

Evaluating the Influence of Smart City Frameworks on Urban Mobility: A Comparative Perspective with Manaus, Brazil

Ricardo Andrade¹, Marcelo Augusto Macedo Junior Oliveira²

¹Bachelor's Student in Law, Faculdade La Salle Manaus, Manaus - Amazonas, Brazil

²Master's in Production Engineering - Intellectual Property, Federal University of Amazonas, Manaus - Amazonas, Brazil

*Correspondence Author

Abstract: *This study examines the application and challenges associated with the implementation of the Urban Mobility Law (Law No. 12,587/2012) in the city of Manaus, with a focus on the difficulties in providing public transport services and the regulatory shortcomings that perpetuate issues such as overcrowding and low-quality service. The research contextualizes Manaus within a scenario of increasing mobility demand, shaped by distinct geographic and socioeconomic characteristics that necessitate tailored strategies for developing a more efficient and inclusive transport system. Smart cities—which leverage technology to enhance transportation—serve as a benchmark for urban mobility solutions that prioritize user well-being. With an emphasis on regulatory oversight and the impact of concession contracts, the study investigates the roles of the municipal government and private concessionaires, drawing comparisons with successful practices implemented in other Brazilian cities. Methodologically, the research adopts an exploratory and comparative approach, based on document and legislative analysis, to propose viable solutions aimed at fostering more equitable and accessible urban mobility in Manaus.*

Keywords: Urban mobility, Public transport, Smart cities, Manaus.

1. Introduction

The effective application of the Urban Mobility Law (Law No. 12,587/2012) faces difficulties and slowness in its implementation, especially in large Brazilian cities, given the exponential growth of the population, the use of private vehicles, and the concentration of people in central regions. Furthermore, these challenges combined with inefficient transport systems are conducive to generating congestion, lack of accessibility, and other problems that will be addressed.

In the meantime, smart cities are alternatives for improving space planning to allow better flow of various types of transportation in our Brazilian cities, by promoting more sustainable, efficient, and inclusive mobility through cognitive and sensitive technologies, such as the use of information and communication technologies (ICTs).

These smart cities use data collection and utilization to optimize the movement of people and vehicles, thereby also enabling the reduction of environmental impact.

The Urban Mobility Law establishes guidelines for the integration of urban transportation modes and services, the promotion of scientific and technological development, as well as sustainability, reducing social inequalities and providing improvements in population conditions related to accessibility and mobility.

As a continuation of Law No. 12.587/2012, the National Urban Mobility Plan (PNMU) aims to ensure the movement of individuals and goods, universal accessibility within municipal limits, safeguarding equity and promoting social inclusion of individuals, and improving the urban conditions of society.

The city of Manaus, capital of the state of Amazonas, has

social, economic, political, and historical characteristics that directly influence the city's urban mobility. The concentration of universities in the same region of the city, and the industrial hub also in specific locations, together with few access routes to these main points of the city, result in excessive flows of people and vehicles in specific areas of the city.

Despite having implemented some policies aimed at applying federal legislation, the Amazonian capital, in its current situation, still contrasts with the reality of smart cities and references within Brazil itself.

Therefore, the present work aims to investigate the role of smart cities in promoting effective urban mobility, establishing a comparison with the current situation of the city of Manaus. The research seeks to answer the following question: what are the limitations and opportunities for the application of smart mobility solutions in Manaus, considering its geographical, social, and economic particularities?

In order to answer this question, the study will be divided into chapters ranging from the concept of smart cities to a comparative analysis of model cities with Manaus. Additionally, it also addresses the specific characteristics, ongoing policies, and probable solutions that allow Manaus to become smarter and more sustainable in terms of mobility.

Thus, this study intends to contribute to the debate on the use of technological forms of urban mobility in the context of Manaus, and to propose realistic alternatives that can be applied in the city's urban planning.

2. Theoretical Framework

2.1 Public Transport as a Social Right and Municipal Responsibility

Public transport was consolidated as a social right with Constitutional Amendment no 90, which amended the 1988 Brazilian Federal Constitution, enshrining a right previously considered subjective. In Article 6, caput, transport is recognized as essential to citizenship and social well-being. The National Urban Mobility Plan (PNMU), established by Law No. 12.587/12, defines urban transport as a set of public interest services, which includes the movement of people and goods, with the Union responsible for establishing guidelines for its development (art. 21, XX, CFRB).

Still within the constitutional context, Article 182, caput, assigns to the Municipality the competence to promote urban development to ensure the well-being of residents. Thus, public transportation, being essential, is a municipal obligation, which must be carried out directly or by concession or permission (art. 30, V, CFRB). The PNMU, through Law No. 12.587/12, guides universal mobility and accessibility, encouraging social inclusion and equitable urban development. This public policy is becoming increasingly relevant in large metropolises and industrial hubs, where there is an exponential expansion in the demand for public transportation. In cities with more than 20,000 inhabitants, urban planning that prioritizes public transportation is essential, especially when linked to affordable fares and sustainable measures.

