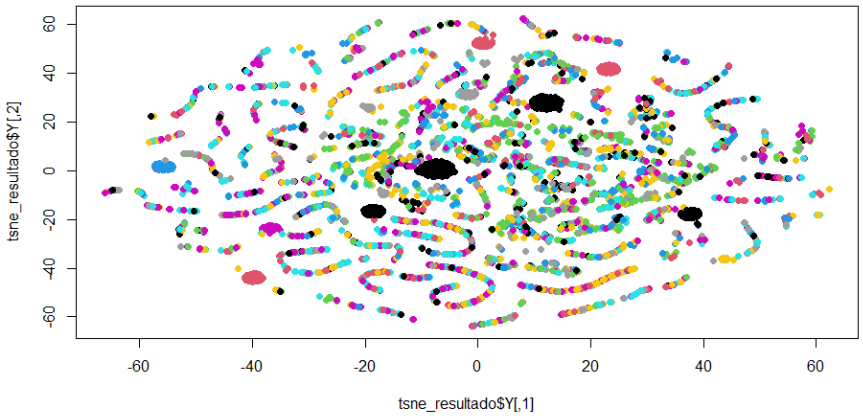



```
Importance of components:
                            PC1    PC2    PC3
Standard deviation     1.0409 1.0143 0.9936
Proportion of Variance 0.2709 0.2572 0.2468
Cumulative Proportion  0.2709 0.5281 0.7749
                            PC4
Standard deviation     0.9488
Proportion of Variance 0.2251
Cumulative Proportion  1.0000
```

Source: Quinello, 2023

Following PCA, t-SNE was applied to visualize the primary groups, but the analysis identified multiple potential clusters (more than 10), which made interpretation challenging (Figure 4).

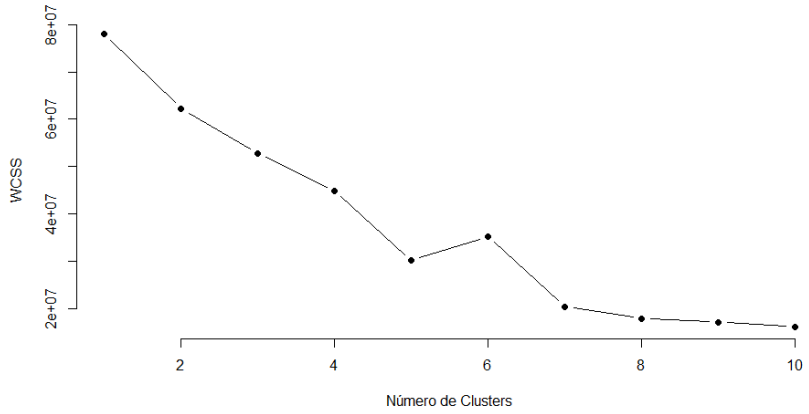
Figure 4. t-SNE of the Sample



Source: Quinello, 2023

To reduce the number of clusters, the optimal cluster count was determined using the Elbow Method. This approach runs the clustering algorithm for each K-value and calculates the Within-Cluster Sum of Squares (WSS), which measures the sum of squared distances between points and their cluster centroid. As shown in Figure 5, beyond 7 clusters, there is no significant improvement in model performance.

Figure 5. Elbow Method for Cluster Selection



Source: Quinello, 2023

For the further reduction of these groups, the unsupervised learning algorithm K-means was used. Its primary function is to group a dataset into K clusters, where K is a predefined number of clusters (in this study, K = 7). Each cluster consists of observations (data points) whose mean (centroid) is the closest. This process minimizes variance within each cluster, grouping similar data points together while separating dissimilar ones.

Without cluster separation, the most frequent combination of real estate assets in the balanced dataset was: UF- Rio de Janeiro (Southeast region); Year of Registration- 2001; Type- Land plot and Area - 174 m².

