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Proposal for the Expansion of the Light Rail Vehicle Network

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Abstract

The objective of this study is to present a preliminary study to demonstrate the importance of expanding the Light Rail Vehicle (LRV) in the city of João Pessoa. This would ensure the best level of operational comfort, safety, social inclusion, and sustainability with the existing transport network in the city. The methodology used began with the collection of data provided by public agencies that regulate urban transport modes in the city and other technical sources that report on the feasibility of implementing the LRV. Then the main bus routes used by the population were analyzed (in relation to passenger volume) and how these routes could be improved if LRV could be inserted as a viable option. With the study, it was realized that there is no possibility of replacing one mode of transportation with another to drive all passengers. The optimal solution is to make expansions in the system that can make LRV an affordable and quality alternative for people to move around the city.

Keywords: Urban Mobility; Light Rail Vehicle (LRV); Urban Transportation Systems; João Pessoa.

1. Introduction

Currently, urban problems are becoming more and more relevant. Among these problems is the one of mobility, which has stimulated on the part of municipal administrations to solve major bottlenecks. It is important to emphasize that regardless of the strategy used for urban and transportation planning, it is necessary to have a diagnosis and quantification of the processes involved during this execution [1–3]. Every problem that is related to the mobility of people or goods in large urban centers directly affects the life quality of that population. An inefficient mobility system worsens not only the economic space but also the social and environmental space, in addition to the loss of time [4].

According to the Brazilian Ministry of Cities (2006) [5], urban mobility relates to "the ease of movement of people and goods in the urban area", so that it is not only about displacement or the use of public transportation. In this case, the involvement of the population with each space, object, or means during this displacement is also included; that is, it involves historical processes, cultural characteristics, and reflects the daily life of a local society, showing its own features. Access to transportation is a social right guaranteed by the Federal Constitution. It is a basic right that provides access to others, such as going to a hospital (health), going to school (education), and going home (housing). Thus, it becomes an essential element to guarantee the basic conditions of life and life and mobility of people in the cities [6–8].

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The choice of an adequate transportation model that is implemented in a planned manner favors service provision not only in terms of accessibility and mobility but also in the development and economic growth of the municipality, including influencing the quality of services provided in terms of cost, comfort, safety, and reliability. Other areas that benefitted are the reduction of environmental problems (congestion, emission of pollutants, reduction of traffic accidents), as well as ensuring a general improvement in the life quality of the population. But for these results to occur, it is necessary to listen to all the parties involved in the process, whether in the call for society on the part of the management agencies or through the population's own initiative in wanting to participate in these decisions [9, 10].

Light Rail Vehicles (LRVs) are a new reality in public transportation in major Brazilian cities. This is because the model has raised discussions about sustainable mobility, easy integration with other modalities, and the low cost of implementation compared to other models of rail vehicles [11]. LRVs typically operate in trains of two, three, or four units, with automated operation and ticketing outside the vehicles. The cars commonly used are between 14 meters (without articulation) and 37 meters (with articulation) in length and have a capacity for 96 to 358 passengers, depending on the size of the internal layout [12]. Figure 1 shows examples of the size and capacity of Light Rail Vehicles in the TUDH BS Mobile model.