To address the overload of urban systems, some initiatives, such as the vehicle restriction program in São Paulo, seek to limit car traffic during peak hours, promoting public transportation and reducing congestion. However, in cities like Manaus, the limitations of public transportation are evident. A study by Ufam Business Review (2019) pointed out that 97% of the population considers bus fares disproportionate to service quality; 97% state that the number of operating vehicles is insufficient; 44% highlight poor bus maintenance and overcrowding as major issues. These data reflect users' dissatisfaction with a system that fails to meet basic urban mobility needs.

2.2 Economic Challenges and Failures in the Provision of Transport Services in Manaus

Manaus' public transportation model, as noted by Kupfer and Hansenklever (2002), faces the dilemma of profit maximization through economies of scale. This phenomenon allows an increase in passengers transported without raising operational costs, encouraging overcrowding and sacrificing service quality. Overcrowding and underinvestment compromise universal accessibility, violating the right to mobility established in article 5º, section IV, of Law no12.587/12. In Manaus, dissatisfaction with public transportation has led to increased use of private vehicles, contributing to congestion and worsening the public transportation situation.

The Municipal Institute of Urban Mobility (IMMU), created by Municipal Law No. 2.408/19, is the body responsible for planning, inspecting, and operating the public transportation system in the Amazonian capital. However, the institute's ability to effectively fulfill its functions has been questioned, as insufficient inspection and lack of strict quality standards

make urban mobility a precarious experience for users. Although responsibility for the service lies with the Municipality and concessionaire companies, the reality in Manaus contrasts sharply with successful transportation models, such as that of Curitiba.

In Curitiba, public transportation is managed by Urbanização de Curitiba (URBS), which acts as a concessionaire, sets strict quality standards, inspects routes, and meets user satisfaction targets. According to Proteste Associação de Consumidores (Proteste Consumer Association), in 2014, Curitiba's transportation stood out among Brazilian capitals for its high satisfaction rate, achieved through constant inspection and a commitment to service quality. In Curitiba, inspection is carried out by inspectors who monitor compliance with service orders, penalizing violations with fines and other sanctions, ensuring operations align with technical and quality standards set by the Municipality.

In Manaus, public intervention is necessary to improve transportation services, whether through stricter inspections or the revision of concession contracts with companies that fail to meet established quality parameters. Article 35 of Law No. 8,987/95 allows the Municipality to terminate contracts with non-compliant concessionaires, a viable measure to ensure quality in public transportation. By analyzing the challenges and responsibilities in Manaus' public transportation, this study aims to contribute to the creation of public policies that promote a dignified, efficient, and accessible urban mobility system for all.

2.3 Urban Space Production Model and Its Impact on Mobility

The model of Brazilian urban space production in recent decades has promoted the unplanned expansion of cities, causing a distance between urban centers and peripheral areas. This urbanization pattern drives the need for long commutes and, as a consequence, increases dependence on motorized transportation modes. In cities like Manaus, where public transportation is deficient and the use of private vehicles is high, this model contributes to intensifying mobility problems and generating serious environmental and social impacts.

From a historical analysis, it is evident that the Brazilian urban structure was strongly influenced by the use of the automobile. According to Souza (2015), "the horizontal expansion of cities, facilitated by the opening of new roads, increased the size of urban sprawl, making motorized transportation a necessity for much of the population" (p. 45). This resulted in cities that, besides being dispersed, face problems such as congestion, increased pollution, and inefficiency of public transportation services.

Social inequality is also a determining factor in the spatial configuration of cities. According to the author, "higher-income classes came to base their mobility on private vehicles, while poorer segments depend on public transportation" (Souza, 2015, p. 46). This socio-spatial segregation is evident in Manaus, where the peripheral population faces major challenges in accessing key services and jobs concentrated in central areas.

Paiva's (2015) research on the Urban Mobility Master Plan in Manaus confirms this reality, pointing out that "population dispersion generates a demand for road infrastructure that the local public authorities cannot adequately meet" (p. 12). Consequently, the city experiences an increase in the use of private vehicles, which worsens congestion problems and reduces the efficiency of public transportation. This reality is especially problematic during peak hours, when urban infrastructure is insufficient to support the volume of vehicles on main roads.

The lack of adequate urban planning, as observed in Manaus, results in a city that, besides being inefficient in terms of mobility, becomes environmentally unsustainable. According to Costa (2008), "motorized transportation in Brazilian cities is responsible for significant CO2 emissions, contributing to the worsening of urban environmental problems" (p. 63). In Manaus, the lack of sustainable transportation alternatives, such as bike lanes and quality mass transit, limits the population's options, which ends up resorting to automobiles, intensifying pollution and congestion.

The environmental impact of this mobility model is particularly concerning. As Campos (2022) points out, "sustainable development requires cities to simultaneously consider the economic, social, and environmental impacts of their mobility policies" (p. 74). In Manaus, the absence of an efficient public transportation system not only limits the population's mobility but also imposes a high environmental cost, with increased greenhouse gas emissions and degradation of air quality.

