GC Revista Nacional de Gerenciamento de Cidades
National Journal of City Management

ISSN 2318-8472, v. 13, n. 89, 2025

Development of a framework for the systematization of metro line projects

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Submissão: 24/10/2024
Aceite: 10/05/2025
GABARRA, Murilo Macedo; SILVA, Helena Aparecida Ayoub. Elaboração de base para sistematização de projetos de linhas metroviárias. **Revista Nacional de Gerenciamento de Cidades**, *[S. l.]*, v. 13, n. 89, 2025.
DOI: 10.17271/23188472138920256111. Disponível em: https://publicacoes.amigosdanatureza.org.br/index.php/gerenciamento_de_cidades/article/view/6111

GC Revista Nacional de Gerenciamento de Cidades
National Journal of City Management

ISSN 2318-8472, v. 13, n. 89, 2025

Elaboração de base para sistematização de projetos de linhas metroviárias

RESUMO

Objetivo - Este trabalho visa sistematizar os processos de projeto de linhas de metrô utilizando o Sistema de Informação Geográfica (SIG) por meio de base cartográfica digital com informações provenientes de bancos de dados públicos, que possam orientar a tomada de decisões no planejamento de linhas de metrô na cidade de São Paulo.

Metodologia A metodologia adotada fundamenta-se na aplicação de técnicas de geoprocessamento para o mapeamento de restrições ambientais, urbanísticas e legais, tais como a presença de áreas contaminadas, imóveis tombados e parâmetros de densidade construtiva. Para tanto, foram utilizados dados abertos provenientes de órgãos públicos, como a Companhia Ambiental do Estado de São Paulo (CETESB) e o portal Geosampa. Esses dados subsidiaram a estruturação da base cartográfica e a elaboração de mapas temáticos.

Originalidade/relevância - A originalidade deste trabalho reside na sistematização do processo de escolha de terrenos e traçados para linhas de metrô, etapa de projeto de linhas metroviárias, utilizando uma abordagem baseada em SIG

Resultados - Como resultado da aplicação do método proposto, foram gerados mapas temáticos organizados por categorias relacionadas à seleção de terrenos para implantação de estações e ao desenvolvimento do traçado das vias metroviárias. Esses produtos configuram-se como uma ferramenta de apoio ao planejamento e à concepção de projetos de linhas metroviárias.

Contribuições teóricas/metodológicas - Ao integrar diferentes fontes de dados geográficos e técnicas de mapeamento de restrições, o estudo oferece uma ferramenta replicável para o planejamento e projeto de infraestrutura urbana, contribuindo para a inovação em projetos de transportes públicos subterrâneos em grandes centros urbanos.

Contribuições sociais e ambientais - A metodologia contribui para a transparência no planejamento, a redução de impactos socioambientais e a ampliação do acesso equitativo à mobilidade urbana.

PALAVRAS-CHAVE: Linhas Metroviárias; Geoprocessamento; Projeto de Infraestrutura.

Development of a Framework for the Systematization of Metro Line Projects

ABSTRACT

Objective – This study aims to systematize the design processes of metro lines using Geographic Information Systems (GIS), through the development of a digital cartographic database based on public data sources, in order to support decision-making in the planning of metro lines in the city of São Paulo.

Methodology – The methodology is based on the application of geoprocessing techniques to map environmental, urban, and legal constraints, such as the presence of contaminated areas, heritage-listed buildings, and building density parameters. Open data from public agencies, such as the Environmental Company of the State of São Paulo (CETESB) and the Geosampa platform, were used to structure the database and generate thematic maps.

Originality/Relevance – The originality of this work lies in the systematization of site and route selection processes for metro lines through a GIS-based approach, contributing to a key phase in the design of underground transportation infrastructure.

Results – As a result of the proposed method, thematic maps were produced, organized into categories related to station location and metro line routing. These outputs serve as support tools for the planning and preliminary design of metro line projects.

Theoretical/methodological contributions – By integrating multiple geospatial data sources and constraint mapping techniques, this study offers a replicable tool for urban infrastructure planning, contributing to innovation in the design of underground public transportation systems in large urban centers.

Social and environmental contributions – The methodology contributes to planning transparency, reduction of socio-environmental impacts, and the expansion of equitable access to urban mobility.

KEYWORDS: Metro Lines; Geoprocessing; Infrastructure Design.

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Elaboración de una base para la sistematización de proyectos de líneas de metro

RESUMEN

Objetivo – Este trabajo tiene como objetivo sistematizar los procesos de diseño de líneas de metro mediante el uso de Sistemas de Información Geográfica (SIG), a partir de una base cartográfica digital construida con datos públicos, que pueda orientar la toma de decisiones en la planificación de líneas de metro en la ciudad de São Paulo.

Metodología – La metodología se basa en la aplicación de técnicas de geoprocesamiento para el mapeo de restricciones ambientales, urbanísticas y legales, tales como la presencia de áreas contaminadas, edificaciones protegidas y parámetros de densidad constructiva. Se utilizaron datos abiertos provenientes de organismos públicos, como la Compañía Ambiental del Estado de São Paulo (CETESB) y la plataforma Geosampa, que permitieron estructurar la base cartográfica y elaborar mapas temáticos.

Originalidad/relevancia – La originalidad de este estudio reside en la sistematización del proceso de selección de terrenos y trazados para líneas de metro, etapa clave del proyecto de infraestructura subterránea, mediante un enfoque basado en SIG.

Resultados – Como resultado de la aplicación del método propuesto, se generaron mapas temáticos organizados en categorías relacionadas con la elección de terrenos para la implantación de estaciones y el desarrollo del trazado de las vías. Estos productos funcionan como herramientas de apoyo para la planificación y el diseño preliminar de proyectos de líneas de metro.

Contribuciones Teóricas/Metodológicas – Al integrar distintas fuentes de datos geoespaciales y técnicas de mapeo de restricciones, el estudio ofrece una herramienta replicable para la planificación y diseño de infraestructura urbana, contribuyendo a la innovación en proyectos de transporte público subterráneo en grandes centros urbanos.

Contribuciones Sociales y Ambientales – La metodología contribuye a la transparencia en la planificación, a la reducción de impactos socioambientales y a la ampliación del acceso equitativo a la movilidad urbana.

