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CONTRIBUTIONS OF GEOTECHNOLOGY TO URBAN AND TOURISM PLANNING: THE CASE OF RAILWAY AREAS IN IPERÓ (SP)

CONTRIBUIÇÕES DA GEOTECNOLOGIA PARA O PLANEJAMENTO URBANO E TURÍSTICO: O CASO DAS ÁREAS FERROVIÁRIAS EM IPERÓ (SP)

CONTRIBUCIONES DE LA GEOTECNOLOGÍA AL PLANIFICACIÓN URBANA Y TURÍSTICA: EL CASO DE LAS ÁREAS FERROVIARIAS EN IPERÓ (SP)

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ABSTRACT: The municipality of Iperó (SP), located within the Western Paulista Railway Network, contains a partially inactive railway segment of significant historical and geographical relevance, associated with the former Sorocabana Railway and the Itararé branch line. The deactivation of the track and the discontinuation of passenger services encouraged urban expansion around the rail corridor, leading to the occupation of areas previously linked to railway infrastructure and the emergence of urban bottlenecks. This study analyzes the potential of orthomosaics for the precise mapping of selected railway areas in Iperó, drawing on a literature review of the use of Unmanned Aerial Vehicles (UAVs) to generate high-resolution spatial data. The investigation focuses on applying geotechnologies to strategic locations associated with railway heritage and urban planning, including the railway yard, Varnhagen Station, and the Bela Vista and Bacaetava neighborhoods.

KEYWORDS: Railway infrastructure. Geotechnologies. Urban planning.

***RESUMO**: O município de Iperó (SP), integrante da Malha Oeste Paulista, abriga um trecho ferroviário parcialmente inoperante, de relevante valor histórico e geográfico, vinculado à antiga Estrada de Ferro Sorocabana e ao ramal de Itararé. A desativação da linha e o fim do transporte de passageiros estimularam o crescimento urbano em seu entorno, resultando na ocupação de áreas antes associadas à infraestrutura ferroviária e na formação de gargalos urbanísticos. Este estudo analisa o potencial dos ortomosaicos para o mapeamento preciso de áreas ferroviárias selecionadas em Iperó, fundamentando-se em revisão bibliográfica sobre o uso de Veículos Aéreos Não Tripulados (VANTs) na geração de dados espaciais de alta resolução. A investigação concentra-se na aplicação de geotecnologias em pontos estratégicos relacionados à memória ferroviária e ao planejamento urbano, como o pátio ferroviário, a Estação Varnhagen e os bairros Bela Vista e Bacaetava.*

***PALAVRAS-CHAVE**: Infraestrutura ferroviária. Geotecnologias. Planejamento urbano.*

***RESUMEN**: El municipio de Iperó (SP), integrante de la Red Ferroviaria del Oeste Paulista, alberga un tramo ferroviario parcialmente inoperante, de notable valor histórico y geográfico, vinculado al antiguo Ferrocarril Sorocabana y al ramal de Itararé. La desactivación de la línea y el fin del transporte de pasajeros impulsaron el crecimiento urbano en su entorno, lo que resultó en la ocupación de áreas anteriormente asociadas a la infraestructura ferroviaria y en el surgimiento de estrangulamientos urbanísticos. Este estudio analiza el potencial de los ortomosaicos para el mapeo preciso de áreas ferroviarias seleccionadas en Iperó, basándose en una revisión bibliográfica sobre el uso de Vehículos Aéreos No Tripulados (VANT) en la generación de datos espaciales de alta resolución. La investigación se centra en la aplicación de geotecnologías en puntos estratégicos vinculados a la memoria ferroviaria y a la planificación urbana, como el patio ferroviario, la estación Varnhagen y los barrios Bela Vista y Bacaetava.*

***PALABRAS CLAVE**: Infraestructura ferroviaria. Geotecnologías. Planificación urbana.*

Introduction

Railway infrastructure played a central role in the territorial shaping and socioeconomic development of Brazil, significantly influencing the processes of urbanization, occupation, and regional integration, especially between the 19th and 20th centuries. Implemented with the purpose of moving agricultural and mineral production, and connecting productive areas to the coast and the foreign market, the railway network shaped the formation of cities and structured economic and social dynamics in various regions of the national territory.

The Sorocabana Railway distinguished itself in passenger transport in the state of São Paulo, contributing to the transformation of villages into dynamic urban centers, influencing urban layout, the location of public facilities, and the configuration of working-class neighborhoods and commercial areas. However, the process of deactivating railway sections and the decline in passenger transport have resulted in underutilized urban fragments, often associated with inadequately regulated level crossings and the creation of physical barriers in the urban fabric. As Perpétuo and Tardin-Coelho (2021) highlight, residual spaces resulting from railway deactivation should not be understood as logistical bottlenecks, but as latent infrastructures that, when neglected, tend to reinforce territorial fragmentation; when integrated into urban planning policies, they can assume a strategic role in environmental and social reconnection, transforming liabilities into urban assets.

On the other hand, international experiences demonstrate that former railways can be repurposed into tourist, cultural, and environmental corridors, fostering processes of territorial redevelopment and urban integration. The Rails-to-Trails Conservancy (2025), a North American organization dedicated to creating trails from deactivated railways, documents the transformation of more than 42,500 miles of railway lines into bike paths, trails, and linear parks in the United States, highlighting the potential of these spaces to reconnect communities, preserve railway heritage, and encourage active mobility practices. In the Brazilian context, Afonso (2017) analyzes the socioeconomic and environmental impacts of activating tourist trains, highlighting their relevance for local income generation, heritage preservation, and territorial valorization.

In this context, geotechnologies have assumed a strategic role in territorial diagnosis and the management of railway assets. The advancement of technologies such as Unmanned Aerial Vehicles (UAV), remote sensing, and Geographic Information Systems (GIS) platforms has enabled more precise, continuous, and real-time analyses. Maghazei and Steinmann (2020) highlight the integration of these technologies in Swiss railway operations, pointing out their

application in the monitoring, planning, and maintenance of railway lines. Complementarily, Askarzadeh, Bridgelall, and Tolliver (2023), in conducting a systematic review, indicate that the use of UAVs reduces the need for extensive manual surveys, increases the accuracy of geospatial data, and enhances the preventive maintenance of infrastructure. Giunta *et al*. (2025) evaluate in their study that three-dimensional modeling and the assessment of the structural integrity of the permanent way, within a perspective of advanced digital management, can assist in inspections.