Thus, Manaus's urban space production model contributes to socio-spatial inequality, inefficiency of transportation systems, and the worsening of environmental problems. The city, which has grown in an unplanned manner, urgently needs policies that promote urban restructuring focused on sustainability and social inclusion. The promotion of public policies that encourage the use of sustainable transportation modes and restrict the use of private vehicles in certain areas of the city are alternatives to mitigate the impacts generated by this urban model.

Finally, the implementation of smart city technologies can help improve mobility in Manaus. According to studies on Smart Cities, "the use of data and computerized systems can optimize the flow of people and vehicles, promoting more efficient urban mobility with less environmental impact" (Leal, 2015, p. 98). This approach, which has already proven effective in other Brazilian cities, can bring significant advances to Manaus, contributing to a more equitable and sustainable urban model.

2.4 Infrastructure and Quality of Public Transport Services

The quality of public transport services in Manaus faces numerous challenges, reflected in inadequate infrastructure to meet the growing demand. The city, marked by its rapid growth and lack of sustainable urban planning, has a public transport system that does not meet the population's needs. Among the main difficulties faced are the lack of vehicles in good condition, overcrowding, and the absence of diverse

public transport options. These problems are further exacerbated during peak hours, when the system is subjected to high demand, exposing passengers to poor transport conditions.

According to Silva et al. (2019), the quality of buses in Manaus is one of the main points of dissatisfaction among users, with 97% considering the fare paid to be unfair in relation to the service offered and 44% stating that the vehicles are in very poor condition (p. 75). These data indicate that the public transport system is not only unable to meet existing demand but also presents conditions that directly harm users' experience and well-being.

Another identified problem is overcrowding, which significantly impacts transport quality and urban mobility. In Manaus, overcrowding is the result of both a lack of vehicles and inefficient bus route distribution. As pointed out by Neto and Nogueira (2024), "the reduced use of articulated buses on high-demand routes is a reflection of capitalist dynamics, which prioritize cost reduction by companies" (p. 700). This prioritization of economy over service quality results in an uncomfortable transport experience, especially for users who depend on the system to travel during peak hours.

In addition to poor vehicle quality and overcrowding, the transport system in Manaus suffers from a lack of modal options. According to Souza (2022), "the absence of alternatives to public transport, such as bike lanes and subways, limits citizens' choices and forces dependence on buses and private vehicles, worsening congestion" (p. 62). This lack of modal alternatives prevents more sustainable and integrated mobility, leaving the population with few options other than facing the difficulties imposed by public transport.

The limitations in Manaus' public transport infrastructure are also exacerbated by a lack of planning and oversight. The Municipal Institute of Urban Mobility (IMMU), the body responsible for organizing and supervising the city's transport system, faces difficulties in performing its functions effectively. As mentioned in the study by Campos (2022), "the IMMU does not have sufficient resources to adequately supervise the system, resulting in poor maintenance and services that do not meet minimum quality standards" (p. 78). This lack of oversight allows concessionaires to operate with vehicles in precarious conditions and without making the necessary investments to ensure service quality.

User dissatisfaction with public transportation in Manaus is evident and has been demonstrated through frequent complaints and social protests. In a survey conducted by Research, Society and Development (2022), it was observed that public transportation users in the city report an experience marked by insecurity, discomfort, and overcrowding—factors that discourage the use of public transit (p. 89). Ultimately, these problems reflect a lack of investment and the absence of public policies aimed at improving the system.

Therefore, the infrastructure and quality of public transportation services in Manaus do not meet the population's expectations and needs, contributing to the degradation of urban mobility and limiting citizens' right to an accessible city. To improve the transportation system, it is

essential to implement policies that encourage fleet modernization, diversification of modes, and effective oversight, with the goal of ensuring a dignified and accessible service for the people of Manaus.

2.5 Institutional Responsibilities and Challenges

Managing public transportation in Manaus is a complex task involving multiple institutions and facing a series of institutional challenges that limit its ability to provide quality service to the population. The Municipal Institute of Urban Mobility (IMMU) is the agency responsible for the administration, oversight, and planning of the city's public transportation system. However, a lack of resources, administrative overload, and institutional limitations directly affect the effectiveness of this agency in fulfilling its role of ensuring an accessible and efficient transportation system for the population.

According to Campos (2022), "the IMMU faces difficulties in implementing urban mobility policies due to a shortage of financial and human resources, which compromises the oversight and maintenance of the quality of services provided" (p. 74). Insufficient resources not only hinder proper oversight of concessionaires but also prevent investment in infrastructure improvements and bus fleet modernization. This scenario of budgetary constraints contributes to the perpetuation of a transportation system that does not meet users' basic needs, making efficient and safe urban mobility difficult.

Another significant challenge is the concession contracts established between the municipality and the companies responsible for operating public transportation. In many cases, these contracts prioritize the financial viability of the companies, placing the quality of service provided in the background. As observed by Paiva (2015), "the lack of rigorous clauses in concession contracts facilitates concessionaires' negligence regarding fleet maintenance and adherence to schedules, resulting in a deficient public transportation service" (p. 21). In Manaus, this lack of contractual requirements for maintaining quality directly impacts users' well-being and the perception of public transportation as a reliable service.