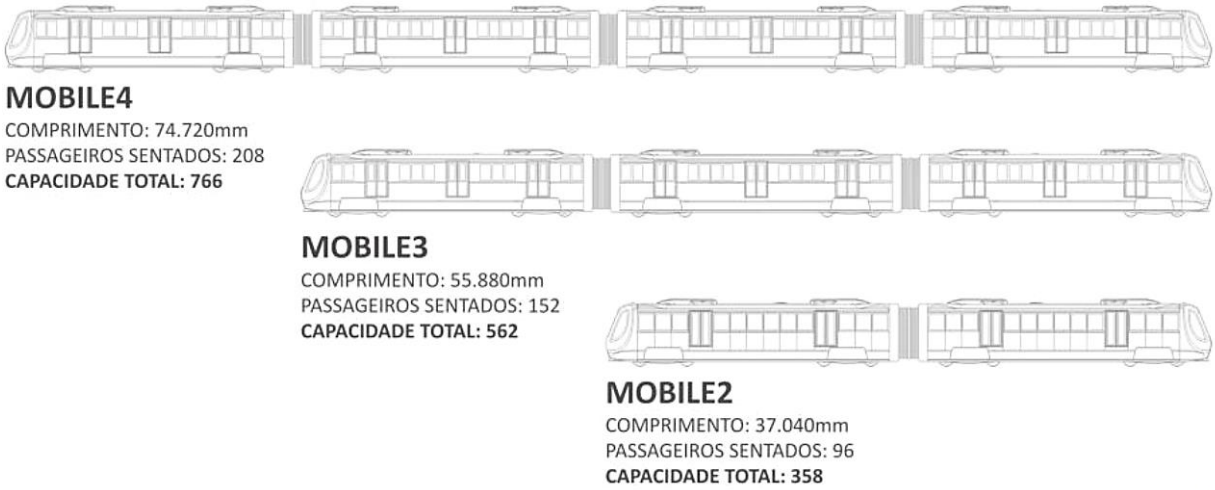

Figure 1. Size and Capacity of the Model TUDH BS Mobile, CBTU (2021) [13]

Grava (2003) [14] lists some qualities of LRV services, such as flexibility in design and deployment (adaptability to local conditions and demand) and mechanical and energy efficiency, since this means it is able to transport a large volume of passengers with little energy consumption and is powered by biodiesel. In addition to safety in operation, the system provides controlled operation with greater stability and motion control, which greatly reduces its propensity for accidents; simplified maintenance and operation: since only one operator is required, the system is not difficult to maintain; and the design of the vehicles allows easy access to the components. Finally, it provides a comfortable service with great public acceptance and a good image in society. If well maintained, it operates with little noise. Grava (2003) [14] also presents some constraints that can generate some problems in the implementation of a tramway system. For example: It does not offer the same capacity as the subway system; its deployment has a high cost and therefore requires a significant contribution of resources. This system has little mobility since the trips are made over a fixed infrastructure. It usually runs alongside automobile traffic, which reduces safety and speed levels at intersections. It faces resistance from car owners, since the resistance from car owners, since the implementation of exclusive lanes for LRT results in reduced space for it faces resistance from car owners, since the implementation of exclusive lanes for LRV results in reduced space for automobiles on the tracks.

It is also important to point out that LRV can serve as an initial step towards a subway system. Thus, the implementation of LRV requires a specific analysis of the advantages and disadvantages of this mode of public transport according to the physical, social, and institutional characteristics of the region under study. And it requires well-designed strategic planning that pursues short-, medium-, and long-term objectives.

This study aims to present a scenario of economic, environmental, social, and landscape importance for future functional and operational projects of real implementation of the expansion of the LRV system in the city of João Pessoa.

2. Materials and Methods

The methodology applied for the development of this article was to gather data provided by the Executive Superintendence of Urban Mobility (SEMOB) [15] of the city of João Pessoa and Companhia Brasileira of Urban Trains (CBTU) [13], as well as data collection in bibliographic and documentary research, based on articles, books, master's,

and related publications, with regard to the feasibility of the implementation of the Light Rail Vehicle system in several cities in Brazil. Due to the COVID-19 pandemic, it was not possible to conduct research in loco.

In Figure 2, it is possible to observe the methodological procedure adopted. After data collection, an analysis of the main paths traveled by bus lines was performed. Finally, possible changes to be made in the LRV network to improve access to the population were observed.

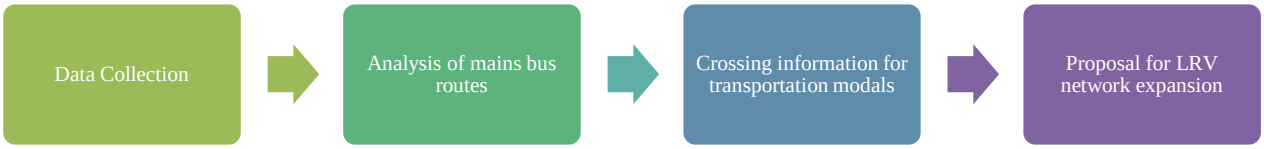

Figure 2. Flowchart of the research process

3. Results and Discussions

Currently, the crisis in urban mobility in large Brazilian cities is the priority that private and individual transportation receives over public transportation. This is justified by the loss of productivity and attractiveness of public transport, coupled with the constant increase in fares and poor service delivery [16]. Another factor is the increasing ease of acquiring a private vehicle, be it an automobile or motorcycle, to make up for the deficiency of public transportation systems.

The city of João Pessoa is the capital of the State of Paraíba, located in the extreme east of Brazil (Figure 3), and has 817,511 inhabitants, according to Brazilian Institute of Geography and Statistics (IBGE) [17] estimates. And as in large Brazilian cities, the scenario has very limited transportation options, which generally vary between public transportation or individual transportation, motorized or not.