PALABRAS CLAVE: Líneas de Metro; Geoprocesamiento; Diseño de Infraestructura.

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1 INTRODUCTION

This study aims to develop a digital cartographic database based on publicly available data, containing information to support the design of metro lines in São Paulo. It also seeks to document the adopted methodology for replication in similar contexts. This work is part of a broader research project focused on systematizing contemporary design procedures for high-capacity underground metro lines in the Metropolitan Region of São Paulo (MRSP), in accordance with the current legal framework.

We briefly present the metro line design process to contextualize the proposed methodological approach.

1.1 Stages of Metro Projects

Given the complexity of developing a metro transportation project, its design is divided into several stages. In the case of the Metropolitan Region of São Paulo (MRSP), the São Paulo Metro Company (CMSP) is responsible for defining the metro network. The process begins with the "Origin-Destination" (OD) survey, conducted every ten years to assess transportation demand. Based on the OD survey, the "Future Network" (Figure 1) is developed and revised, defining the new lines to be built.

The next step is the "Functional Design," which progresses in technical aspects such as demand definition, vehicle specifications, construction methods, load distribution, passenger demand per station, headway[1], selected vehicle type, track support (tunnel, elevated, surface, etc.), land acquisition for construction units, construction methods for stations and tunnels, and guidelines for electromechanical systems. Based on this design, the Basic Project is created, which includes the project budget. Finally, the Executive Project is developed, providing detailed instructions for implementation.

[1] Headway is the time interval between trains during peak hours, a measure directly related to the line's load.

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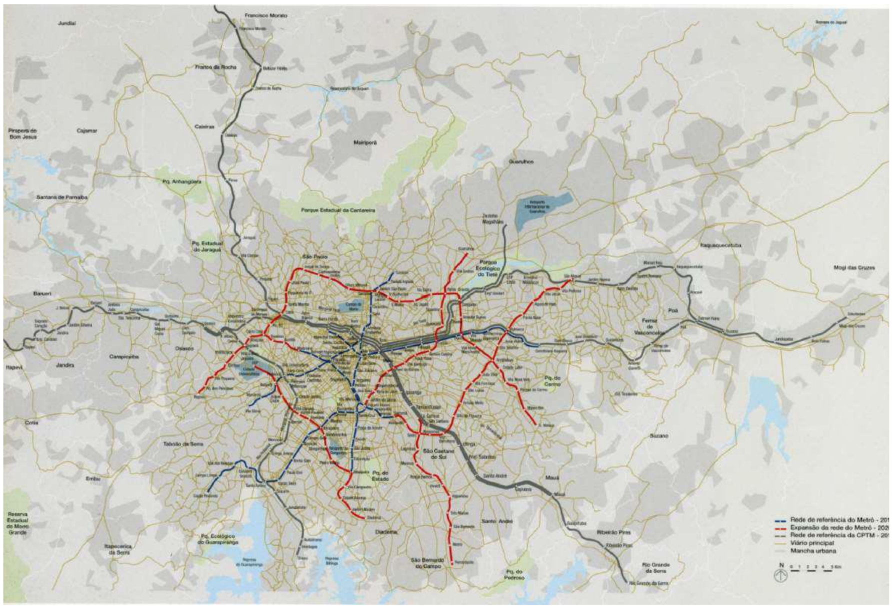
Figure 1 - Future Network: PITU-2020.



Source: Companhia do Metropolitano de São Paulo (2006).

1.2 The State of the Art of Metro Design in São Paulo

Over its more than 50 years of existence, CMSP has accumulated extensive experience in the design and construction of metro lines and sections using different methods. Focusing solely on the construction method for track support, we can list the first section with an open-cut trench between the Jabaquara and Liberdade stations on Line 1 – Blue, the first section built using a tunnel boring machine[2] (TBM), and the elevated section on the same line, as well as the surface-level track on Line 3 – Red.

An analysis of the geographical characteristics of the areas in the MRSP and the construction trends adopted by CMSP over time reveals patterns for future lines. The track support method is the primary defining factor. Due to the decreasing availability of suitable urban areas for surface and elevated lines, as well as criticism of their urban impact, the clear trend is toward the use of underground tracks.

Among underground construction methods, open-cut trenches (VCA) have become increasingly unfeasible, as they require terrain with a compatible grade and relatively shallow excavations, in addition to significant disruptions for extended periods. Thus, the construction of long sections using VCA is becoming rarer. Regarding tunnels, there is a clear trend toward the adoption of tunnel boring machines (TBMs), as shown in Graph 1, which presents CMSP's underground projects in chronological order.

[2] Tunnel Boring Machine (TBM): equipment used for tunnel excavation and lining installation.

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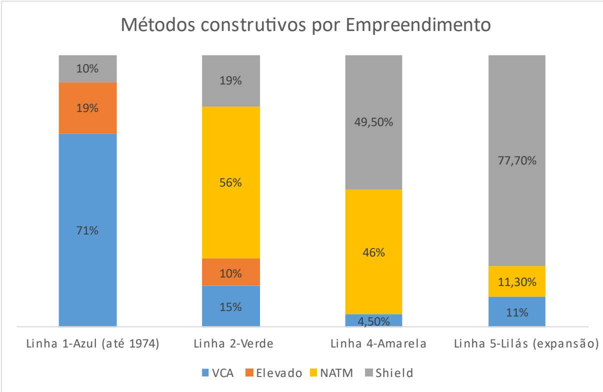
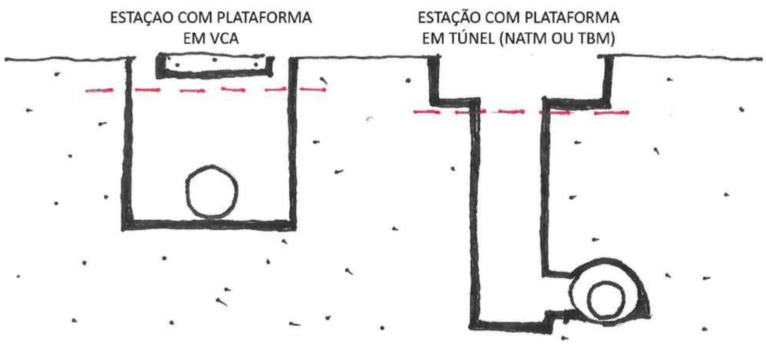
Graph 1 - Construction Methods by Metro Project Developed by CMSP, Considering Predominantly Underground Lines (Line 3 – Red, which is predominantly surface, the elevated section of Line 5 – Lilac, built by CPTM, and the elevated monorails were not considered).