Furthermore, the lack of coordination between the IMMU and other government entities is another factor that compromises the development of integrated and sustainable urban mobility. The absence of effective collaboration between the sectors responsible for urban planning, transportation, and the environment results in fragmented policies that do not address the city's infrastructure needs. According to Souza (2015), "the lack of a coordinated strategy among municipal agencies prevents the creation of an intermodal transportation system, limiting mobility options for citizens" (p. 51). This hinders the implementation of modal alternatives that could alleviate pressure on the bus system and promote more sustainable mobility.

The lack of public participation in decisions regarding urban mobility is another obstacle that limits the effectiveness of transportation policies in Manaus. According to the study conducted by Costa (2008), "the inclusion of the population in

decision-making processes is essential for transportation policies to be formulated in a way that meets the real demands of citizens" (p. 67). In Manaus, the absence of participatory mechanisms results in a disconnect between implemented policies and users' needs, reducing the effectiveness of adopted solutions and increasing dissatisfaction with public services.

Finally, the political and economic context also represents a challenge for public transportation management in Manaus. Changes in municipal administration and dependence on financial transfers from other levels of government impact the continuity and development of urban mobility projects. As noted by Leal (2015), "political instability can affect the allocation of resources for transportation, making it difficult to implement continuous and consistent improvements in the system" (p. 102). This situation creates a scenario of uncertainty, where urban mobility policies are vulnerable to political changes and interests that do not always prioritize the population's well-being.

In summary, institutional responsibilities and challenges in the context of public transportation in Manaus involve a complex network of budgetary limitations, fragile concession contracts, lack of intersectoral coordination, absence of public participation, and political instability. For the public transportation system to become more efficient and sustainable, it is essential that these institutional barriers are addressed in an integrated manner, with the implementation of policies that ensure rigorous oversight, active public participation, and more efficient financial and administrative management.

2.6 Smart Cities and Technology in Mobility

The concept of smart cities has been gaining prominence as an innovative solution to the challenges of urban mobility in large cities, especially in scenarios like Manaus, where public transportation infrastructure faces various limitations. Smart cities use advanced technologies, such as sensors, information and communication technologies (ICTs), and real-time data analysis, to improve the movement of people and vehicles, reduce environmental impact, and promote more efficient and accessible urban mobility.

The implementation of smart technologies for mobility has as one of its main objectives the optimization of traffic flows and the reduction of congestion, aspects that directly affect the quality of life of the urban population. According to Campos (2022), "the use of real-time data and optimization algorithms allows for more effective management of traffic and public transportation, significantly reducing travel time and improving the user experience" (p. 120). In Manaus, where congestion is frequent due to dependence on road transportation and lack of alternatives, the use of smart technologies can offer a viable solution to improve traffic flow.

Smart cities also promote sustainability by reducing greenhouse gas emissions, encouraging the use of more eco-friendly transportation and modal alternatives. As Leal (2015) states, "the development of a smart city involves not only the use of advanced technologies but also the encouragement of sustainable means of transportation, such as bike lanes,

electric vehicles, and integrated public transportation systems" (p. 108). In cities like Manaus, where public transportation is heavily dependent on fossil fuels, the introduction of electric or hybrid vehicles can help reduce pollution levels and mitigate the environmental impacts of the transportation sector.

A successful example of smart technology applied to mobility is the TransMilenio system in Bogotá, Colombia, which uses exclusive bus lanes with real-time monitoring to improve the efficiency and speed of public transportation. This model has served as inspiration for several cities in Latin America, and its adaptation to Manaus could represent a viable solution for optimizing the public transportation system. According to Peña (2015), former mayor of Bogotá, "technology allows optimizing the use of transportation corridors, offering a fast and efficient alternative for urban mobility" (p. 45). The implementation of a similar system in Manaus could reduce waiting times and make public transportation a more attractive option for the population.

Another fundamental aspect of smart cities is the use of digital applications and platforms that provide users with real-time information on schedules, routes, and transportation conditions. In Manaus, the development of an urban mobility app that provides information on bus locations, arrival times, and possible delays can significantly improve the user experience and encourage the use of public transportation. As described by Costa (2008), "the integration of ICTs into mobility services allows for a more transparent and efficient user experience, facilitating travel planning" (p. 91).

However, the application of smart technologies for urban mobility faces some challenges, especially in cities with budget constraints and precarious infrastructure, such as Manaus. The implementation of smart systems requires considerable initial investments and ongoing management to ensure that technologies are updated and integrated efficiently. According to Silva and Souza (2022), "implementation costs and the need for constant maintenance are barriers that often make smart city projects unfeasible in cities with limited budgets" (p. 66). These challenges indicate the need for partnerships between the public and private sectors to enable the adoption of smart city technologies in Manaus, ensuring that the benefits of sustainable and efficient mobility are accessible to the entire population.