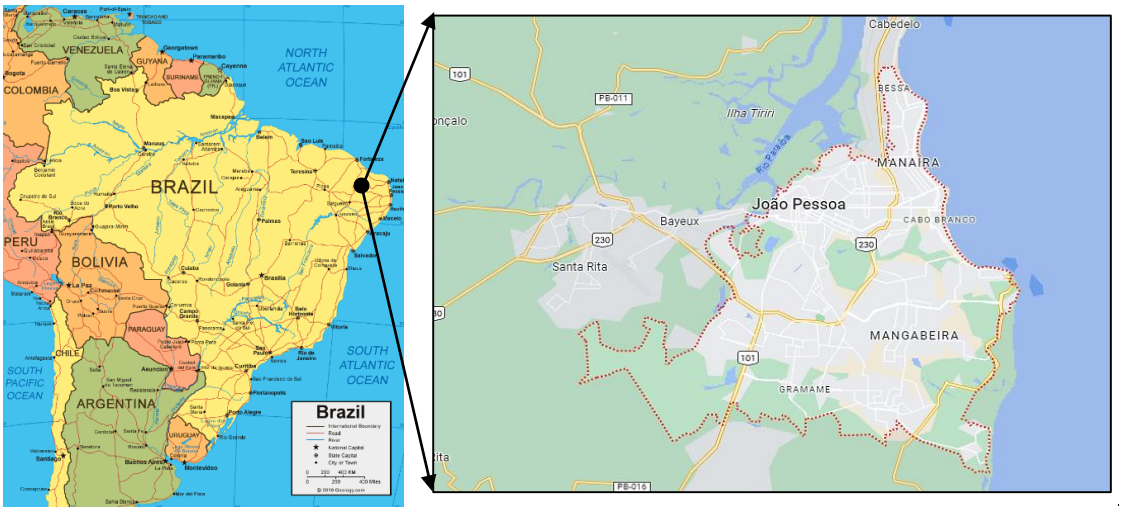

Figure 3. Geographic location of João Pessoa City

Based on data recorded in the year 2019 by SEMOB [15], before the COVID-19 pandemic, João Pessoa had 99 conventional lines and a fleet of 560 buses officially registered, of which 522 were adapted for people with some type of disability. Until today, six concessionaires formed two consortiums of companies, Unitrans (TransNacional and Reunidas) and Nossa Senhora dos Navegantes (São Jorge, Santa Maria, and Marcos da Silva), that together transported in 2019 more than 50 million passengers in the city.

Currently, with the pandemic scenario in evidence, the fleet has been reduced to 366 vehicles that supply 66 conventional lines. The conventional lines are identified by numbers that represent the corridor that the vehicle will serve. Currently, the city is divided into 7 main corridors: Corridor 1: Av. Cruz das Armas; Corridor 2: Av. 2 de Fevereiro; Corridor 3: Av. Dom Pedro II; Corridor 4: Av. Min. José Américo de Almeida (Beira Rio); Corridor 5: Av. Pres. Epitácio Pessoa; Corridor 6: Avenue Gov. Flávio Ribeiro Coutinho (Retão de Manaíra); and Corridor 7: West Access.

Figure 4 illustrates all these corridors on a schematic map, in which the seven routes are highlighted with colored lines and the respective nomenclature used by the bus lines.

Figure 4. Corridors of João Pessoa's conventional bus lines

In 2019, according to information from SEMOB [15], the average age of the fleet reached 6.5 years, one of the lowest in the country, and the fare charged was worth R$ 4.15. For those who have the Passe Legal card, there is a discount of R$ 0.15 in the value of the passage.

Besides public transportation by bus, João Pessoa has the services of the Brazilian Company of Urban Trains (CBTU) [13] that has 12 stations in the Metropolitan Region, 4 of them within the city of João Pessoa (Alto do Mateus Pessoa (Alto do Mateus, Ilha do Bispo, João Pessoa and Mandacaru), at the price of R$ 2,00 the ticket fare.

The 30.03 km rail extension connects the cities of Santa Rita, Bayeux, João Pessoa, and Cabedelo, where, in 2019, before the pandemic, about 2.1 million passengers were transported on a route made by complete in the time of 60 minutes. In Figure 5, it can be seen the route taken by the current line and the location of the twelve stations of the LRV of Greater João Pessoa.

Figure 5. Current map of the LRV route and stations in João Pessoa. (CBTU, 2021)

Mello (1942) [18], Bruton (1979) [19], and Vasconcellos (2005) [20] refer to travel time as one of the main criteria for choosing the mode of passenger transportation, associated with other factors such as cost, comfort characteristics of the displacement, as well as particularities of the passenger. The current railway line used by CBTU for its operations is located just on the outskirts of the city, limiting its use.