In the national context, Souza (2023) highlights structural challenges related to the absence of unified cadastral legislation and the low standardization of territorial data, factors that compromise the consolidation of efficient urban and railway management systems. Thus, the use of geotechnologies transcends a merely instrumental dimension, establishing itself as a strategic tool for sustainable urban planning and the territorial integration of underutilized railway assets.

In the municipality of Iperó, located in the central region of the state of São Paulo, the railway has significantly shaped the urban landscape, local mobility, and cultural identity. With the interruption of regular operations, part of this infrastructure has come to represent a challenge for territorial planning, but also an opportunity for strategies based on historical and cultural tourism. Despite the relevance of the topic, there is a gap in applied studies that connect the precise mapping of the inoperative railway network with proposals aligned with sustainable urban planning. In this context, technologies such as UAVs, associated with cartographic analyses and field surveys, offer accurate data that can support integrated public actions aimed at the reconnection between railway, city, and community.

This study aims to analyze specific sections of the inoperative railway that crosses the municipality of Iperó (SP), delimiting areas of greater relevance to understand its territorial impacts and dynamics of transformation. The diagnosis was prepared based on the integration of satellite imagery and local inspections, with geotechnologies being addressed as fundamental tools to support territorial diagnosis and requalification processes, allowing for the identification of sectors with potential for urban, tourism, and heritage requalification.

Based on this context, the aim is to propose integrated urban planning actions that value historical heritage, encourage sustainable tourism practices, and strengthen the municipality's territorial identity.

Justification

The city of Iperó possesses a significant railway heritage, represented by the disused sections of the old Sorocabana Railway and the historic Fazenda Ipanema, elements that bestow a valuable tangible and intangible heritage upon the urban landscape. However, the lack of integration between these structures and urban planning and territorial management instruments keeps these spaces in a state of underutilization, limiting their potential for the municipality's tourism, cultural, and environmental development. The growing demand for creative and sustainable solutions in the tourism sector has directed attention to the repurposing of obsolete railway infrastructure, especially in small and medium-sized cities. Railway tourism emerges as an alternative that integrates historical preservation, local income generation, and community appreciation. In this sense, the underutilized railway network of Iperó presents itself as a strategic opportunity for the creation of cultural and environmental itineraries.

This perspective is in dialogue with Oliveira (2017), by highlighting that the preservation and activation of railway assets, such as workshops and stations, constitute an essential part of collective memory and work culture, reinforcing the link between historical heritage and urban identity. Furthermore, the advancement of geotechnologies, such as Geographic Information Systems (GIS) and Unmanned Aerial Vehicles (UAVs), allows for new forms of diagnosis and planning, offering technical support for area identification, land use analysis, and territorial monitoring.

These tools transform spatial data into applied knowledge, contributing to more precise and effective decisions in urban planning. Thus, this research is justified by the relevance of recovering historical heritage and reinterpreting the geographical functionality of the railway in Iperó, aiming at its integration into urban dynamics and territorial planning. Through an interdisciplinary approach involving geography, urbanism, tourism, and technology, the aim is to reveal the potential of abandoned railway infrastructure and propose concrete paths for its reintegration into the city's urban and tourist daily life.

Methodology

The bibliographic review conducted covered scientific literature specialized in geotechnologies and the application of UAVs in railway inspection. This study is characterized as exploratory, with a focus on documentary analysis, such as bills. It focuses on understanding

the urban spatial dynamics related to Brazilian railway infrastructure, restructured for tourism purposes.

Technical inspections were also carried out at the old railway stations, both in Iperó and Varnhagen, as well as in the Bacaetava and Bela Vista neighborhoods in Iperó, complemented by analyses of satellite images obtained from digital platforms. This procedure enabled the visual validation of the spatial information and the identification of areas with potential for tourism development in the region. To support the analyses, different instruments were employed: Google Earth Pro, used for obtaining satellite imagery and geographic location; and QGIS (Geographic Information System), applied to georeferencing, for the creation of thematic maps and spatial analysis, delimiting the areas covered by the railway network. The analyzed areas show potential for future applications of geotechnologies aimed at the surveying, monitoring, and documentation of railway heritage. The integration of cartographic and geospatial information constitutes a relevant tool for territorial planning and the management of areas of historical and cultural interest, as discussed by Souza (2023). Complementarily, Askarzadeh, Bridgelall, and Tolliver (2023) and Maghazei and Steinmann (2020) highlight that UAVs can increase the accuracy and efficiency of spatial surveys, favoring conservation, management, and requalification actions for railway infrastructure.

Railway Heritage and Tourism Redevelopment

The integration of tourist trains into urban settings that have idle railway sections has become established as an effective strategy to promote regional development, preserve historical heritage, and stimulate sustainable tourism. According to Bill No. 3803/2024, the intention is to ensure the continuity of non-regular rail transport on sections returned by concessionaires (Brazil, 2024). According to Afonso (2017), this mode of transport transforms old railway lines into cultural and economic attractions, reviving the Brazilian railway identity and fostering new opportunities for the communities involved.

Table 1 presents examples, in Brazil, of locations where the redevelopment of idle railway sections was directed towards tourist passenger transport. Among the environmental and urban benefits associated with the operation of tourist trains, the restoration of old railway stations and significant improvements to local infrastructure stand out. Another relevant aspect refers to the cultural appreciation of the municipalities, promoted by the rescue of historical

traditions. The connection between locations through tourist trains stimulates the flow of visitors and strengthens regional cooperation.

Table 1 – Tourist train operation in Brazil

Tourist train	Location	Dealership	Road length	Average speed	Research source
Maria Fumaça – Bento Gonçalves (RS)	Bento Gonçalves to Carlos Barbosa (RS)	Giordani Turismo / Rumo Logística	23 km	30 km/h	NATIONAL LAND TRANSPORTATION AGENCY
Serra Verde Express – Curitiba to Morretes (PR)	Curitiba to Morretes (PR)	Serra Verde *Express*	68 km	20–40 km/h	NATIONAL LAND TRANSPORTATION AGENCY
Vitória to Minas Railway (MG–ES)	Belo Horizonte (MG) to Cariacica (ES)	Vale S.A.	905 km	up to 70 km/h	NATIONAL LAND TRANSPORTATION AGENCY
Corcovado Train – Rio de Janeiro (RJ)	From Cosme Velho to Christ the Redeemer (RJ)	Esfeco Ltd. / ICMBio	3,824 km	15–25 km/h	ICMBio (Chico Mendes Institute for Biodiversity Conservation)
Water Train – São Lourenço to Soledade (MG)	São Lourenço to Soledade de Minas (MG)	ABPF – Brazilian Railway Preservation Association	20 km	up to 30 km/h	NATIONAL LAND TRANSPORTATION AGENCY
Campinas Steam Train (SP)	Campinas to Jaguariúna (SP)	ABPF – Brazilian Railway Preservation Association	25 km	20 – 25 km/h	ABPF - Campinas Steam Train

Source: Prepared by the authors, based on the literature review (2025)

The railway in its context in the development of the Municipality of Iperó

Railway infrastructure, in its longitudinal sense, was a decisive factor in inducing urbanization and territorial structuring; however, the process of abandoning a large part of the country's railway network eventually rendered even its physical presence invisible (Perpétuo; Tardin-Coelho, 2021, p. 5).

