River Network and the Risk of Flooding for the Railway and Subway Systems in the City of São Paulo, Brazil

Daniel Nery dos Santos¹, Marcos Antonio Maia de Oliveira¹, Alexandre Formigoni¹, João Roberto Maiellaro¹, Antonio Roberto Saad² and Marcelo Eloy Fernandes³
1. Department of Logistics-NUPELOG, São Paulo State Technological College, Campus Guarulhos, São Paulo, Brazil
2. Department of Geosciences, University Guarulhos, Campus Guarulhos, São Paulo, Brazil
3. Department of Information Technology Management, São Paulo State Technological College, Campus Barueri, São Paulo, Brazil

Abstract: This study investigated the risk of flooding along the São Paulo city’s railway network and showed its latest technologies. To that end, we took into account topographic and hydrological features, as well as possible interferences of the flooding phenomenon with the optimal operation of the railway system. When preparing the maps and the flooding risk analysis, we used data from project SRTM (Shuttle Radar Topography Mission) integrated and processed in a GIS (geographical information system), through version 2.14 of the geoprocessing software “QGis”. Results showed risk exposure for logistics operations of the railway system for the transportation of passengers, especially in the Central and Eastern regions of the city, where there is a higher concentration of points of flooding, thus making it more difficult for passengers to come and go in the greatest city of Brazil.

Key words: Urban mobility, rivers, logistics, São Paulo, flooding, railroads.

1. Introduction

This research work was carried out to approach the assessment of geological risks related to flooding in APP (permanent preservation areas), at valley bottoms, where there are multiple transportation modes that involve millions of people from the city of São Paulo, the greatest metropolis of Brazil.

Throughout the history, mankind has always wanted to know where they are and understand their surroundings. Rivers have always represented a significant opportunity for men to settle down in a single place. However, over time there was a disordered occupation of margins of rivers, which resulted in serious issues of many kinds, such as risks to human life and issues in the transportation of passengers and cargo, not to mention the negative environmental impacts on the fluvial system.

The city of São Paulo has nearly 12,038,175 [1] people and, according to CPTM [2], 68.5 kilometers of railways, 61 stations, and 154 trains. In 2015, 1.1 billion passengers have been transported. The system is integrated with CPTM at the stations of Luz, Pinheiros, Tamanduatei, Brás, Palmeiras-Barra Funda, Tatuapé, Corinthians-Itaquera, and Santo Amaro, as well as with other transportation modes in the city of São Paulo (Fig. 1).

2. Methodology

This work used the documentary research method, which according to Gil (2002) is the optimal method, since it relies on materials with no current analytical treatment or that could be improved based on the research objects.

A watershed analysis was carried out with emphasis on morphometric parameters in a GIS (geographical information system) environment, which allowed us to calculate and combine variables obtained through geoprocessing techniques, particularly fluvial hierarchy, interpolation, and spatial multi-criteria analysis.
Fig. 1  Study area location map. Subway and railway meshes in São Paulo.
We used images from the SRTM (Shuttle Radar Topography Mission) (values SF-23-Y-C and SF-23-Y-D; WGS84 projection), available at the Embrapa’s [Brazilian Agricultural Research Corporation] website.

For the analysis of topography and flood intensity, we used the MDE (digital elevation model) process, level curves, and data interpolation, the latter through the inverse distance in the GIS environment.

Interpolation is a technique used to estimate the value of a certain property in non-sampled locations based on points sampled at that same area or region. It relies on the inference that, in average, the property values are likely to be similar at closer locations than distant locations [3].

The IDW (Inverse Distance Weighting), Global Polynomial, Local Polynomial, Radial Basis Function, Kriging, and Co-Kriging methods calculate the value of a given quantity in space among the samples or observations based on a linear combination of the obtained values [3].

For the flooding plain analysis, we used the Multiresolution Index of Valley Bottom Flatness geoalgorithm–SAGA.

Information on points of flooding, railway meshes (CPTM), and subway meshes was obtained from the São Paulo’s city government’s library, at the GeoSampa’s website.