Source: Gabarra (2016).

Another trend is the standardization of stations. In 2020, CMSP set a goal to design standardized stations for use in typical situations. This standardization is suitable for most underground stations that do not connect to other lines (Figure 2), as demonstrated in the expansion of Line 5 – Lilac (Gabarra, 2016). These standardized designs are being applied to future lines, such as Line 19 – Celeste, for which the basic design was completed in 2024. Standardized projects offer solutions for different depths, passenger demand, and terrain, allowing for surface-level customizations to integrate with the urban fabric. Standardization provides predictability in the dimensions of land required for station implementation, which is useful for establishing design processes, such as the one proposed in this study. Other definitions also establish standards that should not be drastically altered and can be considered as design parameters, such as curve radii and grades.

Figure 2 – Sketch of typical cross-sections of shallow standardized stations (in VCA) and deep stations (with platform in conventional NATM tunnel[3]), with a red dashed line representing the boundary between the standardized deep section and the surface customization.



Source: Gabarra (2016).

1.3 GIS in the Planning and Design of Transportation Infrastructure

[3] Conventional tunnel: excavated and constructed without the use of a Tunnel Boring Machine (TBM).

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This study aligns with a growing trend in urban planning and transportation infrastructure that recognizes Geographic Information Systems (GIS) as a fundamental tool for spatial analysis and decision-making (Filho; Lopes, 2018).

GIS is a technology developed for the analysis and management of spatial data, distinguishing it from other information systems. Essentially, it represents reality through an abstract model that includes georeferenced objects with additional non-spatial attributes (Olivatto et al., 2024).

GIS can be defined as a computerized system that allows for the collection, input, storage, manipulation, analysis, representation, and output of spatial and non-spatial data, addressing user needs in the decision-making context (Álvarez; Gonçalves, 2023). Recent studies already demonstrate its application in initiatives such as the prioritization of areas for urban renewal and the classification of zones for the installation of metro stations (Álvarez; Gonçalves, 2023; Ma et al., 2022). This multifunctional capability makes GIS particularly useful in complex projects like the expansion of metro systems (Álvarez; Gonçalves, 2023).

The use of public databases to assist in the selection of areas for expropriation and alignment — considering costs, densely built areas, and contaminated zones — reflects the practical application of GIS in spatial planning (Dias; Oliveira, 2021).

GIS allows for mapping and territorial modeling, enabling the overlay of different layers of information (costs, population density, environmental data) to identify the most suitable areas for intervention and optimize the design of infrastructures (Liberti; Nucci, 2018). The adoption of GIS in transportation planning, especially through open-source tools, can also contribute to transparency, democratization, and public participation in decision-making processes in sector policies (Lovelace, 2021).

The proposal to use GIS for improving the management and planning of urban infrastructure by public authorities (Soule; Bueno, 2021), when applied to practical design situations, also enables its integration, in later stages, with other technologies focused on building design. This convergence between different computing-based methods has been identified by the acronym CGB, which combines the initials of CAD, GIS, and BIM — an emerging trend in urban-scale planning approaches (Olivatto et al., 2024), although this integration still faces technical and methodological challenges (Chen et al., 2024). The practical adoption of CGB in metro design projects is discussed by Dong et al. (2020), who explore its application in large-scale geotechnical projects. D'Amico et al. (2020), in turn, analyze the benefits of integrating geospatial data (GIS) and BIM models, highlighting how this convergence can contribute to a more efficient, integrated, and data-driven design approach, especially in the context of transportation infrastructures. This perspective reinforces the potential for reusing the databases developed in this study in subsequent stages of the design cycle.

2 Objectives: Systematization of Metro Line Design Projects

This study has the general objective of structuring and relating the processes involved in metro line design projects, guiding decision-making and ensuring the project flow until its completion.

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Based on the parameters derived from the experience accumulated by CMSP, the specific objective of this study is to identify the relationships between processes, decision-making, and their respective typical responses.

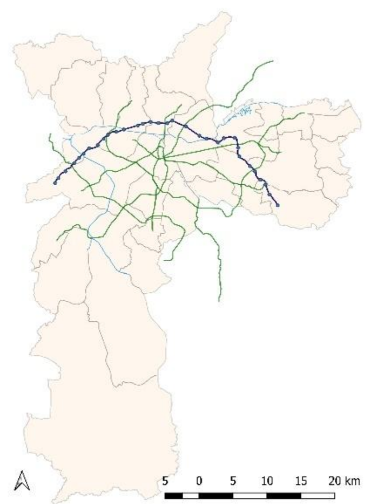
As an expected result, this study aims to develop maps that synthesize identified constraints, which will inform and guide decision-making regarding the selection of station sites and route development. This, in turn, will also influence the choice of tunnels and their respective tunnel boring machines (TBMs), based on the constraints that are being considered in this type of project.

3 Case Study, Materials, and Methods

For the development of this study, we will use the material from one of the Future Network studies developed by CMSP, the Blue Network, published in 2006, which includes the priority lines to be constructed in the medium term in the São Paulo Metropolitan Area (RMSP) (Companhia do Metropolitano de São Paulo, 2006). From this, we selected the North Arc Line for our case study (Figure 3).

We chose this line because it is of significant length (if constructed, it will exceed 40 km), which presents a challenge in terms of the study's scope, although it is entirely within the city of São Paulo, where we will use part of the digital databases. This line also features some unprecedented characteristics in the São Paulo network, such as having a perimeter layout, as opposed to the radial layout typical of most of the lines currently in operation.

Figure 3. Map of the Municipality of São Paulo and the Rede Azul.



Source: Prepared by the author based on Lisboa (2019).