The project aims, through the construction of a new branch line (Figure 6) with an extension of 2,740 meters, to expand the Light Rail Vehicle system to the interior of the city of João Pessoa. Three new stations would be built (Tancredo Neves, Flávio Coutinho, and Manaíra) and would serve the users that commute to the Bairro dos Ipês and Manaíra, places with a high presence of residences, commerce, large shopping centers, and the coastal area.

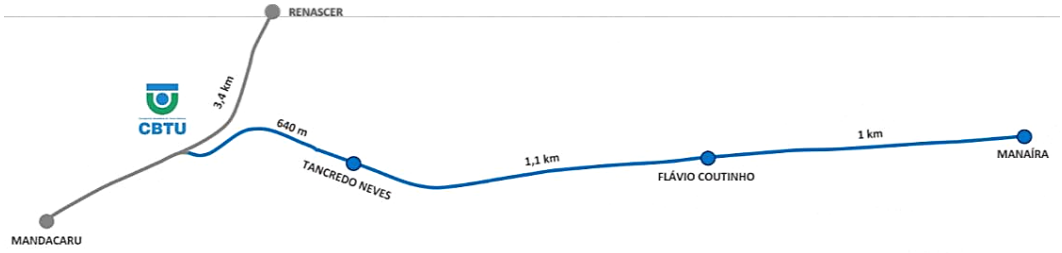

Figure 6. New route layout

Figure 7 indicates that the connection of the new extension to the current one in operation would be at Av. Pres. Tancredo Neves, on a piece of land that has been expropriated of two commercial establishments (Líder Veículos and WK Peças e Serviços). The line will follow through the avenue's central 640 meters to the first station (Tancredo Neves), which will be located at the entrance contour of Bairro dos Ipês.

Figure 7. Location of the junction between the current and the new branch

Figure 8 presents where the Tancredo Neves station would have been, where today is the current return at the entrance of the Bairro dos Ipês.

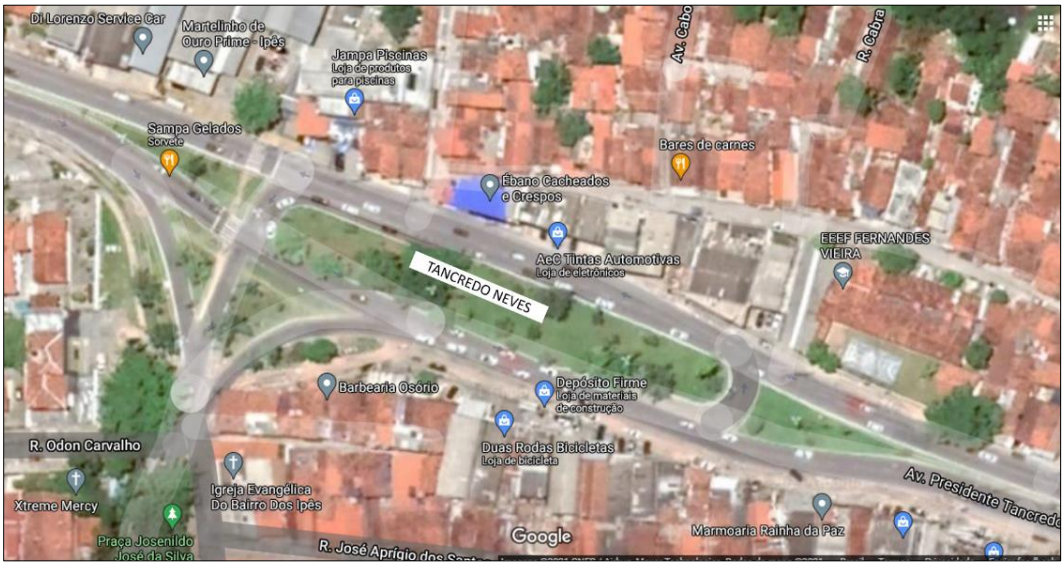

Figure 8. Tancredo Neves Station Location

On the next track, the LRV would continue for another 1,100 meters, where it would cross the BR-230 viaduct, reaching the second station (Flávio Coutinho) that would be located near the Manaíra Shopping Center. Figure 9 shows where the Flávio Coutinho station would be located, next to the mall.