The municipality of Iperó emerged around the old Sorocabana Railway, inaugurated in 1928, as a strategic point on the main line and the Itararé branch. In this context, the Santo Antônio Nova Station was built, later named the Iperó Railway Station (Prefeitura de Iperó, 2025). The railway played a fundamental role in the city's urban and economic development until the interruption of passenger transport in 2001. Table 2 presents the evolution of the railway, highlighting its historical influence and the impacts resulting from its trajectory.

Table 2 – History of the Iperó railway

Year	Event	Description	Research source
1870	Foundation of the EFS (Sorocabana Railway)	Created by businessmen led by Luís Mateus Maylasky to connect São Paulo to the Royal Iron Factory of Ipanema.	Railway Memory Project – UNESP
1875	Official inauguration	The first section of the Sorocabana Railway is inaugurated, connecting São Paulo to Sorocaba.	Railway Stations of Brazil
1876	Arrival of the railway in Iperó	Implementation of the Santo Antônio Nova station, a strategic point on the trunk line.	Iperó Railway Station – SP
1909	Itararé Branch Line	Construction of the branch line connecting Iperó to Itararé, expanding regional integration.	UNESP – Railway Memory
1928	Urban expansion	The railway boosts the urban and economic growth of Iperó.	IBGE – Municipal History
1944	Vila Santo Antônio becomes a district	The railway village is elevated to the category of district of Boituva.	Iperó City Hall – History
1965	Political emancipation	Iperó becomes a municipality, consolidating its urban railway identity.	IBGE – Municipal History
1971	Merger with FEPASA	The EFS is incorporated into Ferrovia Paulista S.A., marking the beginning of the decline of passenger transport.	Railway Memory – UNESP
2001	Discontinuation of passenger transport	Iperó station ends its regular passenger operations.	Iperó Railway Station – SP
2026	Termination of the concession - Malha Oeste	The concession for the railway operated by Rumo Logística expires on July 1st, 2026, as provided for by ANTT.	ANTT – Railway Concessions

Source: Prepared by the authors, based on the literature review (2025).

In this context, the municipality of Iperó (SP) represents an exemplary case: with urban roots directly associated with the old Sorocabana Railway, the city grew around the Santo Antônio Nova station, becoming a territorial hub between Sorocaba (SP) and Tatuí (SP). The railway boosted the economy and organized urban space until its deactivation in 2001.

The approval of Law No. 3803/24 (Brazil, 2024) represents a strategic opportunity for the redevelopment of railway assets, opening up new perspectives for use focused on sustainable tourism, heritage enhancement, and integrated territorial management. In this context, the configuration of the railway lines in Iperó, according to data from the National Land Transportation Agency (ANTT, 2025), reinforces the importance of these sections as structuring elements of the territory and potential drivers of new urban and socioeconomic dynamics.

The railway line that runs through the municipality of Iperó has the following railway configuration (ANTT, 2025):

- **Line name**: Sorocabana Branch / West Network;
- **Track Gauge[4] predominant**: Metric (1.00 m), the standard used in most of the São Paulo railway network;
- **Current status**: Inoperative sections partially used for cargo transport;
- **Current concessionaire**: Rumo Malha Oeste S.A.

On May 18, 2025, a technical, documentary, and photographic inspection was carried out at locations indicated by tourism agents in the city of Iperó, Table 3. The right-of-way extends through urban and peri-urban areas, as well as the vicinity of Fazenda Ipanema and the city's historic center. The railway crosses the urban core, directly influencing the pattern of population growth around it.

Table 3 – Railway Configuration of Iperó in the studied locations

Element	Iperó Station	Beautiful View	Bacaetava	Varnhagen
Gauge	Metric (1.00 m)	Metric (1.00 m)	Metric (1.00 m)	Metric (1.00 m)
Rail kilometer	km 127 and 130 of the main line, with an intersection with the Itararé branch	Iperó, heading south of the state	km 133.932 (1931 reference)	km 124 (1931 reference)
Opening date	December 21, 1928	Activated from Iperó in 1929	August 1, 1880 (new station in 1928)	1928 – construction and commissioning of the new station
Original name of the station	Saint Anthony New	The branch line originally started from Boituva	Bacaetava (New)	Ipanema – renamed to Varnhagen in 1949
Historical function	Strategic point of the Sorocabana main line	Connection between Sorocaba and Itararé (SP), passing through Itapeva (SP) and Apiaí (SP)	It served the village of Bacaetava and the Ipanema Farm	It served the Royal Iron Factory of São João de Ipanema
Current situation	Section active for freight; out of service for passengers since 2001. Partially used for cargo transport	Inactive for passengers since 2001	Station demolished in 1981; platform still visible. Partially used for cargo transport	Listed by CONDEPHAAT in May 2022, becoming part of the historical heritage of São Paulo.

Source: Prepared by the authors, based on the literature review (2025).