This suggests that FREM would primarily focus on urban properties that are semi-new and relatively small. However, upon detailed cluster analysis, the complexity increases, as multiple configurations emerge, requiring specific FREM strategies, as detailed in Table 2

Table 2. Cluster Characteristics

Cluster	Region (UF)	Predominant Type	Area (m²)	Registration Year	UF (% of total)	Type (% of total)	Lifecycle (years)
1	RJ (Southeast)	Universities	1.588	2001	18.48	9.67	43
2	PR (South)	Marine	3.950.579	2001	11.74	6.58	43
3	SP (Southeast)	Offices	10.000	2001	17.13	4.79	44

Cluster	Region (UF)	Predominant Type	Area (m²)	Registration Year	UF (% of total)	Type (% of total)	Lifecycle (years)
4	RJ (Southeast)	Military Base	9.438.000	2001	10.85	6.33	37
5	RJ (Southeast)	Museums	202	2001	11.38	6.44	43
6	SP (Southeast)	Shipyards	174	2001	11.62	8.95	42
7	SP (Southeast)	Píers	1.506.303	2001	8.05	6.04	55

Source: Quinello, 2023

The cluster analysis reveals the diversity of federal real estate assets and the necessity for an integrated yet regionally tailored management approach. The property life cycle framework proposed by Santander and Sanchez-Silva (2008) reinforces the importance of considering all stages—from planning to decommissioning—to ensure efficiency and sustainability. The lack of integration in FREM, as highlighted by the TCU report (2022), results in inefficient management and asset underutilization. Therefore, adopting a comprehensive and multifunctional approach is crucial for optimizing the use, maintenance, and renovation of federal properties, ensuring their continued adequacy and functionality.

Cluster 1: This cluster highlighted properties located in urban centers, such as Rio de Janeiro (RJ), predominantly composed of educational facilities such as universities, with an average area of 1,588 m², most of which were registered in 2001. In the context of FREM, managing these assets involves significant complexity due to the diversity of spaces required (classrooms, laboratories, libraries, administrative areas, among others). Their maintenance requires robust planning to ensure safety, accessibility, and functionality, with a strong focus on user experience.

Cluster 2: This configuration, located in the southern region of Brazil, is predominantly composed of marinas, with a total area of 3,950,579 m². Marinas require a specialized management approach, focusing on the maintenance of aquatic structures, vessel management, and support services (such as refueling and security). The vast area covered poses logistical and operational challenges, where environmental preservation and compliance with maritime regulations are essential for efficient and sustainable operations.

Cluster 3: This group, located in the southeastern region, is characterized by office spaces with an average area of 10,000 m². Managing large office spaces involves optimizing space usage, ensuring comfortable and productive environments for occupants. Key aspects include climate control, lighting, security, and cleaning services. Additionally, flexibility in adapting spaces to organizational changes and occupant needs is a crucial practice in FREM.

Cluster 4: Still in the southeastern region, this cluster presents the largest individual area, totaling 9,438,000 m². Large-scale bases, possibly military or industrial, require complex facility management, encompassing perimeter security, maintenance of

heavy infrastructure, and operational efficiency. Worker safety and compliance with safety and environmental regulations are essential. Managing such facilities involves detailed coordination of various systems and processes to ensure continuous and secure operations.

Cluster 5: This group, represented by museums with an average area of 202 m², consists of cultural facilities. Managing museums requires special attention to collection preservation, environmental control (temperature, humidity), and security to prevent theft and damage. Additionally, visitor experience is central, necessitating accessible, informative, and comfortable facilities.

Cluster 6: This cluster, covering the southeastern region, includes shipyards with a support area of 174 m². Managing shipyards is challenging due to the need for coordinating large-scale construction projects, maintaining heavy machinery, and managing risks. Workplace safety, compliance with environmental regulations, and operational efficiency are crucial. Waste management and pollution control are critical aspects to ensure sustainable shipyard operations.

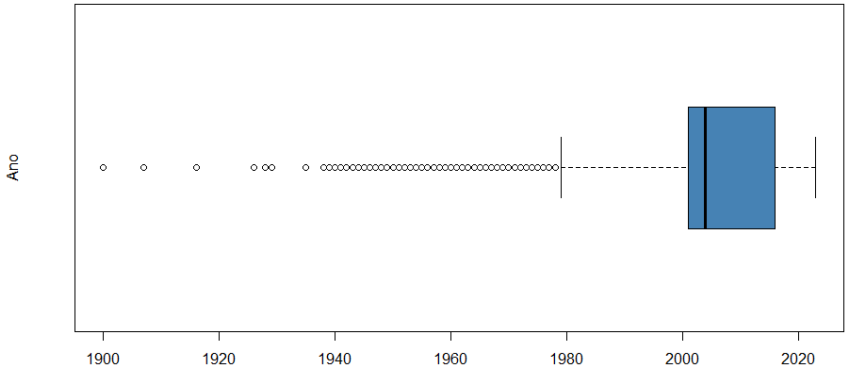
Cluster 7: Finally, the pier cluster, located in São Paulo (SP), covers an area of 1,506,303 m². Managing these facilities involves maintaining maritime structures, overseeing commercial and recreational activities, and ensuring security and accessibility. Piers require an integrated approach that considers both environmental preservation and operational efficiency. Facility management must ensure structural integrity, safe activity operations, and minimal environmental impact.

