THE USE OF WATERWAYS FOR URBAN LOGISTICS: THE CASE OF BRAZIL

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Abstract
Waterway transport is the most economical compared to other modes and it causes less social and environmental impacts. However, cargo transportation in urban centers is a challenge to be studied, as it generates problems such as congestion, accidents, and high delivery costs. This research aims to identify acceptable international practices in urban waterway logistics and, based on these examples, identify, and analyze modal use in Brazilian cities comparatively. Initially, from a literature review, practices were explored in countries where waterways are essential in the transport matrix and used in urban areas. Subsequently, the modal use in Brazilian cities was identified and analyzed according to available information and relationships found among the cases studied. A field survey was carried out in the city of Belém (PA) and a comparative analysis highlighted a great potential of this city for the use of waterways as an aid to urban logistics. Given the importance of goods distribution for cities' survival, the identified implementation possibilities can contribute to their development sustainably and to reduce cargo vehicles' impact on the quality of life.
Keywords: Urban logistics; Intermodal transport; Waterways; Sustainability;

1. INTRODUCTION

Among the modes used for the movement of goods, river transport presents a low cost of a transported ton (CNT, 2019). It is due to the ability to accommodate large volumes of the cargo combined with low fuel consumption. It is still possible to find advantages in waterway transportation as safer and less polluting (CNT, 2019).

Theoretical and Empirical Researches in Urban Management
Volume 16 Issue 1 / February 2021

Brazil has 63 thousand kilometers of rivers, with potential for waterway transport, but a small part of that potential is exploited. According to the CNT (2019), inland navigation commercially uses just over 30% of this extension. Thus, only 5% of cargo handling is done by rivers. For greater efficiency in handling, reducing dependence on the road modal, and taking advantage of Brazil's water potential, infrastructure, and network maintenance is necessary for a more balanced transport matrix.

In Brazil, this transport sector is still a challenge to be studied. Many cities have been developed without planning, quickly and cluttered, resulting in great chaos, with their mobility compromised combined with significant levels of pollution (Carvalho, 1998). In the limited city center space, the high number of activities created problems to the transport of goods, such as congestion, accidents, and high cost and time of operations (Diziain; Taniguchi; Dablanc, 2014). The conflicts in the urban space reveal the need to explore Brazil's great potential in the search for alternatives to solve the problem.

Several countries use river transport in urban areas, such as Netherlands and France, for example. Each kilometer of the waterway can reduce congestion, accidents, and energy consumption, contributing to reducing the greenhouse effect, a significant cause of climate change in the world (Amos et al., 2009). For Diziain, Taniguchi, and Dablanc (2014), waterways are a useful alternative for urban freight transport, even in short distances.

Janjevic and Ndiaye (2014), in their study on navigation for urban distribution of goods, concluded that although inland navigation is more commonly used to transport bulk products, there are also several small-scale solutions. This practice is viable for part of the total load in cities with a high density of waterways. According to the authors, several studied examples of European cities show a significant potential for using waterway networks for the goods distribution in various areas of urban freight.

A significant increase in interest in alternative methods of implementing urban freight transport is expected due to the growing road traffic in urban areas and the incompatibility and deterioration of urban road infrastructure (Trojanowski; Iwan, 2014). In September 2011, five European capitals, including Brussels, Paris, Berlin, Budapest, and Vienna, with the support of their port authorities, committed to using rivers to aid urban distribution, considering the waterway urban mobility planning (Greenport, 2013).

Among the 17 objectives of sustainable development proposed by the United Nations (UN) is the search for sustainable cities. According to the UN, sustainable cities' search consists of making inclusive, safe, and sustainable cities and human settlements. It also supports economic, social, and environmental relations between urban, peripheral, and rural areas, intensifying national and regional development planning.

Besides studies that encourage sustainable practices for cities and reduce cargo vehicles' impacts, it is significant to analyze practices already implemented and their benefits. Hernandez-Moreno (2019) points out that in Mexico, for example, proposals from the State Action Programs on Climate Change are structurally well designed. However, in the practical phase of insertion into urban and regional development, they encounter several technical obstacles and deficiencies in the implementation procedures.