[4] Track Gauge: the distance between the rails of a railroad

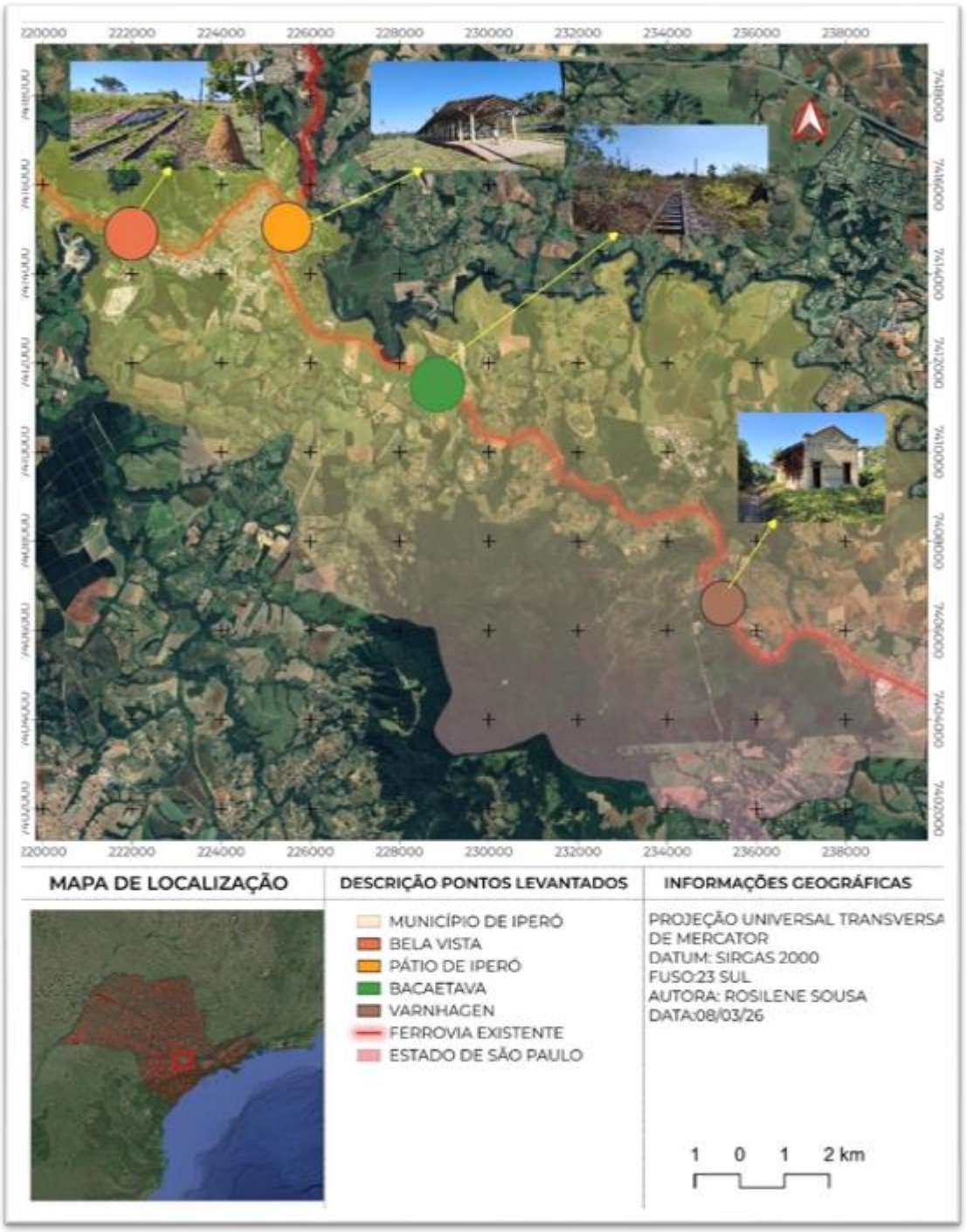
The locations highlighted in Figure 1 correspond to strategic points in the municipality of Iperó related to railway history. The station yard represents the former operational zone, where support structures for railway activity were concentrated. Varnhagen Station marks the site of the former stop, integrated into the historical complex of the Sorocabana Railway. The neighborhoods of Bela Vista and Bacaetava, in turn, maintain direct links with the original railway layout, revealing the persistence of this infrastructure in the contemporary urban configuration. The presented cartography contributes to understanding how these spaces are articulated between railway heritage, territory, and potential for tourism redevelopment.

During the inspection, it was possible to assess that the infrastructure associated with the Iperó station constitutes a railway yard with some operational tracks, a reversing triangle, rail workshops, an electrical substation, and the preserved station building.

According to the Prefeitura Municipal de Iperó (2025), the development of the municipality was directly related to the expansion of the Sorocabana Railway. The station became part of the electrified main line in 1946 and received the name Iperó in 1949, consolidating itself as an important element of regional economic and social dynamics throughout the 20th century.

According to information obtained by the Empresa [...] report (2023), the station remained for some years as a parking area for freight and passenger cars, while its complex deteriorated, exposed to the elements. The analysis of satellite images allowed for the mapping of the railway yard facilities, which include a permanent way sector, overhead line maintenance areas, a power substation, a rail welding workshop with an access spur, a large yard with multiple tracks, and a reversing triangle.

Figure 1 – Boundary of the municipality of Iperó and study areas



Source: Authors' elaboration (2026).

In 2017, the station indicated in Figure 2 was restored after being recognized as a Heritage Site of the Municipality of Iperó. The building regained characteristics of its original configuration, preserved throughout nearly one hundred years of history. Currently, the space houses social and cultural projects, such as the School of Arts, the Senior Citizens' Center, and the Anti-Drug Project (Restaurada [...], 2025).

Figure 2 – Iperó Railway Yard and Railway Station

Source: Authors' elaboration (2025).

In the railway station complex, there is still a remnant of the structure of the Sorocabana Railway's Welding Workshop (Figure 3). It represents a space with high potential for urban, cultural, and tourism redevelopment, especially due to its historical dimension, strategic location, and connection to the city's railway heritage. The area underwent cleaning and space adaptation interventions, culminating in its official transfer from the Union to the municipality (Railway Memory Project – Unesp, 2025).

Figure 3 – Remnant of the old welding workshop

Source: Authors' elaboration (2025).

The same project describes that the Sorocabana Railway's rail welding workshop was built in 1938, remained active until the passenger network deactivation process in the 1990s,

and was subsequently abandoned for decades. Located near the urban center and the axis of the old main line, with easy access via municipal roads, it represents one of the last vestiges of the Sorocabana's technical infrastructure. The removal of more than 200 scrapped railcars enabled the transformation of the space into a multipurpose area, fostering urban reconfiguration and the emergence of new uses in the surrounding area.

Four kilometers from the railyard, there are remains of the Bela Vista railway platform. Near the old Itararé branch line stood the former permanent way warehouse. This location has undergone various processes of informal subdivision and urban occupation in areas originally belonging to the railway right-of-way.

The Iperó City Hall has initiated land regularization actions in the Bela Vista neighborhood (adjacent to Boa Vista), highlighting the occupation of public areas and the need for legalization. The presence of abandoned railway infrastructure (Figure 4) contributed to peripheral expansion, with residential occupations in areas formerly designated for railway operations.