The scope of this study focuses on the transition from the Network Study phase to the Functional Design phase in the expansion of the metro system. It is at this stage that key

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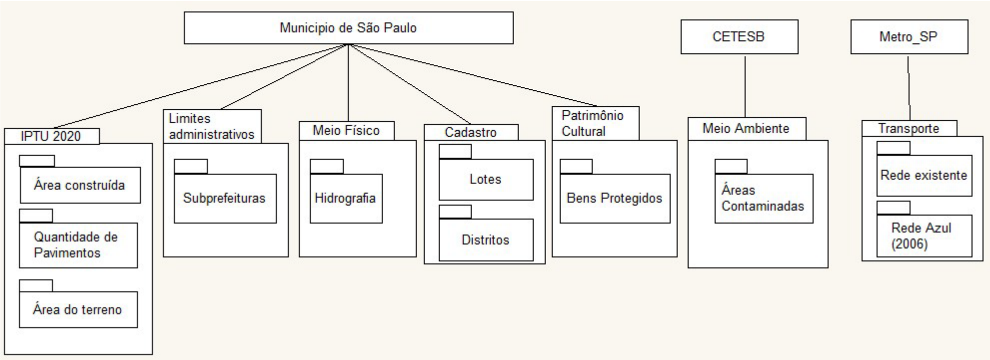
decisions are made, such as the construction method for stations and tunnels, as well as depth definitions.

Geoprocessing will be employed to map constraints based on publicly available data. The mapping will be divided into two main themes: one focused on site selection and the other on alignment development, each with specific subthemes.

The dataset used in this study (Figure 4) is composed of files from the Municipality of São Paulo, obtained through the Geosampa platform; CETESB files accessed via the DataGEO portal; and the network alignment from CMSP's future network plan (2006).

Figure 4. Diagram of the data used in this study.



Source: Elaborated by the authors.

3.1 Data Collection and Processing Tools

Data collection and processing were carried out using a Windows 10 Pro (64-bit) operating system and the QGIS geoprocessing software, version 3.16.5-Hannover.

3.2 Applied Methods

Based on knowledge of construction techniques and the applicable legislation for building metro lines and stations, a geoprocessing strategy was developed to map constraints using public digital GIS databases. Different aspects are analyzed for station implementation scenarios and route alignment.

3.2.1 Mapping of Constraints for Station Site Selection

The mapping of constraints for the selection of land to be expropriated for the construction of metro stations is based on conditions to be avoided, as identified in previous metro projects. These can be assessed using publicly available databases, thus creating parameters:

a- Building Density – since existing structures on the land must be compensated by the state during expropriation, higher density increases costs;

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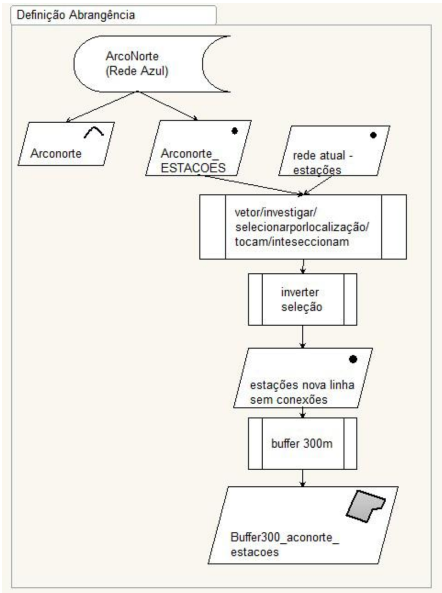
b- Contaminated Areas – which can raise construction costs due to additional expenses for the disposal of excavated soil and potential remediation or treatment, potentially affecting both budget and schedule;
c- Heritage-Listed Properties – which must be preserved and therefore should be identified and avoided.

3.2.1.1 Definition of the Mapping Coverage Area

The first step in defining the mapping coverage area is to exclude transfer stations connecting with other lines, as their locations depend on existing stations and require specific criteria. For mid-line stations—those that do not involve transfers—a 300-meter radius was established around the location suggested by the Network Study. In the geoprocessing process, we used data from the future network layout, the Arco Norte line, and the station points for that line. After excluding transfer stations, the remaining ones were selected, and a 300-meter buffer was applied to define the study's coverage area (Figure 5). Figure 6 presents the resulting mapping for this area.

Figure 5. Diagram of operations for defining the coverage area for mapping constraints related to station implementation.



Source: Elaborated by the authors.

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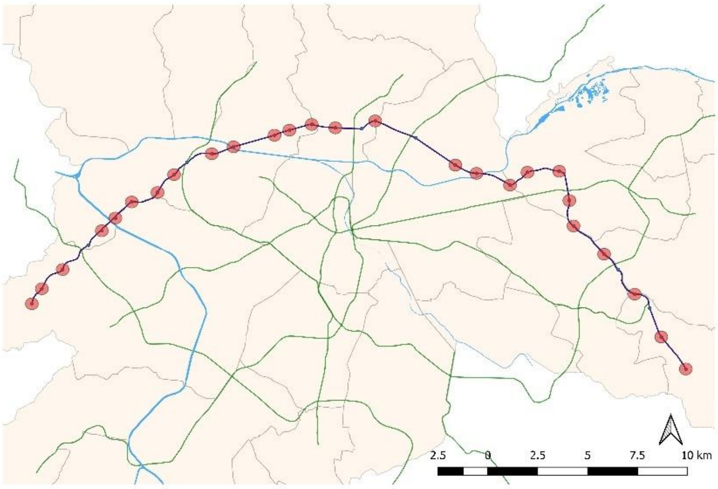
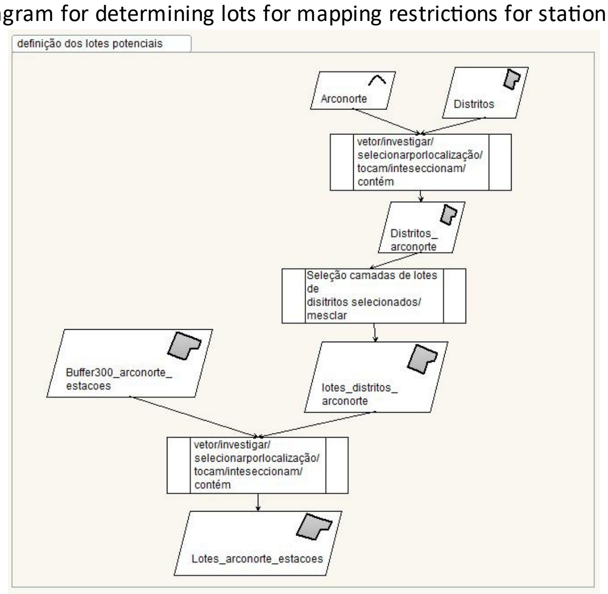
Figure 6. Map of the Rede Azul (CMSP, 2006) with the Arco Norte line highlighted in blue and the study coverage area.