The cluster analysis highlights the diversity of federal real estate assets and the need for an integrated management approach that respects regional particularities throughout the entire life cycle. The real estate life cycle, as described by Santander and Sanchez-Silva (2008), underscores the importance of considering all stages—from planning to decommissioning—to ensure efficiency and sustainability.

The lack of integration in FREM management, as mentioned in the Federal Court of Accounts (TCU) report (2022), can lead to inefficient administration and underutilization of assets. Therefore, implementing an integrated and multifunctional approach is crucial to optimize the use, maintenance, and renovation of federal properties, ensuring their continued adequacy and functionality.

Additional Observations Based on Data Analysis: (i) Diversity and Complexity: The diversity of real estate types (63 subtypes), including land plots, farms, buildings, and others, highlights the complexity of managing these assets. Each property type requires specific strategies, considering physical characteristics such as size and purpose; (ii) Regional Concentration: While São Paulo and Rio de Janeiro hold a significant concentration of properties, the importance of other regions with distinct geographic characteristics should not be overlooked. A more detailed analysis could reveal usage patterns and specific demands in each geographic area, establishing critical infrastructure and tailored service contracting strategies; (iii) Property Age: As previously highlighted, analyzing the average age of properties provides valuable insights into the life cycle of these assets. The uneven distribution, predominantly between 2000 and 2020, suggests the presence of different maturity stages, implying varied needs for maintenance, technology updates, and investment, as illustrated in Figure 6.

Figure 6. Boxplot: Year of Property Registration



Source: Quinello, 2023

Overall, the data provided a comprehensive view of the landscape of federal real estate assets in Brazil. For more effective management, it would be beneficial to conduct more granular analyses, considering different variables and segmenting the data according to specific criteria. Additionally, specific strategies can be developed to address the identified challenges, aiming to optimize resource utilization and reduce operational costs.

4. Conclusions and recommendations

Currently, the FREM industry in the private sector, which is already well established, presents significant figures both in terms of the number of professionals and the volume of allocated resources. According to a report by McKinsey (Adhikari et al., 2018), the sector was projected to generate around $1.9 trillion globally between 2018 and 2024, with an annual growth rate of 6.2%. The number of professionals working in the field in the United States alone, where official records and statistics exist for this occupation, exceeds 700,000 formalized workers (DATA USA, 2023). In Brazil, due to the recent approval of the Brazilian Classification of Occupations (CBO) in 2023, there are still no official statistics on these numbers (BRASIL, 2023b). Nevertheless, it can be concluded that the management models adopted in this field have a high social, economic, and political impact.

According to Mordor Intelligence (2021), an integrated management model is expected to see the highest growth in the coming years. This aligns with academic studies, which indicate an extrapolation of the discipline's endogeneity, given the externalities previously described in the sections above. Thus, the primary contribution of this study was to present a FREM model that can contribute to integrated and efficient management while respecting the regional particularities of Brazilian real estate assets. This management approach is crucial for the country's economy, which will also face major challenges in the near future, such as decarbonization, energy transition, and the new green agenda.

FREM can leverage its theoretical and practical framework, developed over decades in the private sector, and apply it to the public sector. It is essential to rethink the strategic positioning of real estate assets and the infrastructure associated with them. Although some isolated cases of FREM adoption have emerged in certain government agencies—such as SABESP, the Ministry of Economy, ENAP, and SPGG—these efforts are insufficient to scale the proposed model to encompass the vast portfolio of federal real estate assets. However, beyond the recommendations of the Federal Court of Accounts (TCU, 2022), effective FREM management in the public sector should consider several key premises.