Figure 9. Flavio Coutinho Station Location

The last stretch of 1,000 meters would be through Av. Coutinho, which would lead to the third station (Manaíra, Figure 10) located at the end of the mentioned avenue near Mag Shopping.

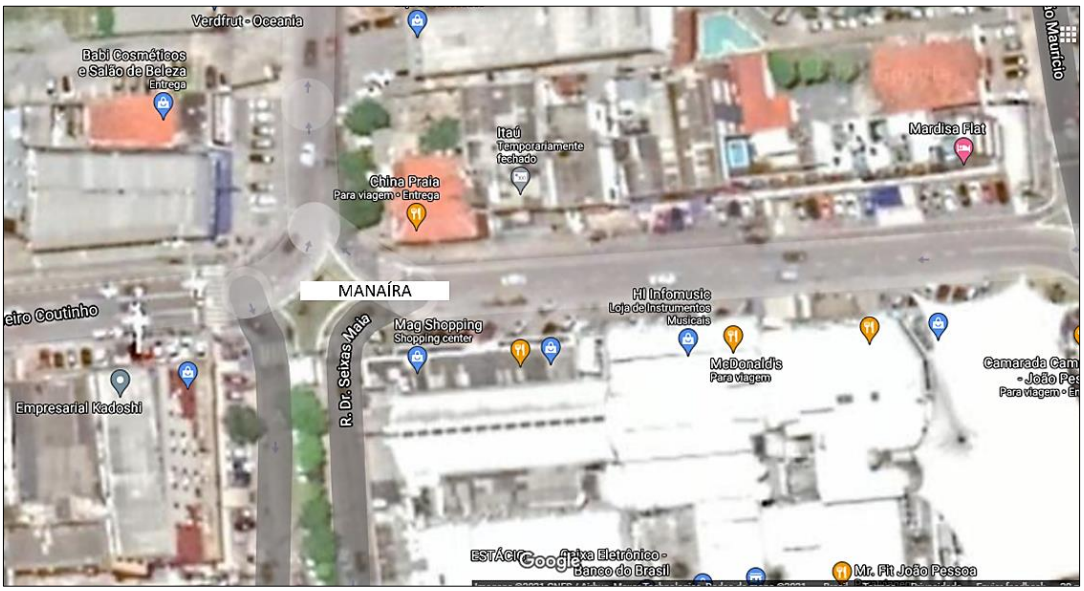

Figure 10. Manaira Station Location

If the current travel time of CBTU's light rail operations is taken into consideration, the section that is closest to the new branch line is operated between the Santa Rita and Várzea Nova stations, which is about 2,870 meters long and takes 5 minutes.

Table 1 contains the distance in meters and the elapsed time between one station and another currently traveled by LRV.

For example, if the user wants to go to Mag Shopping in the neighborhood Manaíra leaving from the Integration Terminal Varadouro and wants to choose the bus as their transport, they will pay the fare of the ticket in the value of R$ 4,15, board a bus without air conditioning, face the traffic, make dozens of stops, move around, and travel around 20 minutes (according to data from the JampaBUS APK, 2021) to their final destination (Figure 11).

Table 1. Distance and time between LRV stations (CBTU, 2021) [3]

Station 1	Station 2	Distance (m)	Time (minutes)
Santa Rita	Várzea Nova	2870	5
Várzea Nova	Bayeux	3030	6
Bayeux	Alto do Mateus	1980	4
Alto do Mateus	Ilha do Bispo	1390	4
Ilha do Bispo	João Pessoa	1930	5
João Pessoa	Mandacaru	3600	7
Mandacaru	Renascer	3400	6
Renascer	Jacaré	4400	7
Jacaré	Poço	2200	5
Poço	Jardim Manguinhos	3400	6
Jardim Manguinhos	Cadedelo	1900	4
Total	-	30100	59