The development of research that searches for efficient and environmentally correct alternatives for the country's urban logistics is relevant since this is directly related to economic, social, and environmental development. This research aims to identify acceptable international practices in urban waterway logistics through a literature review and, based on these examples, to analyze comparatively the use of the modal in Brazilian cities. A field survey was carried out in the city of Belém (PA), where waterway transport is commonly used in urban areas. The analysis of international cases already implemented can contribute to identifying opportunities to improve urban logistics operations. The use of the Brazilian waterway potential is an efficient and promising alternative.

2. THE WATERWAYS FOR URBAN LOGISTICS

Urban logistics is closely related to the development of cities. According to Taniguchi and Heijden (2000), the distribution of goods is important to plan a city, and the actions to improve urban transportation are essential for sustainable economic growth. Transportation is part of the economic process of production and acquisition, moving goods to be transformed.

Consumption expansion impacts the distribution of goods. Insufficient resources and many residents cause inconveniences to logistics in cities, such as traffic infrastructure, which is commonly restricted and unable to be expanded (Prata et al., 2012). Dutra (2004) states that the problem related to urban cargo distribution in Brazil is not recent and has ceased to be considered in city planning. The author defends industry and commerce's importance for generating wealth in a region that depends on cargo transportation.

Among the social, economic, and environmental impacts of cargo transportation, Sanches Júnior (2008) reflects how to live in the city without distributing goods. The needs of the urban population depend on an adequate supply of products. Urban transport must be dynamic, flexible, and efficient to master critical and unusual situations and reduce its impacts (Lessa et al., 2015).

In the quest to reduce the impacts caused, several cities adopt waterway transport alternatives in urban centers. In countries such as the United States, Germany, Italy, France, China, and the Netherlands,

Theoretical and Empirical Researches in Urban Management
Volume 16 Issue 1 / February 2021

waterway transport is more widely used. The VNF (Voies Navigables de France) manages France's waterways and significantly supports river transport in urban areas. VNF (2011) argues that a river that flows in large cities' hearts is an ally to meet the future needs of urban logistics and that the waterway is a vital link in the future supply chain. VNF (2017) highlights that the fluvial distribution of goods in urban areas takes place in a simplified and direct way, moving goods to destinations closer to consumption centers. They bring benefits such as the reliability of delivery times and the optimization of inventories, reduction congestion, and environmental pollution reduction.

The analysis of initiatives in European cities shows significant potential for urban waterways for goods distribution. From parcel deliveries to the transport of waste, it is possible to implement these solutions in cities with a lower density of river networks with the aid of road vehicles (Van Duin; Kortman; Van De Kamp, 2017). Conditions for the urban goods distribution have changed dramatically in recent years, always creating opportunities for developing alternative modes of transport (Maten; Pielage; Rijsenbrij, 2003), increasing companies' interest authorities efficient and clean solutions.

Besides the impacts of economic growth on the distribution of goods and the population's health, in the last decades, sustainable development is a frequent issue in relevant discussions around the world, given its importance for the future of the planet. Achieving economic growth while preserving the environment is a challenge for current and future generations in the public and private sectors.

In the urban space, the emission of GHG (Greenhouse Gases) has high values. Different environmental pollution types affect large cities' central areas, and the inhabitants generally perceive it. The atmospheric, visual, and noise pollutions come mainly from the excess of vehicles in these areas, releasing waste through exhausts and noise and contributing to the landscape's deterioration. Countries are currently making commitments to reduce GHGs, and above all, there is concern about CO2, which is emitted on a large scale by the transport sector. The alternative of using more sustainable modes, such as waterway transport, can contribute to reducing pollution.

Inland navigation can play an important role in supply chains, increasing their performance and generating support for greater urban distribution integration (Caris et al., 2014). The practices implemented based on existing infrastructure result in better solutions (Diziain; Taniguchi; Dablanc, 2014). Janjevic and Ndiaye (2014) believe that waterways will be a recurring activity in the coming years.