Source: Elaborated by the authors.

As the goal is to select plots of land for the construction of stations, the study platform consists of land parcels. Therefore, the preparation of the base involves selecting the parcels from the study area. Since the parcel files are separated by districts, the operation consisted of selecting the districts, loading the layers corresponding to the parcels from the selected districts, and selecting the plots within the coverage area for station land searches. The process is described in the diagram presented in Figure 7, with the base map for the study shown in Figure 8, highlighting the Amador Bueno station.

Figure 7. Diagram for determining lots for mapping restrictions for station installation.



Source: Elaborated by the authors.

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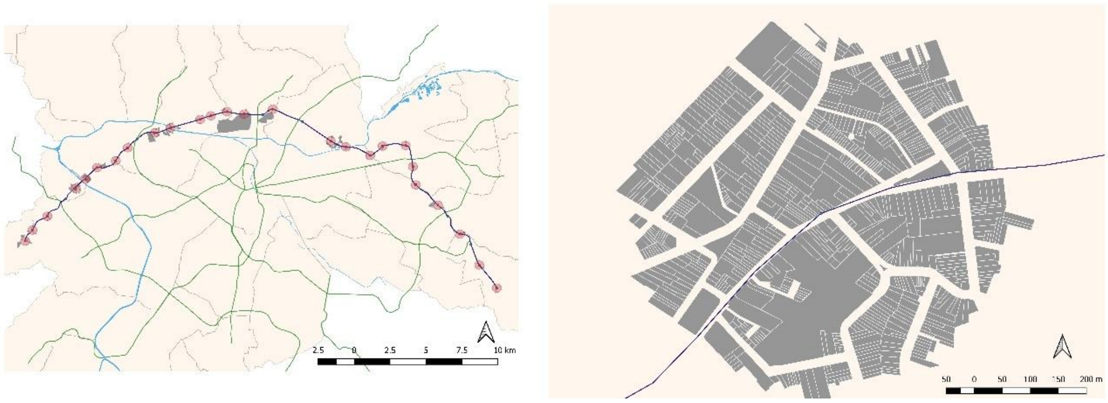
Figure 8. Map with the Arco Norte line and lots for mapping restrictions for station installation, with the Amador Bueno station highlighted (on the left) and a detail of the area with an approximate diameter of 600 m showing potential lots for the installation of the Amador Bueno station of the Arco Norte line (on the right).

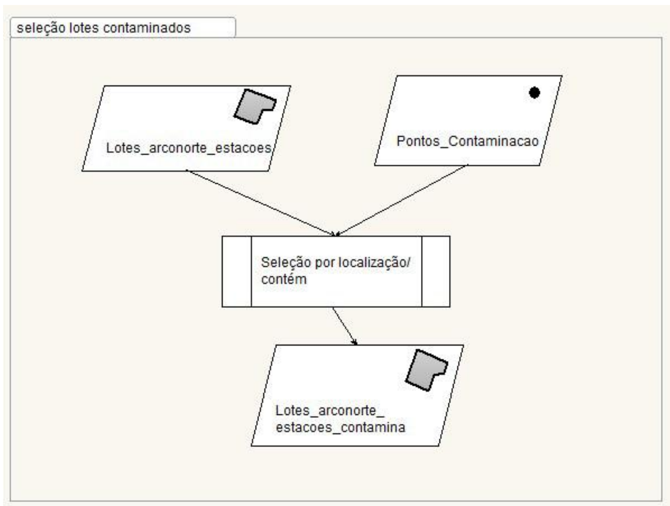


Source: Elaborated by the authors.

3.2.1.2 Verification of Contaminated Areas

The first restriction to be verified on the base map produced according to the process described earlier is the existence of contamination points and the marking of plots in such situations. For this, the contaminated area points file created by CETESB was used, along with the selection of plots within the study area that contain these points (Figure 9).

Figure 9. Diagram with the operation for obtaining the file of lots with contaminated soil within the area of potential land for station installation.



Source: Elaborated by the authors.

3.1.1.3 Verification of building density and listed buildings.

For this process, some operations benefit from data tables from the files used. The files and data from the tables used are (figure 10):

- Sector, block, lot from the Lot file;

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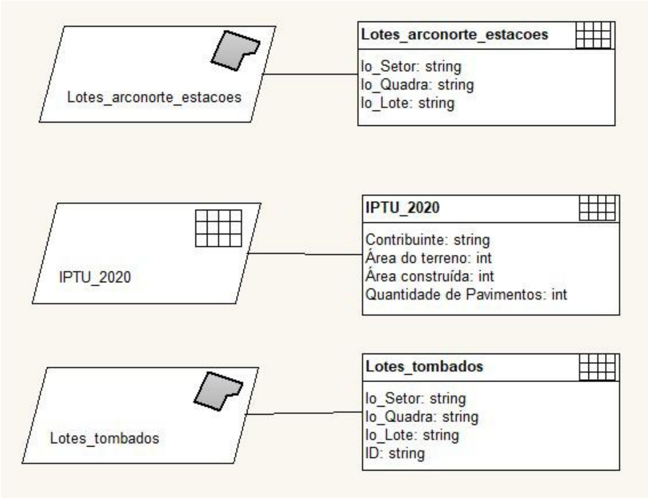
- Taxpayer number, built area, land area, and number of floors from the 2020 IPTU[4] file;
- Sector, block, lot, and ID from the listed lots file.

Figure 10. Diagram with table data from the files used in the mapping of lot restrictions for stations.



Source: Elaborated by the authors.

To determine the restrictive building density, a value greater than or equal to 1.5 for the Floor Area Ratio (F.A.R.) and/or 4 or more floors was arbitrarily set.