Figure 4 – Remnant of the platform of the former Bela Vista Station

Source: Authors' elaboration (2025).

The Bacaetava neighborhood, in the district of Iperó (SP), originally linked to the station inaugurated in 1880 and demolished in 1981, has experienced recent urbanization with the Residencial Nova Bacaetava development, covering approximately 270,000 m² and with a forecast of 600 housing units. The reconfiguration of the neighborhood includes public investments in security, health, leisure, and basic infrastructure, in addition to environmental enhancement due to its proximity to the Ipanema National Forest, which holds important historical and natural landmarks of the municipality (Iperó Municipal Government, 2025).

According to information made available on the official website of the Iperó Municipal Government, the construction of the railway was the main driver of the settlement's formation, contributing to its administrative consolidation as a district seat in 1953. The urban dynamics of the municipality began to be structured around the railway axis, forming a linear occupation, with streets parallel to the tracks and subdivisions established in the vicinity of the old railway yard. A significant growth of the urban area was observed, with partial encroachment onto areas of the former right-of-way, intensified after the demolition of the station in 1981.

The railway section served a strategic connecting function between the George Oetterer, Varnhagem, and Fazenda Ipanema hubs, although it also acted as an element of physical segregation between adjacent neighborhoods. Following the discontinuation of passenger transport, informal occupations were recorded along segments of the railway right-of-way, necessitating land regularization and territorial planning actions.

The inspection carried out identified the persistence of remnants of the original infrastructure, such as the station platform (Figure 5) and the railway bridge, which still constitute spatial references in the urban landscape. The presence of wild and domestic animals was also recorded in the vicinity of the permanent way. The railway section between Varnhagen and Iperó stations has a partially preserved superstructure.

Figure 5 – Remnant of railway infrastructure

Source: Authors' elaboration (2025).

The Council for the Defense of the Historical, Archaeological, Artistic and Tourist Heritage of the State of São Paulo (Condephaat) published the resolution for the heritage listing of the Varnhagen station, located in the municipality of Iperó (Figure 6). The railway complex

is part of the Ipanema National Forest (Flona) area, managed by the Chico Mendes Institute for Biodiversity Conservation (ICMBio), and has become part of the protected cultural heritage of the State of São Paulo (Condephaat, 2018).

Figure 6 – Varnhagem Station

Source: Authors' elaboration (2025)

Potential for railway redevelopment

Urban redevelopment can be understood as an integrated intervention process that aims to solve urban problems and promote lasting improvements in the economic, physical, social, and environmental dimensions of areas undergoing transformation (Roberts; Sykes, 2000). In the case of obsolete linear infrastructures, such as deactivated or underutilized railways, this process takes on specific characteristics, involving the repurposing of pre-existing structures and their adaptation to new uses, such as alternative mobility, tourism, or public open spaces.

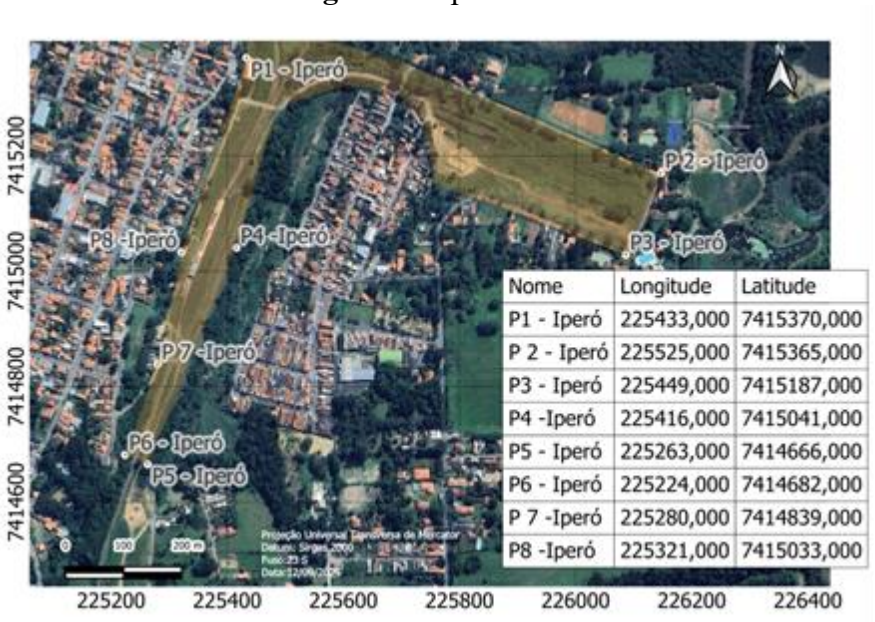
To perform a spatial visualization, the QGIS tool was used for a preliminary analysis of the surveyed locations. The confluence of these sites, presented in the items below, represents a strategic opportunity for integrated territorial planning by linking the preservation of Iperó's railway heritage with the promotion of sustainable practices, social inclusion, and cultural appreciation.

a) Iperó Railway Station Complex

Located between points 4, 5, 6, 7, and 8 of Figure 7, the area has high potential for a railway tourist route, being the final point of a tourist tour between the old Varnhagen station, passing through Bacaetava and ending at Iperó station, with a focus on valuing the railway

heritage of the Sorocabana Railway.

Figure 7 – Iperó Yard



Nome	Longitude	Latitude
P1 - Iperó	225433,000	7415370,000
P 2 - Iperó	225525,000	7415365,000
P3 - Iperó	225449,000	7415187,000
P4 -Iperó	225416,000	7415041,000
P5 - Iperó	225263,000	7414666,000
P6 - Iperó	225224,000	7414682,000
P 7 -Iperó	225280,000	7414839,000
P8 -Iperó	225321,000	7415033,000

Source: Authors' elaboration (2025).