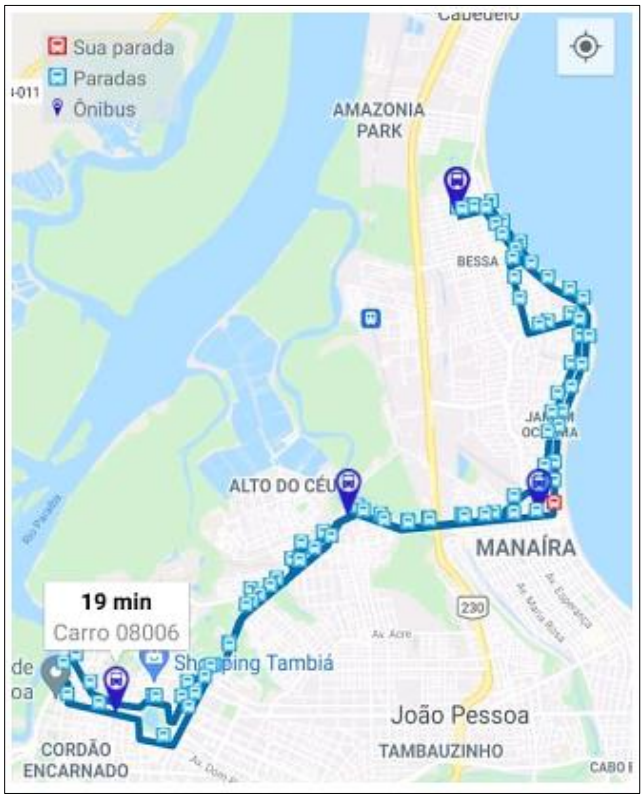

Figure 11. Route with the itinerary of the 601 line leaving from the Integration Terminal

With the branch suggested in this study, the user would pay for the ticket fare of R$ 2.00, board a vehicle with air conditioning, face stops at three stations, not face traffic, and would get to his destination in 5 minutes.

The area where the new branch of the LRV would be implemented is part of the Corridor 6-Flávio Ribeiro Coutinho (Retão de Manaíra), which is explored by the conventional bus lines of the consortia of companies.

On the main corridor, it was identified the presence of 15 bus stops and 7 more bus stops in the vicinity and adjacent streets. The conventional lines that serve these locations are: 505 - Bairro dos Ipês 510 - Tambaú Praia, 600 - Val Paraíso, 601 - Bessa Manaíra Shopping, 602 - Ilha do Bispo Ilha do Bispo Mandacaru, 604 - Bairro dos Ipês via Ayrton Senna, 1001 - Bairro das Industries Manaíra Shopping.

According to data from SEMOB [15], these conventional lines during that year, before the COVID-19 pandemic, transported about 6.5 million passengers on nearly 127,000 trips on a fleet of 37 buses per day during the week and an average of 30 buses per day on weekends. Table 2 presents the total number of passengers carried in 2019 on the bus lines that serve the current location, where the feasibility of this LRV expansion project will be studied.

Table 2. Total passengers carried per line

Lines	Station 2	Total number of passengers transported
505	Bairros dos Ipês	279.415
510	Tambaú Praia	1.308.113
600	Val Paraíso	998.352
601	Bessa Manaíra Shopping	1.120.232
602	Ilha do Bispo Mandacaru	922.375
604	Bairros dos Ipês via Aytorn senna	397.513
1001	Bairro das Industrias Manaíra Shopping	1.381.667
Total	-	6.407.667

Alouche (2008) [21] relates the capacity equivalence of the LRV, the traditional individual car, and the conventional bus, all with their maximum capacity. In Figure 12, it is possible to see that to serve the same number of people carried by the LRV in its full capacity, it would require 120 private cars or 10 conventional buses.

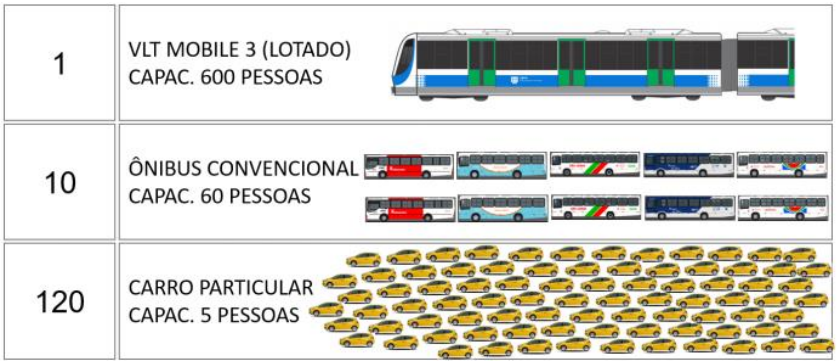

Figure 12. Physical comparison of transport capacity

In the whole of 2019, about 12,777 conventional buses were needed to transport about 6.5 million passengers on nearly 127,000 trips only in the Corridor 6 area. A single LRT vehicle of the TUDH BS Mobile 3 model, the same one currently used by CBTU, with capacity for about 600 passengers in total, would carry the same number of passengers with quality, comfort, speed, and a cheaper fare in only 10,834 trips, a reduction of 91.47% in relation to the traditional bus.