To obtain the F.A.R. value in the *lotes_arconorte_estacoes* dataset (which contains spreadsheets derived from the lot representations of the City of São Paulo from Geosampa), it is necessary to merge data from the IPTU spreadsheet with the lot shapefile. This requires creating a common column in these files. In the *lotes_arconorte_estacoes* table, it is necessary to concatenate the values from the columns "lo_setor," "lo_quadra," and "lo_lote" to obtain the taxpayer number. In the IPTU table, a "left" operation must be performed to extract the verification digit from the taxpayer number, thus allowing the two tables to be merged based on a common attribute.

Once the tables are merged, the F.A.R. field is created by dividing the built area by the land area. Filter the values greater than or equal to 1.5 to reach the established limit. Also, filter the column with the number of floors equal to or greater than 4, and combine it with the previous selection. Export the selection to obtain the *lotes_estacoes_densidade_construtiva* dataset. Figure 11 shows the operations for mapping high building density.

[4] IPTU ("*Imposto Territorial Urbano*") refers to the Urban Property Tax in Brazil. It is a tax levied on real estate properties located in urban areas, such as land and buildings. The amount of the tax is typically calculated based on the value of the property, which may include factors such as its location, size, and use. IPTU is an important source of revenue
for municipal governments in Brazil.

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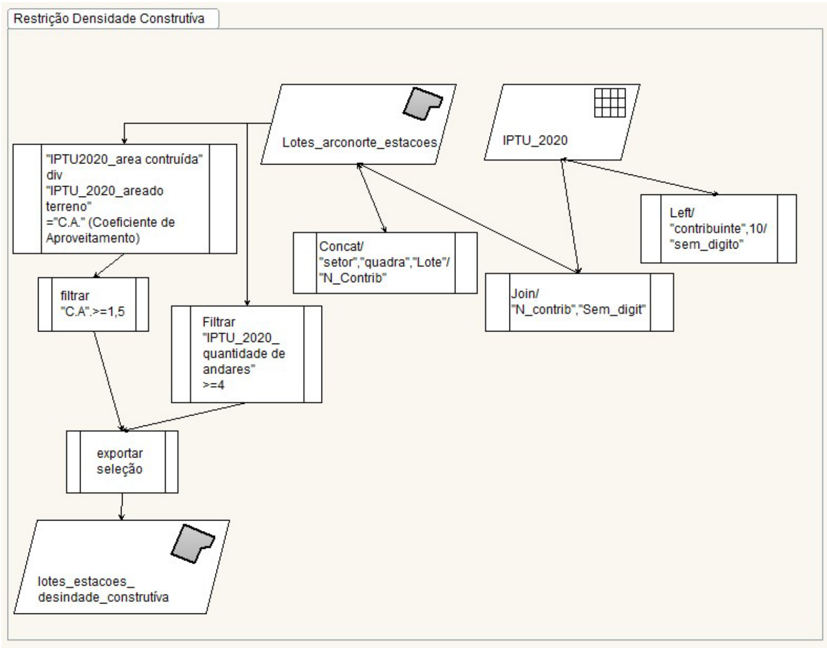
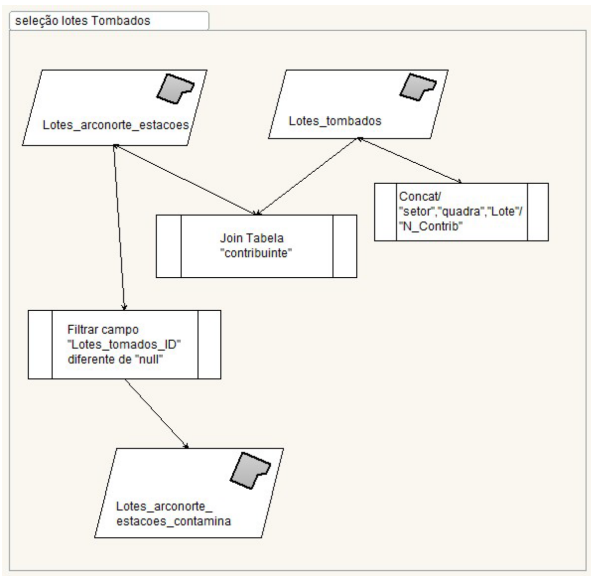
Figure 11. Operations to obtain lots with building density above the established value.



Source: Elaborated by the authors.

To verify listed properties, it is also necessary to concatenate the values of sector, block, and lot, obtain the taxpayer number from *Lotes_tombados*, and merge it with *Lotes_arconorte_estacoes* using this key, bringing the ID field into the latter file. Filter this field for values different from "null". Then, combine this selection with the previous selections (see Figure 12).

Figure 12. Operations to obtain contaminated lots within the coverage area of potential lots for station installation.



Source: Elaborated by the authors.

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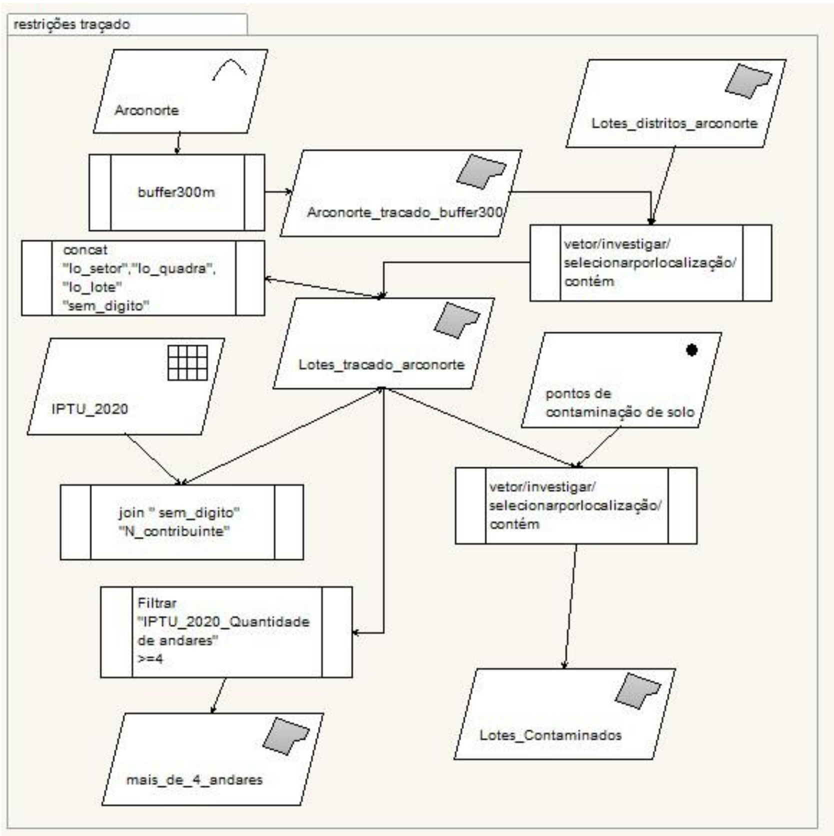
3.2.2 Mapping of restrictions for establishing the alignment of the track/tunnel