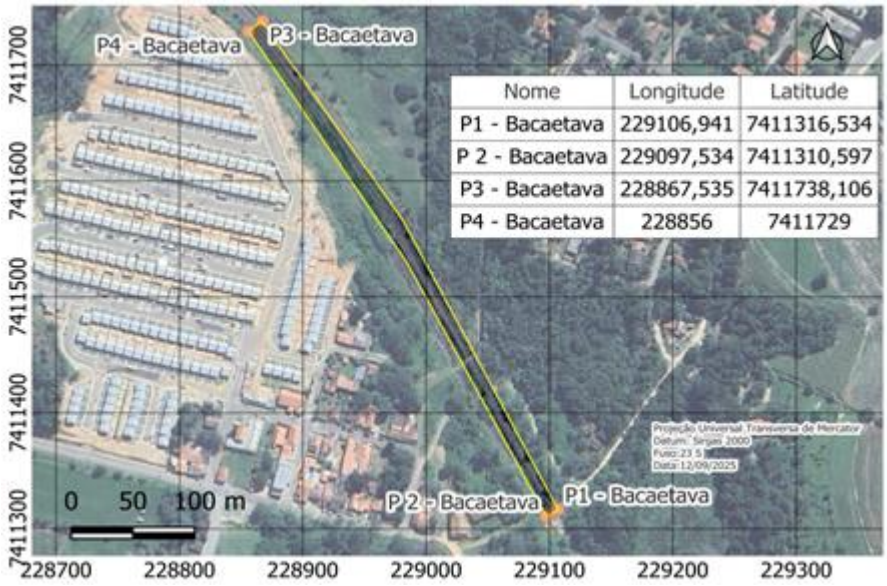
In the railway station complex, only traces of the former Sorocabana Railway Welding Workshop remain between points (1, 2, and 3) of Figure 7. Despite no longer existing as an active structure, the space has high potential for urban, cultural, and tourism redevelopment, due to its historical relevance, strategic location, and connection to the city's railway memory. The area underwent cleaning and adaptation interventions, culminating in its official transfer by the Union to the municipality of Iperó, with the support of the National Department of Transport Infrastructure (DNIT) and the concessionaire Rumo Logística. As recorded by the Railway Memory Project – UNESP (2025), the requalification project was incorporated into the Municipal Culture and Heritage Plan.

The proposal for the redevelopment of the old railway workshop aims not only at the preservation of Iperó's historical-industrial heritage, but also at the promotion of the sustainable use of idle federal public infrastructure. The initiative integrates culture, tourism, and urban planning, anchoring itself in institutional instruments and community participation.

b) **Bacaetava Neighborhood**

The area has high potential for urban and territorial transformation, especially because it is inserted in a context historically associated with the federal railway network and has already been impacted by processes of informal occupation and peripheral expansion (Figure 8).

Figure 8– Railway section in Bacaetava



Nome	Longitude	Latitude
P1 - Bacaetava	229106,941	7411316,534
P 2 - Bacaetava	229097,534	7411310,597
P3 - Bacaetava	228867,535	7411738,106
P4 - Bacaetava	228856	7411729

Source: Authors' elaboration (2025).

There are significant territorial potentialities associated with environmental enhancement and the remaining railway heritage. The proximity to the Ipanema National Forest facilitates the neighborhood's inclusion in sustainable tourism strategies, ecological trails, environmental education, and territorial-based economy. The bibliographic review conducted by Santos, Enokibara, and Fontes (2018) demonstrates that themes such as urban drainage, urban ecology, green corridors, and urban landscape emerge as structuring axes of national research on Green Infrastructure, reinforcing the relevance of the integration between nature, urban function, and environmental requalification within consolidated areas.

In this context, the convergence between natural assets, such as the Ipanema National Forest, and underutilized railway structures creates favorable conditions for redevelopment strategies that reconcile environmental conservation, railway heritage, and new urban dynamics. The perspective of green infrastructure, widely discussed in the trends identified by Santos *et al*. (2018), strengthens this understanding by highlighting the role of ecological corridors and the multifunctionality of green spaces as instruments of urban regeneration and the promotion of sustainability.

While green infrastructure projects are often associated with environmental improvements and strengthening urban resilience, recent studies indicate that such interventions can likewise trigger processes of land value appreciation and socioeconomic displacement. Anguelovski *et al*. (2019) demonstrate that climate adaptation initiatives based on

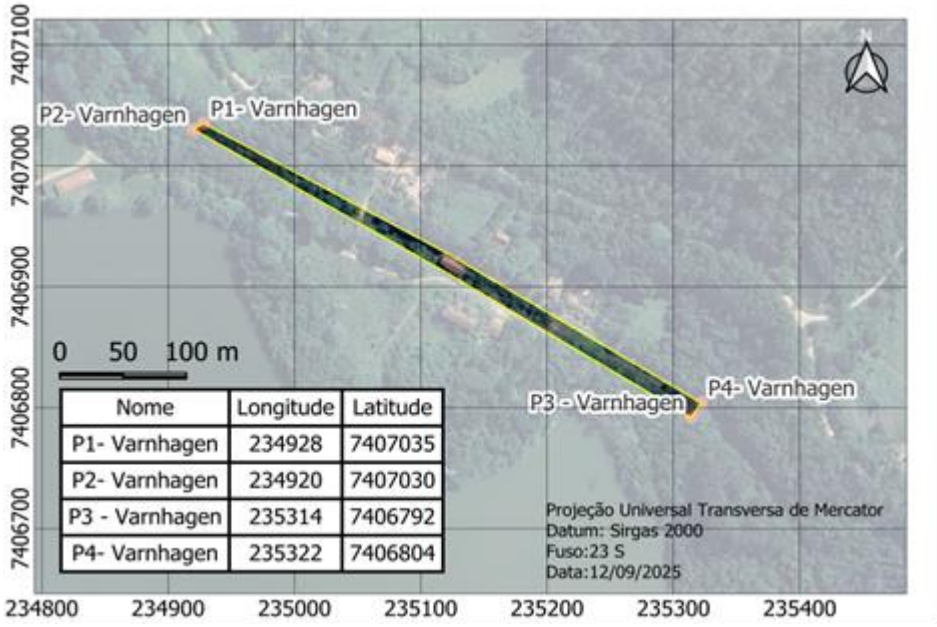
environmental solutions, when implemented without adequate social safeguards, tend to favor urban restructuring dynamics that pressure low-income populations and racialized groups, resulting in indirect displacement driven by speculation and the transformation of urban spaces. In the same vein, Lees (2008) argues that urban renewal policies driven by redevelopment objectives, when conducted without effective mechanisms to protect resident populations, tend to intensify inequalities and foster processes of resident displacement. For the author, interventions of this kind can only promote inclusion when they incorporate safeguards that ensure the permanence of the communities, valuing their social ties and their historical conditions of belonging.