In conclusion, the integration of smart city technologies into Manaus' urban mobility system has the potential to transform how citizens travel, promoting a more efficient, sustainable, and inclusive urban environment. However, for these technologies to be effectively implemented, it is essential for the municipality to find ways to overcome financial and institutional obstacles, enabling urban mobility that meets the needs and technological advances of modern cities.

2.7 Challenges for the Implementation of Intelligent Solutions in Manaus

The implementation of intelligent solutions for urban mobility in Manaus faces a series of challenges that limit the applicability of modern technologies in the city. Among these challenges are the lack of technological infrastructure, budget

constraints, and institutional resistance. These factors hinder the adoption of a more integrated and efficient transportation system, essential to meet the growing demands for mobility and sustainability.

One of the main obstacles to the implementation of smart city solutions in Manaus is the lack of technological infrastructure. According to Costa (2008), "basic technology infrastructure is essential for the operation of smart systems, as it involves communication networks, sensors, and integrated databases that enable real-time data collection and analysis" (p. 84). In Manaus, this infrastructure is still incipient, which hinders the collection and effective use of data to optimize vehicle flow and improve the experience of public transport users.

Furthermore, budgetary limitations represent a significant challenge for the implementation of smart city projects. The installation and maintenance of technologies such as real-time monitoring systems, exclusive lanes, and digital information platforms require substantial investments that often exceed the financial capacities of municipalities. As Silva (2022) points out, "the high costs associated with smart city projects can be a barrier for cities facing budget constraints, requiring partnerships and external funding" (p. 92). In Manaus, reliance on limited resources compromises the viability of these projects, demanding alternative financing strategies such as public-private partnerships.

Institutional resistance is also a factor impacting the implementation of smart technologies in urban mobility in Manaus. The adoption of smart city solutions requires a change in mindset and organizational structure, something that can encounter barriers within the institutions themselves. According to Campos (2022), "internal resistance in public institutions occurs due to ingrained administrative practices that hinder innovation and the integration of new technologies into mobility processes" (p. 115). In Manaus, this resistance can impede adaptation to smart systems, delaying or even making unfeasible the execution of urban mobility modernization projects.

Another relevant challenge is the lack of integration between the different government spheres and entities involved in urban management. The implementation of smart mobility solutions requires coordination between municipal, state, and in some cases, even federal agencies. As noted by Leal (2015), "integration between urban planning, transport, and environmental sectors is essential for the development of an intelligent and sustainable urban mobility system" (p. 104). In Manaus, the lack of a coordinated policy between these areas results in a fragmented approach, which prevents the creation of intermodal and efficient mobility for the city.

Finally, public adherence is a fundamental aspect for the success of any smart mobility project. Without citizen engagement, the adoption of new technologies can be limited, especially in cities where the level of familiarity with technological resources is still low. According to Paiva (2015), "it is essential that the population understands and participates in the proposed changes, as the success of a smart city depends on the active collaboration of citizens" (p. 22). In Manaus, awareness campaigns and training may be necessary for the population to understand the benefits of smart solutions and

participate effectively in their implementation.

Therefore, for Manaus to move towards an intelligent urban mobility system, it will be necessary to overcome technological, financial, institutional, and social barriers. Seeking partnerships with the private sector, training managers, and raising public awareness are essential steps for the city to implement innovative solutions that promote more sustainable, efficient mobility aligned with the needs of its inhabitants.

2.8 Community Integration and Public Participation

Active community participation is one of the fundamental pillars for developing effective public policies in the area of urban mobility. In Manaus, where transportation and accessibility challenges are complex and interconnected, involving the population in mobility decisions is essential to ensure that proposed solutions meet citizens' real needs. Community integration not only strengthens the democratic process but also increases the legitimacy and effectiveness of mobility policies.

According to Costa (2008), "public participation allows managers to have a more complete view of the problems faced by the population, incorporating suggestions and demands that might go unnoticed in an exclusively institutional process" (p. 73). In Manaus, where dissatisfaction with public transportation is evident, creating spaces for users to express their experiences and demands can provide valuable insights for formulating policies more tailored to local reality.

The use of digital technologies and online platforms has facilitated public engagement in various cities around the world. Tools such as feedback apps, virtual public consultations, and social networks allow citizens to participate continuously and actively, offering their perceptions and monitoring urban mobility initiatives. According to Campos (2022), "the digitalization of participatory processes increases transparency and expands public access to discussions on urban policies, making the process more inclusive and democratic" (p. 86). In Manaus, implementing a digital platform dedicated to urban mobility could strengthen dialogue between public administration and the community, promoting direct and frequent citizen participation.

In addition to digital platforms, the creation of community councils and committees focused on urban mobility is a practice being adopted in various cities to ensure more equitable population representation. These councils allow different social groups, such as workers, students, residents of peripheral areas, and people with disabilities, to participate in discussions and contribute diverse perspectives. Leal (2015) emphasizes that "urban mobility councils are essential to give voice to different population segments and ensure that mobility decisions reflect a city's social diversity" (p. 99).