For the tunnel alignment, a recurring restriction is the foundations of buildings. This is not a topic considered in the available data, but one way to address it, albeit not in-depth, but offering an initial approach, is to search for medium- and high-rise buildings, which typically have deep foundations. Another situation to avoid is the excavation of contaminated soil, for the same reasons already discussed for stations.

The first step is again defining the coverage area. Since the line has already been drawn considering the approximate radii accepted for metro routes, two parallel lines 150 meters on each side of the original axis, totaling a 300-meter-wide strip (a 300-meter buffer), are sufficient to accommodate the track. The lots are selected within the area defined by this buffer.

For filtering contaminated land, the operation performed for the station territory is repeated, this time for the territory defined for the alignment, the lotes_traçado_arconorte. For filtering lots of buildings with four or more floors, the IPTU file is used, with a column created from the taxpayer number without the verification digit, to serve as the key for joining with the concatenated sector, block, and lot fields from lotes_traçado_arconorte. After merging the tables, the values of "IPTU_2020_quantidade de andares" are used to filter buildings with four or more floors. The operations are described in the diagram presented in Figure 13.

Figure 13. Diagram with operations for obtaining restrictions for the alignment development.



Source: Elaborated by the authors.

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4 RESULTS

As a way of presenting the results, we will separate them by the processes described in the methods, starting with the restrictions related to the implementation of stations, providing an overview of the Arco Norte line and a closer look at the Amador Bueno station, and later for the track alignment of the tunnel.

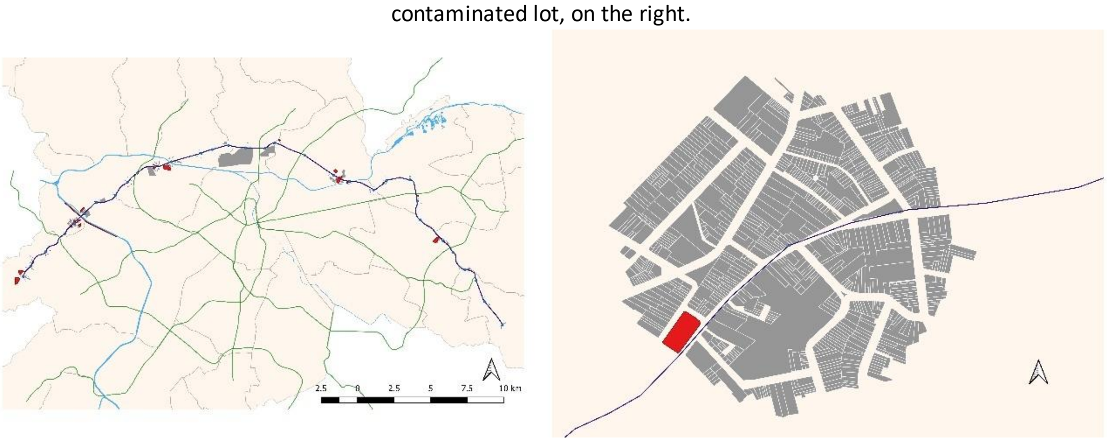
4.1 Mapped restrictions in the case study for the implementation of stations.

As a result of the proposed method, maps were obtained showing lots with restrictions related to contaminated areas, high building density, and listed buildings in areas planned for the installation of stations on the Arco Norte Line.

4.1.1 Contaminated áreas

A total of 48 lots with contamination were located within 300 meters of the planned station installation site in the case study, and a specific file with these geometries was generated. In Figure 14, the mapping of contaminated lots along the entire line can be seen, with a focus on the Amador Bueno station on the left, showing a contaminated lot.

Figure 14. Map of the Arco Norte Line with contaminated land lots (in red) on the left and a detailed area with an approximate diameter of 600 meters showing potential lots for the installation of the Amador station, with a contaminated lot, on the right.



Source: Elaborated by the authors.

4.1.2 Building density and listed properties

A total of 1,351 lots were obtained with a Floor Area Ratio (F.A.R.) greater than or equal to 1.5 and/or 4 or more floors and/or listed properties, as shown in the full line on the left and the detail of the Amador Bueno station on the right in Figure 15.

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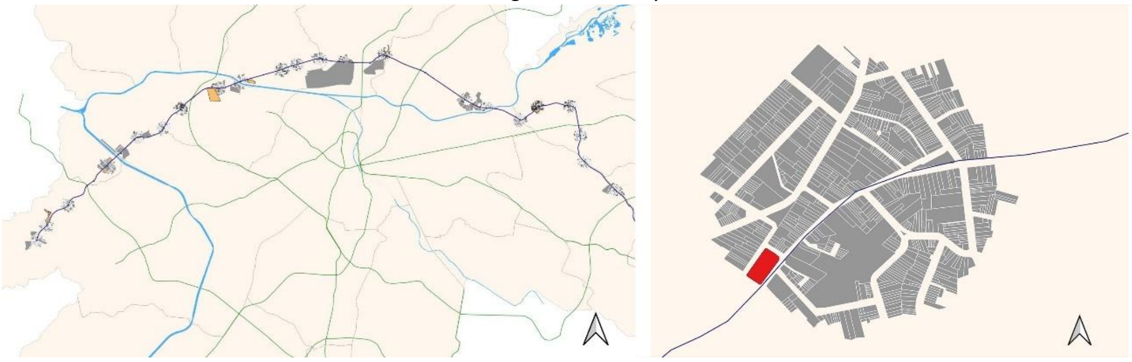
Figure 15. Lots (in orange) with building density above the established limit and listed properties, on the left along the entire Arco Norte Line and on the right in the study area of the Amador Bueno station.