Regarding railway infrastructure, the section is currently operated for freight transport by the concessionaire Rumo Logística. Part of the tracks remains active; however, segments with high vegetation and signs of irregular maintenance can be observed. The historic railway platform, built in 1928, remains as a remnant element of the railway complex. The strategic location, associated with the historical heritage and the proximity to the Ipanema National Forest, reinforces the area's relevance for a sustainable territorial development project, provided it is accompanied by appropriate urban planning and socio-environmental protection measures.

c) **Varnhagen Station Complex**

The electrical substation has been deactivated since 1999, presenting precarious infrastructure that is vulnerable to theft. It was listed as a heritage site by CONDEPHAAT in May 2022 as part of the Varnhagen Railway Complex, which also includes the railway station and the remaining houses of the employees' village. Structural and contextual aspects relevant to the reconstruction and requalification of the area were evaluated during a technical inspection carried out on-site (Figure 9).

Figure 9 – Railway section in Varnhagen



Source: Authors' elaboration (2025).

A high potential for territorial appreciation was noted when incorporating the existing historical heritage. Its heritage listing reinforces the initiative's cultural and tourist appeal. Integration with environmental tourism constitutes another strategic vector, considering the area's proximity to the Ipanema National Forest, enabling the creation of itineraries that link railway heritage and environmental education. From a socioeconomic perspective, the potential operation of tourist trains can boost the local economy, creating jobs, increasing the flow of visitors, and stimulating regional commerce.

Furthermore, utilizing existing infrastructure constitutes an environmentally sustainable alternative, as it avoids demolitions and promotes the reuse of tracks and platforms, reducing environmental impacts. From a legal and institutional perspective, the project can be structured through an inter-municipal agreement, along the lines of the Projeto Trem Turístico Sorocabana (Law No. 729/2010).

However, its feasibility depends on rigorous environmental licensing, since the area is located within a conservation unit, requiring authorization from ICMBio and environmental impact studies. Added to this is the complexity of asset management, as the railway is under federal jurisdiction, which requires coordination between DNIT, SPU, ANTT, and the concessionaire Rumo Logística. In this context, institutional cooperation between the city hall, ICMBio, the railway concessionaire, and state agencies becomes essential. It should also be noted that the existing structures are in a precarious state, requiring investment for restoration, in addition to public use restrictions typical of protected areas, which limit vehicle traffic and

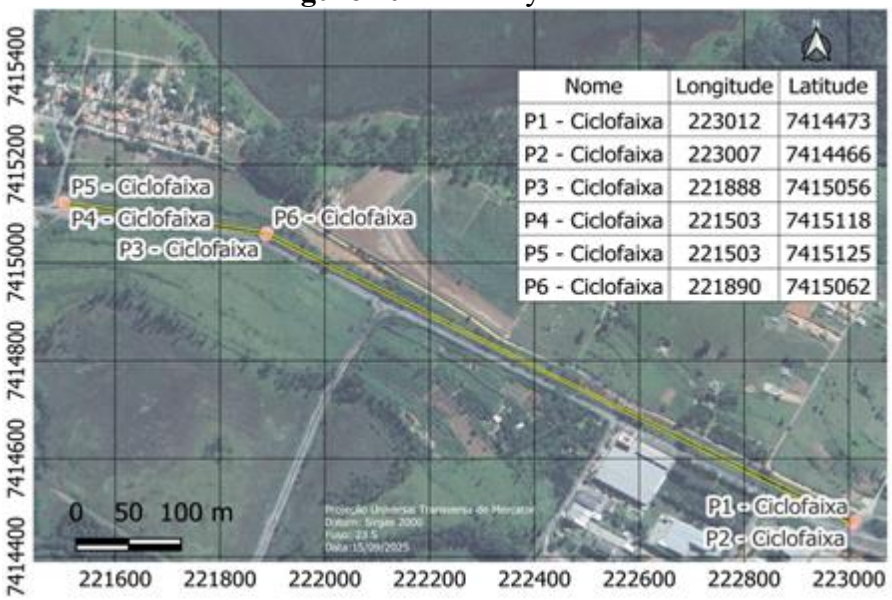
the hosting of large-scale events.

d) **Boa Vista Neighborhood (Itararé Branch Line)**

The railway bed located in the Bela Vista neighborhood (Figure 10) is situated in an area historically linked to the federal railway network and, according to information from the Prefeitura Municipal de Iperó (2025), has been undergoing structural interventions that include land regularization actions in the adjacent area and the execution of asphalt resurfacing, drainage, and sewage connection works, carried out between 2021 and 2024, highlighting the priority given to the improvement of local urban infrastructure. These improvements create favorable conditions for the implementation of a bike lane along the former railway line, aimed both at promoting regional tourism and meeting daily mobility needs, especially for residents who use bicycles as a means of accessing the city center.

The proposal contributes to expanding public use of the territory and enhancing the remaining railway heritage. From a contemporary theoretical perspective, interventions of this nature require not only environmental and urban improvements but also consideration of their potential socio-spatial effects.

Figure 10 – Railway bike lane



Source: Authors' elaboration (2025).

Geotechnologies and Unmanned Aerial Vehicles (UAV) in Railway Asset Management

International literature reveals the advancement of technologies such as UAVs and BIM (Building Information Modeling) integration in the management and monitoring of railway assets.

In the context of railway corridor reconversion and territorial qualification based on green infrastructure, the incorporation of UAVs emerges as a complementary technical strategy for the diagnosis, monitoring, and planning of the permanent way.

The study by Flammini, Pragliola, and Smarra (2017) demonstrates the feasibility of using drones for the identification of structural failures, operational risk assessment, and the analysis of impacts resulting from natural disasters on railway networks. In addition, Maghazei and Steinmann (2020), in applied research with Swiss railways, explore current operational applications and future scenarios for the use of UAVs, highlighting gains in efficiency, safety, and the reduction of inspection costs. From a broader perspective, the systematic review conducted by Askarzadeh, Bridgelall, and Tolliver (2023), which analyzed 47 international studies, confirms the technical benefits of aerial monitoring, while also pointing out challenges related to flight autonomy, data processing, and integration with railway management systems.

Moving in this direction, Aela *et al*. (2024) highlight the performance of sensors embedded in UAVs applied to the inspection of tracks, tunnels, and bridges, reinforcing the potential of these technologies for detailed monitoring of railway superstructure. The most advanced integration between aerial monitoring and digital modeling is presented by Giunta *et al*. (2025), which proposes the coordination between UAVs and Building Information Modeling (BIM) for the generation of three-dimensional models of the permanent way, allowing for more precise structural analyses and support for data-driven decision-making.