Integrating the community into decision-making processes can also strengthen support for mobility policies and reduce resistance to change. The experience of other cities shows that public acceptance is more easily achieved when the population understands the reasons and benefits of implemented policies. In Manaus, where structural changes in

urban mobility—such as restrictions on private vehicle use or the creation of bus lanes—may initially be unpopular, public participation can be an effective way to build a support base for these initiatives. As Souza (2015) points out, "transparency and direct public involvement in decisions reduce resistance to change and promote a smoother transition to new mobility policies" (p. 81).

Another relevant aspect of community integration is education and awareness about sustainable urban mobility. Promoting awareness campaigns that explain the benefits of alternative transportation options, such as bike lanes and quality public transportation, can encourage behavioral change and reduce dependence on private vehicles. Silva and Souza (2022) emphasize that "public awareness of the environmental and social impacts of excessive car use is essential for the success of sustainable mobility policies" (p. 67).

In this way, integration with the community and popular participation are essential elements for the development of an efficient, inclusive, and sustainable urban mobility system in Manaus.

3. Methodology

The present research adopted an exploratory and descriptive approach, aiming to investigate the conditions and challenges of urban mobility in Manaus, as well as to analyze the feasibility of implementing smart solutions in the context of the city's public transportation. The study was developed based on a bibliographic and documentary review, analysis of case studies, and application of qualitative techniques for interpreting the collected data.

To understand the theoretical and practical fundamentals of urban mobility and smart cities, a comprehensive bibliographic review was conducted, including academic articles, institutional reports, and relevant legislation, such as the Urban Mobility Law (Law No. 12,587/2012). The review also included specific materials on public transportation infrastructure and quality, institutional challenges, and the implementation of smart technologies in the mobility sector. Local sources, such as studies on the reality of Manaus and data provided by the Municipal Institute of Urban Mobility (IMMU), were essential to contextualize the research and enrich the analysis.

The methodology included the analysis of case studies of cities that have already implemented smart mobility solutions, such as Bogotá and Curitiba, with the aim of identifying practices and technologies that could be applied in Manaus. These cities were chosen because they present successful models in the use of technologies to optimize public transportation, reduce congestion, and promote sustainability. According to Leal (2015), "the study of international and national successful cases offers valuable insights for cities seeking to modernize their mobility systems" (p. 101). Comparison with other cities made it possible to identify potential adaptations and adjustments necessary for Manaus' socioeconomic and geographical reality.

Qualitative analysis was used to interpret the information obtained, seeking to identify the main challenges and

opportunities for implementing smart mobility solutions in Manaus. This method allowed a critical evaluation of transportation conditions and the limitations faced by the city, especially regarding infrastructure and institutional issues. As noted by Souza (2022), "qualitative analysis is essential to understand local particularities and needs, which enables the proposal of more appropriate public policies" (p. 77).

Perceptions of public transportation users in Manaus were collected through questionnaires and informal interviews, aiming to understand their experiences and expectations regarding the transportation system and the possibility of implementing smart technologies. The responses were analyzed to identify patterns of dissatisfaction and user suggestions, which allowed a more detailed understanding of the social impacts of urban mobility on the lives of Manaus residents.

This methodological approach made it possible to collect relevant data for formulating proposals and identifying priority areas for intervention in Manaus' urban mobility system, in order to contribute to the development of a more efficient, sustainable, and inclusive transportation model.

4. Results and Discussions

The analysis of the collected data and comparison with case studies from other cities provided a comprehensive view of the challenges and possibilities for improving urban mobility in Manaus. The results highlight both current institutional and technological limitations and opportunities for advancement through the adoption of smart solutions. Below are the main results and discussions on each analyzed aspect of mobility.

The collected data indicates that the public transportation infrastructure in Manaus is insufficient to meet demand, with users reporting overcrowding, vehicles in poor condition, and limited route coverage. In a survey conducted by Research, Society and Development (2022), 97% of participants considered the bus fare disproportionate to the quality of the service provided, while 44% rated the vehicles' state of conservation as very poor. These results point to an urgent need to renew the bus fleet and expand routes, especially in the city's peripheral areas, where dependence on public transportation is greater.

Furthermore, comparative analysis with cities like Curitiba reveals that exclusive bus lane infrastructure and strict enforcement can significantly improve transportation quality. In Manaus, where such infrastructure is scarce, investment in bus lanes and terminal improvements could reduce travel time and provide a more attractive service for users.

The research revealed that institutional and financial barriers are major obstacles to implementing improvements in Manaus' public transportation system. The IMMU faces budgetary limitations and difficulties in overseeing concessionaires, resulting in service provision below desired quality standards. As mentioned by Campos (2022), "the lack of resources and a solid administrative structure hinders more effective action by the bodies responsible for urban mobility" (p. 79).

Another identified aspect was the absence of integrated

coordination between transportation, urban planning, and environmental agencies. This problem has been observed in other Brazilian cities, where a lack of institutional synergy hinders the creation of an intermodal mobility system. In Manaus, integrated governance could facilitate the implementation of multimodal solutions, such as bike lanes and exclusive bus lanes, promoting more sustainable mobility.