Geographic Distribution of Assets: Given Brazil's vast territorial dimensions, it is crucial to adopt technological solutions such as satellite mapping and conduct frequent audits to assess the condition of properties and building infrastructure. This includes evaluating the quality of services provided in these spaces. Without this data, it is impossible to accurately estimate the necessary budget for the proper conservation and allocation of these assets.

Diversity of Assets: Due to the immense variety of property types, efficient management must incorporate multiple action strategies to establish optimal quality standards and contractual agreements for service provision. Additionally, it is necessary to seek the best synergy strategies for scope standardization, supplier accreditation, continuous validation, and operational standardization whenever possible.

Centralization of FREM Activities: Coordinating all FREM actions under a single federal agency, consolidating all data and initiatives, similar to the model adopted by the United Kingdom, could significantly optimize costs by eliminating redundant positions and activities.

These practices not only ensure the functionality and efficiency of real estate assets but also reflect a pioneering commitment to the quality of services provided to citizens. The effective implementation of these processes is essential for the success of government real estate asset management, aligning with regulatory principles and promoting sustainable use of public property.

Although this study addresses important aspects of public sector real estate asset management, it is essential to acknowledge certain limitations and outline potential areas for future research: (i) Limitations: This study did not conduct an in-depth analysis of legal and regulatory issues related to real estate asset management in the Brazilian context. Future studies could explore these dimensions to provide a more comprehensive understanding of the legal environment; (ii) International Comparison: A comparative analysis with international public-sector real estate management practices could provide valuable insights. Investigating approaches adopted by other countries could inspire best practices and innovative strategies for the Brazilian context; (iii) Inclusion of Municipal and State Properties: The same efforts recommended for the federal level should also be applied to state and municipal properties, especially with the opening of real estate data; (iv) Improving Available Data: There is an urgent need to add and consolidate key information, including: Total built area for each property (not just land area); Condition of conservation; Occupancy data (fixed and variable number of users). Without this

data, it becomes difficult to extrapolate figures for adequate budget planning. By acknowledging these limitations and pointing to future research directions, it is possible to further strengthen the understanding and effective application of FREM in the Brazilian public sector. This will promote sustainable and efficient management of public real estate assets, ultimately generating positive impacts on society.

Conflict of Interest Statement

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Acknowledgment

Not the case.

References

Adhikari, S.D., Hoffman, S., and Lietke, B. (2018). *Six emerging trends in facilities management sourcing.* McKinsey & Company. Retrieved from: Six-emerging-trends-in-facilities-management-sourcing.pdf.

Alexander, K., Brown, M. (2006). Community-based facilities management. *Facilities*, 24(7/8), 250-268. https://doi.org/10.1108/02632770610666116

Bjørberg, S., Haugen, T.I., and Lindkvist, C. (2017). Contribution of facilities management to value creation. *Journal of Facility Management*, 14, 7-21.

Brasil. (2019). Ministério da Economia. *Projeto gestão integrada de prédios públicos*. Retrieved from https://www.gov.br/economia/pt-br/assuntos/gestao/central-de-compras/noticias/ministerio-da-economia-contrata-servico-de-gestao-integrada-de-predios-publicos.

Brasil. (2023a). *Artigo 99 da Lei nº 10.406 de 10 de janeiro de 2002*. Código Civil. Retrieved from http://www.planalto.gov.br/ccivil_03/leis/2002/L10406.html.

Brasil. (2023b). *Classificação Brasileira de Ocupação*. Retrieved from http://www.mtecbo.gov.br/cbosite/pages/pesquisas/BuscaPorTitulo.jsf

Brasil. (2024). *Secretaria do Patrimônio da União*. Dados abertos. Retrieved from https://clusterqap2.economia.gov.br/extensions/SPU-Transparencia_Ativa/SPU-Transparencia_Ativa.html.

Bröchner, J., Haugen, T.I., and Lindkvist, C. (2019). Shaping tomorrow's facilities management. *Facilities*, 37(7/8), 366–380. https://doi.org/10.1108/F-02-2018-0023

Chotipanich, S. (2004). Positioning facility management. *Facilities*, 22(13/14), 364-372. https://doi.org/10.1108/02632770410563086.