In this scenario, in addition to the economic benefits and the comfort guaranteed to users, LRT implantation reduces the number of buses circulating on the streets, which contributes to reducing the emission of carbon dioxide caused by burning fossil fuels. Thus, ensuring a better quality of life as well as reducing the incidence of congestion and visual pollution caused by the high quantity of vehicles on the streets. Also, according to Alouche (2008) [21], the implementation of a public transportation mode in a city requires an appropriate study of the urban environment in which it will be implemented, as well as the technical characteristics and cost of the chosen technology. It is important to understand that to define the true project, some factors such as short- and long-term planning, analysis of expected future mobility, sustainable development, and the quality of transportation must be considered.

The issue of choosing the bus or the train directly influences the role of the city's public transportation. This is because the choice of a mode of transportation involves a political appeal, which, if not well defined, can have a direct impact on the life of the population and on the evolution of the growth of that place. According to Alouche (2008) [21], LRV has not yet been introduced in a practical form in Brazilian cities, despite the numerous networks that have been implemented with great success in dozens of European, American, Australian, and Asian cities.

Durão (2011) [12] states that it is noticeable the economic importance that the sector of passenger transport by bus still exerts in cities and its great influence in discussions about issues involving public transport. It is perceived that the interests of businessmen among the concessionaires of buses do not always coincide with the interests and desires of the population that uses the services granted by their city governments. However, it is a fact that the public has the obligation to act in the search for the best solutions to deliver a quality service that fulfills the needs that its population pays for.

The city of João Pessoa, as well as many other cities in Brazil, has been suffering from the dominant presence of individual automobiles as the primary way to move around. This is also due to the high price charged for public transportation services that do not present enough comfort, quality, and attractiveness. It is necessary that there be a change in cultural thinking and that it is essential to prioritize quality mass transportation, even if its greatest financial return is in the long term.

The LRV system currently has sustainable, modern, and economical features that contribute to the welfare, quality of life, and appreciation of the urban environment where the system will be deployed. In this way, it amplifies the relationship of the urban environment with the geographic scenario of the locality.

4. Conclusion

The present study sought to highlight the importance of implementing a broader vision for the process of urban planning and public transportation in the city of João Pessoa. One of the main obstacles to the real implementation of the expansion of the Light Rail Vehicle system is the high cost that is necessary to start the project, as well as to maintain the management of the systems and future adaptations, redesigns, and continuous improvements of the services. But it must also be taken into consideration that LRV excels when compared to the other transport modes currently used in the city and that, with good long-term planning, the economic, social, and environmental advantages are of great value to society.

The objective of this study was to show the real importance of always searching for a product that is comfortable, of good quality, economical, and does not harm the environment. The importance of public transport made by conventional buses is well known because not all places are feasible to implement a railway system, so it is essential to have multimodal systems.

The concepts of feasibility and cost are closely linked within engineering, and this was a determining factor in limiting this study. It was not possible to measure the real cost of implementing a tramway system, given the complexity of a large project that transforms the entire scenario of the region where it will be implemented. And it is necessary to evaluate factors such as climate, soil, equipment deterioration, fleet, logistics, quotes, and bids, among others.

Another lack is that, due to the COVID-19 pandemic and the recommendation that social distancing be conducted, it was not possible to carry out market research and in-location mapping with users of the current transportation system, which makes it difficult to accurately estimate demand and hampers the study of an ideal system for the locality. Thus, it is suggested that a more elaborate technical study be carried out with professionals from various areas to assess the real economic, social, technical, economic, and environmental feasibility of implementing a new branch of the VLT system in the city of João Pessoa.

5. Declarations

5.1. Author Contributions

Conceptualization, A.S.C.N. and C.A.C.S.; methodology, A.S.C.N. and C.A.C.S.; validation, F.C.M., A.S.C.N., and C.A.C.S.; formal analysis, A.S.C.N. and C.A.C.S.; investigation, A.S.C.N. and C.A.C.S.; data curation, A.S.C.N. and C.A.C.S.; writing—original draft preparation, A.S.C.N. and C.A.C.S.; writing—review and editing, F.C.M. and L.M.; supervision, L.M. and F.C.M.; funding acquisition, L.M. All authors have read and agreed to the published version of the manuscript.

5.2. Data Availability Statement

Data sharing is not applicable to this article.

5.3. Funding

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5.4. Acknowledgements

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5.5. Conflicts of Interest

The authors declare no conflict of interest.

6. References

[1] Jiang, Y. H., Gao, S., Yin, Y. H., Xu, Z. F., & Wang, S. Y. (2023). A control system of rail-guided vehicle assisted by transdifferentiation strategy of lower organisms. Engineering Applications of Artificial Intelligence, 123(April), 106353. doi:10.1016/j.engappai.2023.106353.