3. METHOD

The literature review and analysis of urban waterway logistics' theme aimed to describe the question presented in step 1 of Figure 1 below. This figure also shows the procedures used, horizon, search terms,

and the databases used in the search. After conducting the literature review, the examples found were described and analyzed to study Brazilian cities.

After selecting papers on the subject under study, a survey of waterway practices was carried out for cities in Brazil with the potential for navigation in urban areas. With this information obtained, it was possible to compare international and Brazilian practices and identify the city that most resembles the examples found. A data survey was carried out based on an observation protocol to understand better the current urban logistics practices. Finally, the methodology sought to highlight the possibilities of using waterways to assist urban logistics in the Brazilian scenario.

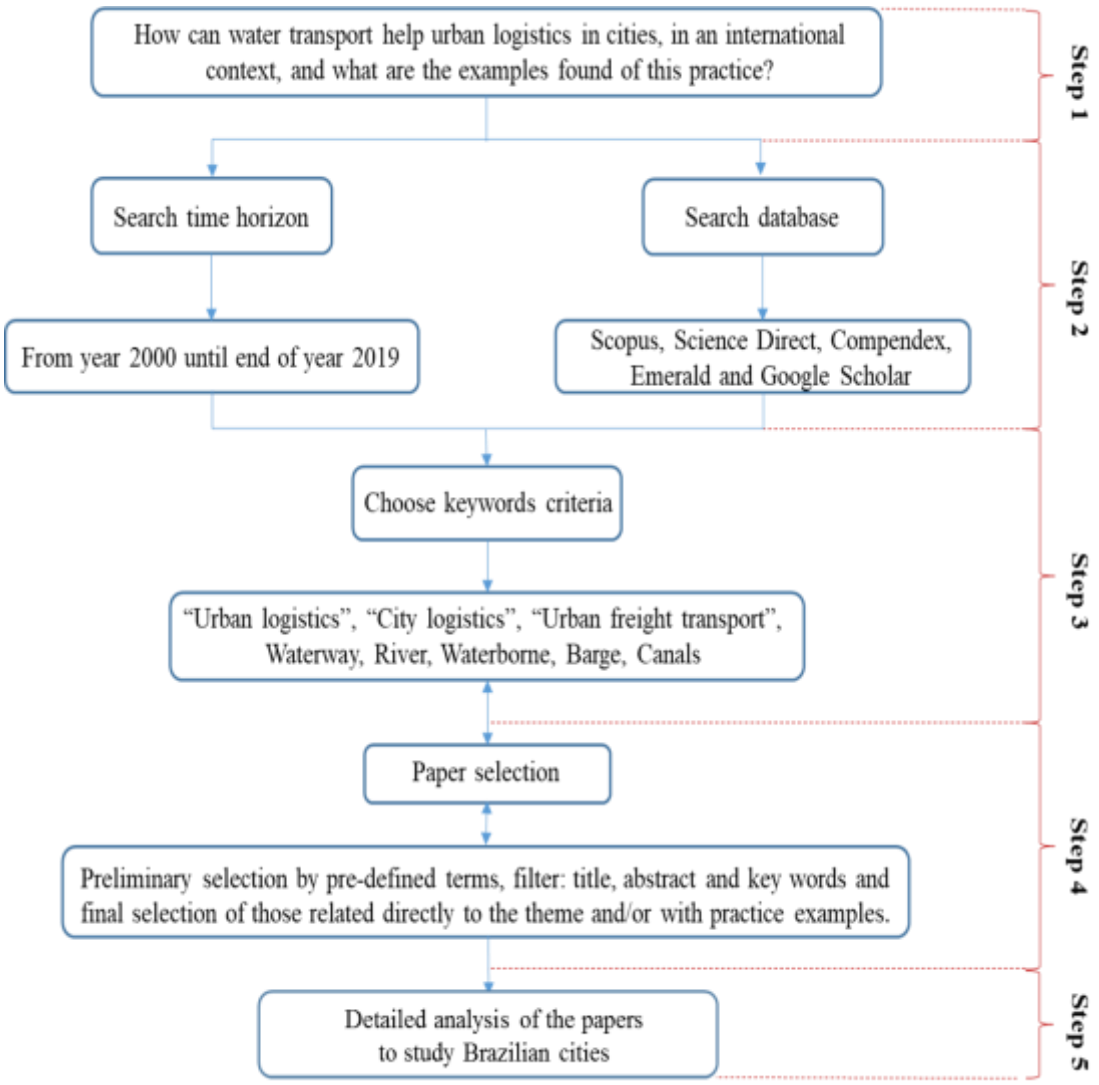

FIGURE 1 - RESEARCH PROTOCOL FLOWCHART
SOURCE: Based on Soni and Kodali (2011)

Theoretical and Empirical Researches in Urban Management
Volume 16 Issue 1 / February 2021

4. INTERNATIONAL PRACTICES AND THE BRAZILIAN SCENARIO

4.1. Review of international waterway practices