Cintra, J.P. (Ed.). (2022). *Territórios em disputa*. São Paulo: EDUSP.

Danivska, V., Appel-Meulenbroek, R. (2022). Collecting theories to obtain an interdisciplinary understanding of workplace management. In R. Appel-Meulenbroek & V. Danivska (Eds.), *A handbook of management theories and models for office environments and services*. https://doi.org/10.1201/9781003128786.

Data USA. (2023). *Facilities managers*. Retrieved from https://datausa.io/profile/soc/facilities-managers.

Decreto nº 9.745, de 08 de abril de 2019. Estrutura regimental e o quadro demonstrativo dos cargos em comissão e das funções de confiança do Ministério da Economia. Retrieved from https://legislacao.presidencia.gov.br/atos/?tipo=DEC&numero=9745&ano=2019&ato=933UTU65keZpWTf87.

Decreto nº 9.760, de 5 de setembro de 1946. Dispõe sobre os bens imóveis da União e dá outras providências. Retrieved from http://www.planalto.gov.br/ccivil_03/Decreto-Lei/Del9760.htm.

Dhalmahapatra, K., Ghosh, S.K., and Chakraborty, S. (2019). Decision support system for safety improvement: An approach using multiple correspondence analysis, t-SNE algorithm and K-means clustering. *Computers & Industrial Engineering*, 128, 277-289. https://doi.org/10.1016/j.cie.2018.12.044.

ENAP. (2021). Escola Nacional de Administração Pública. *Consulta Pública nº 01/2021* - Facilities - Termo de Referência. Retrieved from https://www.enap.gov.br/pt/acesso-a-informacao/licitacoes-e-contratos/licitacoes/licitacoes-2021/consulta-publica-n-01-2021-facilities-termo-de-referencia.

Gomez, S.M., Mendoza, O.E., and Ramírez, M.P. (2020). Stress and myths related to the COVID-19 pandemic's effects on remote work. *Management Research: Journal of the Iberoamerican Academy of Management*, 18(4), 401-420. https://doi.org/10.1108/MRJIAM-06-2020-1065.

IBGE. (2024). *Instituto Brasileiro de Geografia e Estatística*. Áreas territoriais. Retrieved from https://www.ibge.gov.br/geociencias/organizacao-do-territorio/estrutura-territorial/15761-areas-dos-municipios.html.

ISO 41.001. (2017). *Facility management — Management systems — Requirements with guidance for use*. Retrieved from https://www.iso.org/standard/68021.html.

Lindkvist, C., Temeljotov-Salaj, A., Collins, D., Bjørberg, S., and Haugen, T.I. (2021). Exploring urban facilities management approaches to increase connectivity in smart cities. *Facilities*, 39(1/2), 96-112. https://doi.org/10.1108/F-08-2019-0095.

Michell, K. (2013). Urban facilities management: A means to the attainment of sustainable cities? *Journal of Facilities Management*, 11(3), 18-32. https://doi.org/10.1108/JFM-12-2012-0051.

Mordor Intelligence. (2021). *Europe facility management market – Growth, trends, COVID-19 impact, and forecasts (2021-2026).* Retrieved from https://www.mordorintelligence.com/industry-reports/europe-facility-management-market.

Ramírez-Alujas, Á.V. (2012). Gobierno abierto es la respuesta: ¿Cuál era la pregunta? Más Poder Local. *Dialnet*, (12), 14-22. Retrieved from https://dialnet.unirioja.es/servlet/articulo?codigo=4013852.

Roberts, P.; Edwards, L.H. (2023). Portfolio management: A new direction in public sector strategic management research and practice. *Public Administration Review*. https://doi.org/10.1111/puar.13633.

SABESP. (2017). *Pregão Sabesp Online CSS 12.826/17*. Retrieved from https://site.sabesp.com.br/site/interna/Default.aspx?secaoId=675.

Santander, C., Sanchez-Silva, M. (2008). Design and maintenance programme optimization for large infrastructure systems. *Structure and Infrastructure Engineering*, 4, 297-309. https://doi.org/10.1080/15732470601116167.

SPGG. (2023). Secretaria de Planejamento, Governança e Gestão. *Audiência Pública Facilities do Estado do Rio Grande do Sul*. Retrieved from https://planejamento.rs.gov.br/audiencia-publica-facilites.