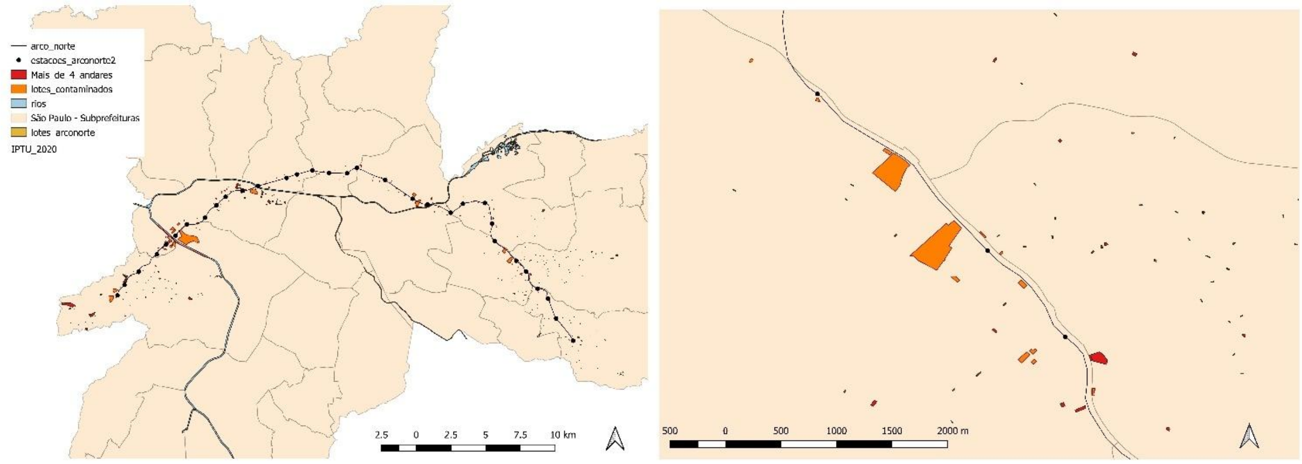


Source: Elaborated by the authors.

4.2 Track/tunnel alignment

As a result of the proposed method for identifying restrictions for the track alignment in the case study of the Arco Norte Line, after filtering, as described in item 3.2.2, which exposes contaminated lands and those with possible deep foundations within a 300-meter-wide strip along the potential track alignment, we obtained the maps presented in Figure 16, with an overview on the left and a detailed section between the Aricanduva and Vila Eulália stations on the right, showing lots with restrictions.

Figure 16. Map with restrictions for track development (lots in orange) of the entire Arco Norte Line on the left and a detail of the Aricanduva – Vila Eulália section on the right.



Source: Elaborated by the authors.

4 CONCLUSION

The maps resulting from the geoprocessing of public data consolidate highly useful information in defining land for station implementation and for the preliminary establishment

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of alignment alternatives for metro lines, systematizing the design processes of underground metro lines constructed with TBM (Tunnel Boring Machine).

Although in the fields of architecture and urban planning, the use of geoprocessing tools and spatial information is more common in analytical activities, in the design of architecture and infrastructure engineering, these tools can also be an important ally in propositional activities. The city of São Paulo has an important collection of information that enables this use, as demonstrated in this work. The data provided by CETESB on the DataGEO portal is also useful and has statewide coverage.

Focusing on the specific case of the metro project, public data can be used to standardize the processes for selecting land for station installation and defining the line alignment, which represents an important step in the systematization of the processes proposed here.

Interesting analyses can be made from the simple plotting of information from the studied case, Arco Norte, whose alignment is peripheral, and it is possible to notice the different nature of the restrictions compared to those typically faced by radial lines, which dominate the current scenario in São Paulo, with more high-rise buildings and higher building density.

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DECLARAÇÕES

CONTRIBUIÇÃO DE CADA AUTOR

- Concepção e Design do Estudo: Murilo Macedo Gabarra teve a ideia central do estudo e Helena Aparecida Ayoub Silva ajudou a definir os objetivos e a metodologia.
- Curadoria de Dados: Murilo Macedo Gabarra organizou e verificou os dados para garantir sua qualidade, que foi revisado por Helena Aparecida Ayoub Silva.
- Análise Formal: Murilo Macedo Gabarra realizou as análises dos dados, aplicando métodos específicos.
- Aquisição de Financiamento: não houve financiamento para o trabalho, que foi desenvolvido com recursos próprios dos autores.
- Investigação: Murilo Macedo Gabarra conduziu a coleta de dados ou experimentos práticos.
- Metodologia: Murilo Macedo Gabarra e Helena Aparecida Ayoub Silva desenvolveram e ajustaram as metodologias aplicadas no estudo.

- Redação - Rascunho Inicial: Murilo Macedo Gabarra escreveu a primeira versão do manuscrito.
- Redação - Revisão Crítica: Helena Aparecida Ayoub Silva revisou o texto, melhorando a clareza e a coerência.
- Revisão e Edição Final: Murilo Macedo Gabarra revisou e ajustou o manuscrito para garantir que atende às normas da revista.
- Supervisão: Helena Aparecida Ayoub Silva coordenou o trabalho e garantiu a qualidade geral do estudo.

DECLARAÇÃO DE CONFLITOS DE INTERESSE

Nós, Murilo Macedo Gabarra e Helena Aparecida Ayoub Silva, declaramos que o manuscrito intitulado " Elaboração de base para sistematização de projetos de linhas metroviárias":

1. **Vínculos Financeiros:** Não possui vínculos financeiros que possam influenciar os resultados ou interpretação do trabalho. Nenhuma instituição ou entidade financiadora esteve envolvida no desenvolvimento deste estudo.
2. **Relações Profissionais:** Não possui relações profissionais que possam impactar na análise, interpretação ou apresentação dos resultados. Nenhuma relação profissional relevante ao conteúdo deste manuscrito foi estabelecida.
3. **Conflitos Pessoais:** Não possui conflitos de interesse pessoais relacionados ao conteúdo do manuscrito. Nenhum conflito pessoal relacionado ao conteúdo foi identificado.