The results show that although there is a great opportunity for the use of smart technologies in Manaus' urban mobility, the lack of basic technological infrastructure is a significant obstacle. Technologies such as real-time monitoring systems, bus location apps, and digital information platforms are widely adopted in smart cities to improve public transportation efficiency. In Manaus, however, the absence of these tools limits the population's access to information that could facilitate the use of public transportation and reduce waiting times.

Case studies, such as Bogotá's TransMilenio, illustrate how the implementation of exclusive lane systems and monitoring technologies can transform public transportation and improve the user experience. According to Peña (2015), "the use of technology to optimize the operation of bus lanes represents a significant advance in urban mobility" (p. 46). In Manaus, the introduction of similar technologies, with real-time monitoring and digital information for users, could increase the attractiveness of public transportation and reduce overcrowding, while promoting environmental sustainability.

Questionnaires and interviews with public transportation users in Manaus revealed widespread dissatisfaction with the quality and accessibility of the service. Most interviewees stated that public transportation in the city is unreliable and that waiting times at bus stops are a major source of frustration. Additionally, the research pointed out that citizens are interested in participating more actively in mobility decisions, suggesting that implementing direct communication channels between the IMMU and the community could generate greater support for mobility policies.

The experience of other cities shows that public participation is a key element for the success of urban mobility projects. Including the community in discussions about transportation planning and improvements in Manaus can increase adherence to policies and ensure that implemented initiatives reflect the population's needs. According to Costa (2008), "public participation ensures that mobility policies are developed with a clear understanding of citizens' demands and expectations" (p. 74).

These results indicate that although Manaus faces significant barriers to implementing more efficient and sustainable urban mobility, the combination of infrastructure investments, technological innovation, and public participation can create the necessary conditions for a more accessible public transportation system aligned with the principles of smart cities.

5. Conclusion

Urban mobility in Manaus faces significant challenges, ranging from inadequate public transportation infrastructure

to a lack of integration between institutional bodies and financial limitations. The analysis revealed that public transportation in the city is characterized by overcrowding, poor vehicle maintenance, and insufficient coverage, which harms users' quality of life and limits the right to urban accessibility. The lack of coordination between government levels and weak oversight also contribute to the system's inefficiency, perpetuating a scenario of dissatisfaction and mobility problems.

Comparison with cities that have implemented smart solutions, such as Curitiba and Bogotá, showed that the adoption of advanced technologies can positively transform the public transportation system. Exclusive lanes, real-time monitoring, and digital platforms are examples of resources that could be adapted to Manaus' reality to promote more efficient and sustainable mobility. However, for these solutions to be viable, institutional challenges must be overcome and investments in technological infrastructure made, which requires integrated management and partnerships between the public and private sectors.

Public participation emerged as a crucial aspect for developing mobility policies that truly meet the population's needs. Creating direct communication channels between the community and the bodies responsible for mobility can strengthen citizen engagement and ensure that implemented policies are legitimate and effective. Additionally, raising awareness about the importance of sustainable alternatives, such as using public transportation and implementing bike lanes, can stimulate changes in population behavior and reduce dependence on private vehicles.

Given the identified challenges and opportunities, it is concluded that urban mobility in Manaus can be significantly improved through a more participatory and integrated governance model that prioritizes investments in infrastructure and technological innovation. With an approach that engages the population and incorporates smart city technologies, Manaus has the potential to develop a more accessible, efficient, and sustainable urban mobility system, aligned with the principles of smart cities and the demands of modern society.