[2] Fageda, X. (2021). Do light rail systems reduce traffic externalities? Empirical evidence from mid-size European cities. Transportation Research Part D: Transport and Environment, 92(February), 102731. doi:10.1016/j.trd.2021.102731.

[3] Claire Schuch, J., & Nilsson, I. (2022). Rail Transit, for Who? Perceptions and factors influencing light rail ridership in Charlotte, NC. Travel Behaviour and Society, 27(October 2020), 38–46. doi:10.1016/j.tbs.2021.06.001.

[4] Yigitcanlar, T., Li, R. Y. M., Inkinen, T., & Paz, A. (2022). Public perceptions on application areas and adoption challenges of AI in urban services. Emerging Sciences Journal, 6(6), 1199-1236. doi:10.28991/ESJ-2022-06-06-01.

[5] Urban Mobility Primer. (2006). Urban mobility is urban development! Ministry of Cities (2nd Ed.). Brasília, Brazil. (In Portuguese).

[6] Woldeamanuel, M., Obsie, A., & Woldetensae, B. (2022). Passengers' perception towards socioeconomic benefits of Addis Ababa light rail transit. Case Studies on Transport Policy, 10(1), 198–207. doi:10.1016/j.cstp.2021.12.002.

[7] Yin, Y., Liu, H., Zhang, S., Yang, Y., & Li, D. (2022). Joint optimization of modular vehicle schedule and fair passenger flow control under heterogeneous passenger demand in a rail transit system. Computers and Industrial Engineering, 173(February), 108749. doi:10.1016/j.cie.2022.108749.

[8] Ramos-Santiago, L. E., Novales, M., & Varela-García, F. A. (2022). Identifying and understanding determinants of regional differences in light-rail patronage and performance. Case Studies on Transport Policy, 10(2), 1188–1206. doi:10.1016/j.cstp.2022.04.005.

[9] Bouhlal, L., Lamdouar, N., & Kassou, F. (2022). Experimental Measurement and Simulation of Railway Track Irregularities. Civil Engineering Journal, 8(10), 2235-2242. doi:10.28991/CEJ-2022-08-10-014.

[10] McGreevy, M. (2021). Cost, reliability, convenience, equity or image? The cases for and against the introduction of light rail and bus rapid transit in inners suburban Adelaide, South Australia. Case Studies on Transport Policy, 9(1), 271–279. doi:10.1016/j.cstp.2021.01.001.

[11] Baker, D. M., & Kim, S. (2020). What remains? The influence of light rail transit on discretionary income. Journal of Transport Geography, 85, 102709. doi:10.1016/j.jtrangeo.2020.102709.

[12] Durão, I. (2011). VLT or BRT that is the Question! (Revista Ferroviária) Railway Magazine. Available online: https://revistaferroviaria.com.br/2011/04/artigo-vlt-ou-brt-eis-a-questao/ (accessed on July 2023). (In Portuguese).

[13] CBTU (2021). Brazilian Urban Train Company. Available online: https://www.cbtu.gov.br/index.php/pt/joao-pessoa/ (accessed on May 2023). (In Portuguese).

[14] Grava, S. (2003). Urban transportation systems. Choices for communities. McGraw-Hill, New York, United States.

[15] SEMOB (2023). Executive Superintendence of Urban Mobility of João Pessoa, Brazil. Available online: https://servicos.semobjp.pb.gov.br/ (accessed on July 2023). (In Portuguese).

[16] IPEA (2023). Institute of Applied Economic Research. Urban Mobility in Brazil. Brasília: IPEA, 2011.

[17] IBGE (2023). Brazilian Institute of Geography and Statistics (Ministry of the Economy), Rio de Janeiro, Brazil. Available online: https://www.ibge.gov.br/en/home-eng.html (accessed on June 2023).

[18] Mello, J. C. (1981). Urban transport planning (Vol. 3). Editora Campus, Santiago de Compostela, Spain. (In Portuguese).

[19] Bruton, M. J. (1979). Introduction to transport planning. Interciẽncia Publisher, Rio de Janeiro, Brazil. (In Portuguese).

[20] Vasconcellos, E. A. D. (2005). The city, transport and traffic. Prolivros, São Paulo, Brazil. (In Portuguese).

[21] Alouche, P. L. (2008). VLT: modern, sustainable and urbanistically correct transport for Brazilian cities. Revista dos Transportes Públicos, 118, 35-44. (In Portuguese).