Maghazei and Steinmann (2020) and Flammini *et al*. (2017), indicate that photogrammetry is a spatial surveying technique that uses photographic images for three-dimensional reconstruction and the extraction of precise geometric information from objects and terrain. Originating in classical cartography and topography, its application has evolved with the advancement of digital technologies, gaining prominence in areas such as architecture, geotechnology, infrastructure, and especially in railway engineering.

In the context of Iperó, the application of photogrammetry using UAVs is a strategic tool for the recording and analysis of railway infrastructure and its associated heritage. The generation of high-precision orthophotos and three-dimensional models establishes a consistent technical basis for future preservation actions, urban planning, and sustainable territorial

development. Such an approach contributes both to assessing the integrity of the remaining infrastructure and to the safe planning of implementing bike lanes or railway tourism initiatives, reducing field inspection costs and minimizing environmental impacts. Thus, the incorporation of UAVs and digital modeling positions the project in line with international trends in intelligent monitoring, data-driven management, and sustainable territorial planning.

Proposal for the Application of Geotechnologies in the Municipality of Iperó (SP)

According to Maghazei and Steinmann (2020), photogrammetry integrated with Geographic Information System (GIS) platforms enables the generation of high-precision spatial models, covering the permanent way infrastructure, track geometry, and the topographic characteristics of the surroundings. This technological integration not only enhances the railway's spatial record but also strengthens maintenance planning and railway asset management by offering detailed diagnostics and decisions driven by georeferenced data.

According to Flammini *et al*. (2017), the use of UAVs expands these possibilities by reducing inspection costs, ensuring high precision in data collection, and enabling surveys in extensive or difficult-to-access areas. In this regard, more recent studies, such as those by Askarzadeh, Bridgelall, and Tolliver (2023), reinforce that the use of drones for railway monitoring enables the early detection of structural failures, track deformations, and terrain changes, directly contributing to preventive infrastructure management.

In the urban context, the application of these technologies transcends simple data collection, playing a strategic role in territorial requalification processes. Photogrammetry and GIS allow for the monitoring of urban expansion, the identification of underutilized areas, and the analysis of the integration between railway infrastructure and the urban fabric, enabling the identification of opportunities for reuse and functional reconversion of spaces.

In the case of Iperó, the flight plan must be restricted to the areas delimited in this study, as it is not feasible to perform the complete mapping of the entire railway route. Thus, the strategy focuses on specific locations linked to railway heritage and the potential for urban and tourism redevelopment: the railway yard, the Varnhagen station, and the Bela Vista and Bacaetava neighborhoods. Photogrammetry applied to these points allows for detailed mapping of the right-of-way, enabling precise characterization of physical conditions, occupancy patterns, and spatial relationships with the urban surroundings.

More than producing data, the generated products—such as orthophotos, digital elevation models (DEM), digital terrain models (DTM), and point clouds—constitute fundamental inputs for territorial analysis. These data allow for the identification of degraded areas, land use conflicts, physical barriers, and potential axes of urban connection, directly supporting the proposal of interventions aimed at the redevelopment of railway space. Thus, geotechnologies contribute to the structuring of strategies that articulate heritage preservation, urban development, and tourism enhancement. Table 4 presents a proposed flight plan, structuring technical parameters, operational guidelines, and priority sectors, with the objective of supporting future stages of territorial diagnosis and planning for the requalification of railway assets in the municipality.

Table 4 – Photogrammetric flight plan

Item	Technical Description
Flight Objective	High-resolution aerophotogrammetric survey of the railway right-of-way.
UAV with GNSS (Global Navigation Satellite System) and RTK (Real-Time Kinematic) technologies	DJI Mavic 3E or Mavic 3 Multispectral with GNSS/RTK.
Flight Altitude	65 m (urban area) / 75 m (peri-urban sections).
Overlap	80% longitudinal and 75% lateral.
Average speed	3–4 m/s.
GSD (Ground Sample Distance) real distance on the ground corresponding to one pixel of the image. Indicates the spatial resolution of the mapping.	1.5 to 2.0 cm/pixel.
GCP (Ground Control Points) distribution	12 GCP + 4 CP distributed in a zigzag pattern.
Geodetic System	SIRGAS 2000 / UTM Zone 23S.
Mission Sectorization	Mission 1: Iperó; Mission 2: Bela Vista; Mission 3: Bacaetava; Mission 4: Varnhagen.
Image Capture	90° Nadir RGB camera, optional obliques.
Generated Products	Orthophoto, Point Cloud, DEM (Digital Elevation Model) and DTM (Digital Terrain Model), and thematic maps.
Authorizations	SARPAS – Remotely Piloted Aircraft Access Request System

Source: Author's elaboration, based on the literature review (2025).

International studies point to methodological advances that are still underexplored in small-scale municipal contexts, highlighting the relevance of adapting such practices to the local scale. In this sense, the railway layout of Iperó, currently incorporated into the urban fabric, presents significant potential for redevelopment, by enabling the connection between railway heritage, tourism use, and territorial integration. In this context, geotechnologies serve

as essential tools for the reading, interpretation, and planning of these spaces, contributing to the formulation of more precise, sustainable interventions that are aligned with local dynamics.

Final considerations

The incorporation of geotechnologies positions international trends in intelligent monitoring, data-driven management, and sustainable territorial planning, paving the way for the continuation of research and the consolidation of Iperó as a reference in technological innovation applied to railway heritage.

Beyond the economic dimension, the railway exerts a strong influence on the urban landscape, consolidating linear axes that fragment or connect parts of the city. Over time, the deactivation of sections and the abandonment of stations have brought new challenges, such as the irregular occupation of rights-of-way and the degradation of assets. This same idleness opens up possibilities for the creative reuse of these spaces, whether focused on cultural tourism, linear parks, or alternative mobility. However, actions must be taken; as highlighted by Souza (2023), the absence of national cadastral legislation, combined with the lack of standardization and the low effectiveness of existing guidelines, compromises the consolidation of an efficient land registration system.

In this scenario, the use of geotechnologies, such as UAVs, emerges as a viable alternative to fill technical gaps and support municipal territorial management. This technological approach can represent not only a tool for railway asset management but also a driver for attracting investment, territorial planning, and regional logistics revaluation.

Based on the surveys proposed in table 4, it will be possible to generate orthomosaics and digital terrain models, which will provide technical products, supporting projects for the development of a BIM interface capable of automatically integrating data from different UAV survey campaigns, allowing for the comparison of road conditions over time, monitoring the evolution of anomalies, and incorporating temporal analysis functions.

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