3. Theoretical Grounding

The history of transportation intermingles with the history of mankind itself, as it unfolded and continues to unfold according to the moment it lives, thus satisfying the needs and different interests depending on how the history plays out.

“Urban transportation, whether of people or goods, is seen as a topic of concern that requires an in-depth understanding in order to optimize interventions that aim at improving the local, regional, and global quality of life in the urban environment” [4].

As of 2001 (MC, 2004), with the approval of the Statute of the City, and then in 2002 with the new federal management, which implemented the Ministry of Cities, the Brazilian political scene changed. All municipalities were required to create conditions for a sustainable, fairer development of their territories. Accordingly, a more efficient transportation of passengers not only brings more comfort and safety to its users, but reduces the associated negative environmental impacts.

According to Alvarenga and Novaes [5], the implementation of a transportation system demands a systemic view, which comprises a planning stage. However, to that end, one needs to understand the flows in the different network links, the current service level, the intended service level, and other parameters that should be observed.

According to Ballou [6], the selection of a transportation system can be used to create a competitive advantage to the service.

Also, according to the above-mentioned author, there are two forms of railway service: regular and private carrier.

4. Natural Aspects

The morphometric analysis of watersheds is an important tool to define and identify the dynamics of a fluvial system, since water courses constitute morphogenetic process of most active in the modeling of the terrestrial landscape [7] (Fig. 2). Hence, a better understanding of the behavior of these natural processes makes it easier to prepare a transportation management plan, subsequently resulting in greater logistic efficiency and lower risk of interruptions in the operation, as in the case of the railway/subway passenger transportation system of the city of São Paulo. These applications have several purposes, particularly relief compartmentalization and further data for landscape studies and on susceptibility to and likeliness of inundation/flooding, as well as on risks to the passenger transportation system, the railway system for the case being.
River Network and the Risk of Flooding for the Railway and Subway Systems in the City of São Paulo, Brazil
River Network and the Risk of Flooding for the Railway and Subway Systems in the City of São Paulo, Brazil

The relief in the study area has as dominant characteristics plan and wavy smooth. As for hydrography, the fluvial hierarchy comprises rivers from the 1st to the 4th order (Fig. 2).

5. Results

There is a significant correlation between the human occupation models and the urban drainage system, especially in underdeveloped countries, such as Brazil, drastically changing the trace of rivers and lowland occupation, in addition to excessive soil sealing.

In general, one can state that railway and subway meshes are more exposed to risks of flooding in the Central and Eastern regions of the city of São Paulo.

Some determining factors to identify the area and that could explain the greater concentration of points of flooding include the topographic and hydrographic characteristics of the location, especially interventions resulting of the irregular occupation of the margins of rivers. Additionally, one can state that the risk of interruption of passenger transportation operations is directly related to the space where the railway and subway meshes are located, clearly at the most low-lying spots of the relief, i.e., the lowlands (Fig. 3).

Flood losses in transportation can reach BRL 0.8 million/year for points of flooding with a radius of 100 meters of influence, and BRL 1.7 million for points with a radius of 200 meters of influence [8].

Also, according to the above-mentioned author, flooding incidents in 2008 in the city of São Paulo caused a loss in the city’s GDP (in millions/BRL) of 35.5 and 116.7 for impacts in a radius of 100 and 200 meters, respectively (Fig. 4).
6. Conclusion

From the analysis of the railway and subway meshes intended for the transportation of passengers in the city of São Paulo, one can see a high concentration of this transportation system in the most low-lying regions of the relief, i.e., at low inclinations, at the valley bottom, thus exposing the system to a greater risk of flooding. However, it is worth emphasizing that the main driver is the irregular occupation in these wetlands, which are
natural flooding areas.

Flood intensity shows a greater concentration of the phenomenon in the Central and Eastern regions of the city, which are the greatest attractive hubs in the everyday movement of people—known as pendulum migration.

Finally, this study addresses the greater concentration of points of flooding in the city of São Paulo and the possible risk of interferences with the optimal operation of the passenger transportation system through the railway system. This model directly affects the quality of people’s mobility in the greatest city of the country, as well as the welfare received by such people from the public administrators.

References