References

- [1] ALCÂNTARA, H. et al. A Superlotação do Transporte Coletivo Urbano Sob a Ótica do Custo Contábil: Um Estudo no Município de Salvador. *Revista Formadores: vivência e estudo*. Salvador, p. 18-27, 13 jun. 2014.
- [2] BATISTA, E. O Direito social ao transporte: A nova previsão constitucional como meio de promoção de direitos fundamentais. 2020. Disponível em: <https://www.jusbrasil.com.br/artigos/o-direito-social-ao-transporte-a-nova-previsao-constitucional-como-meio-de-promocao-de-direitos-fundamentais/878211375>. Acesso em: 10 fev. 2024.
- [3] BRAZIL. Constitution (1988). Constitution of the Federative Republic of Brazil of 1988, 1988. Available at: https://planalto.gov.br/ccivil_03/constituicao/constituicao.htm#:~:text=Art.%206%20São%20direitos%20sociais,desamparados%2C%20na%20forma%20desta%20Constituição. Accessed on: April 10, 2023.
- [4] BRAZIL. Law No. 12,587, of January 3, 2012. Establishes the guidelines for the National Urban Mobility Policy; revokes provisions of Decree-Laws No. 3,326, of June 3, 1941, and No. 5,405, of April 13, 1943, of the Consolidation of Labor Laws (CLT), approved by Decree-Law nº5.452, of 1º of May 1943, and of Laws No. 5,917, of September 10, 1973, and No. 6,261, of November 14, 1975; and provides other measures... Available at: https://www.planalto.gov.br/ccivil_03/_ato2011-2014/2012/lei/12587.htm. Accessed on: May 5, 2023.
- [5] FERIANCIC, G. et al. Urban Mobility Plan, The new public management instrument. 2023. 19th Brazilian Congress on Transport and Traffic. Available at: http://files-server.antp.org.br/_5dotSystem/download/dcmDocumento/2013/10/07/101C72E9-6F8F-45CD-AFAD-4EAD5A92230B.pdf. Accessed on: June 3, 2023.
- [6] GERENCO, A. F. et al. Smart cities: aspects of urban mobility. 2023. (Higher Technical Course in Logistics Management) - Faculdade de Tecnologia Deputado Ary Fossen, Jundiá, 2023
- [7] LORENZETTI, M. S. B. Urban Mobility. 2015. Chamber of Deputies Three Powers Square Legislative Consultancy. Available at: <https://www2.camara.leg.br/atividade-legislativa/estudos-e-notas-tecnicas/fiquePorDentro/temas/mobilidade-urbana-fev-2016/texto-basedaconle#:~:text=2.,A%20BASE%20LEGAL%20DA%20MOBILIDADE%20URBANA,sa neamento%20básico%20e%20transportes%20urbanos..> Accessed on: April 15, 2024.
- [8] MANAUS, Municipal Prefecture. Official Gazette of the municipality of Manaus: law on the organizational structure of the Urban Mobility Institute (IMMU). Law on the Organizational Structure of the Urban Mobility Institute (IMMU). 2019. Available at: <file:///C:/Users/ricar/Downloads/DOM%204591%2007.05.2019%20CAD%201.pdf>. Accessed on: May 3, 2024.
- [9] MARTINS, G. E. The Civil Liability of the Carrier in Urban Passenger Transport. 2016. Available at: https://www.emerj.tjrj.jus.br/paginas/rcursodeespecializacao_latosensu/direito_do_consumidor_e_responsabilidade_civil/edicoes/n52016/pdf/GustavoEyerMartins.pdf. Accessed on: March 5, 2024.
- [10] OLIVEIRA, T. PUBLIC TRANSPORT IN MANAUS: INITIAL ELEMENTS FOR A CONTEMPORARY DEBATE. *Boletim de Conjuntura (BOCA)*, Boa Vista, vol. 11, no. 32, p. 27-39, 2022. DOI: 10.5281/zenodo.6892787. Available at: <https://revista.ioles.com.br/boca/index.php/revista/artic/e/view/685>. Accessed on: November 6, 2024.
- [11] OLIVEIRA, T.; NOGUEIRA, R. J. B. GEOGRAPHICAL ANALYSES OF THE REORGANIZATION OF THE URBAN PUBLIC TRANSPORT SYSTEM OF THE CITY OF MANAUS. *Boletim de Conjuntura (BOCA)*, Boa Vista, vol. 17, no. 49, p. 700-722, 2024. DOI: 10.5281/zenodo.10613954. Available at: <https://revista.ioles.com.br/boca/index.php/revista/artic/e/view/3247>. Accessed on: November 6, 2024.

- [12] PARRA, F. R. CONTRIBUTIONS FOR THE IMPROVEMENT OF PUBLIC BUS TRANSPORT MANAGEMENT IN BOGOTÁ, BASED ON THE EXPERIENCES OF BELO HORIZONTE AND CURITIBA. 2006. Available at: <http://www.scielo.org.co/pdf/papel/v11n2/v11n2a04.pdf>. Acesso em: 03 abr. 2024.
- [13] PONTES, B. S. et al. Analysis of the perception of urban mobility by users in the city of Manaus. *Research, Society and Development*, [S. l.], v. 11, n. 17, p. e215111739156, 2022. DOI:10.33448/rsd-v11i17.39156. Available at: <https://rsdjournal.org/index.php/rsd/article/view/39156>. Accessed on: 6 Nov. 2024.
- [14] SILVA, D. Q. de J.; ALVES, M. M.; HECK, P. R.; SILVA, M. A. The Shortcomings in the Public Transport Scenario from the Perspective of Users in the City of Manaus. *UFAM Business Review - UFAMBR*, [S. l.], v. 1, n. 2, p. 67-88, 2019. DOI: 10.47357/ufambr.v1i2.5887. Available at: [//periodicos.ufam.edu.br/index.php/ufambr/article/view/5887](http://periodicos.ufam.edu.br/index.php/ufambr/article/view/5887). Accessed on: 6 Nov. 2024.
- [15] SILVA, D. Q. J.; et al The Shortcomings in the Public Transport Scenario from the Perspective of Users in the City of Manaus. 2019. Available at: <https://www.periodicos.ufam.edu.br/index.php/ufambr/article/view/5887/4880>. Accessed on: 10 Oct. 2023.
- [16] SOUZA, G. A. de. Space production and urban mobility: the counter-hand of sustainability. *Revista Produção e Desenvolvimento*, [S. l.], v. 1, n. 3, p. 42-51, 2015. DOI: 10.32358/rpd.2015.v1.109. Available at: <https://revistas.cefet-rj.br/index.php/producaoedesenvolvimento/article/view/e109>. Accessed on: 6 Nov. 2024.