Waterway urban logistics practices are inserted in different contexts in the literature. The main themes observed are sustainable alternatives for urban logistics, modal transfer alternatives for greater urban logistics efficiency, waterway studies for city development and efficiency studies, or feasibility of cases in specific cities or regions. From the searches carried out in the Scopus database, it was possible to gather a list of selected articles. Using the VOSviewer.exe software, study the relationship between the terms that appear most in these works, as shown in Figure 2.

The lines shown in the figure indicate the link between the keywords and the thickness indicates the degree of relationship in the works used. It is also possible to note that there was a change in the focus over the years. Around 2010 the study of waterways was related to the terms "distribution of goods" and "urban planning". In 2014 where the largest number of research is located, terms like "city logistics" are in evidence. In the most recent publications, between the years 2018 and 2020, the focus is on research involving the term "sustainability".

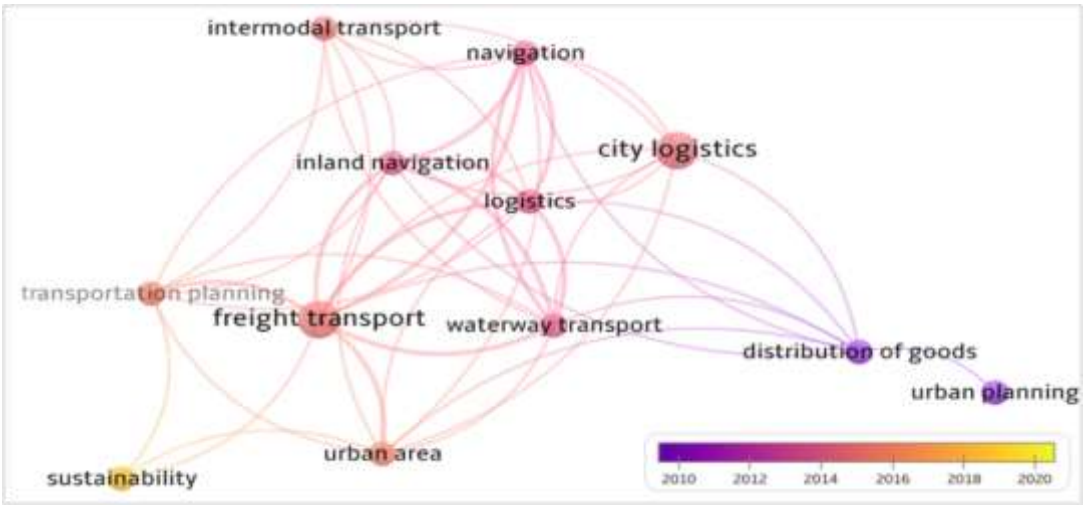

FIGURE 2 - KEYWORDS RELATED TO URBAN WATERWAY LOGISTICS AND ANNUAL OCCURRENCE
SOURCE: Software VOSviewer.exe

Most of the papers were found in international journals such as "Journal Procedia - Social and Behavioral Sciences". However, the theme was also discussed at congresses of urban logistics, such as the "International Conference on City Logistics" and "International Conference on Urban Transport and the Environment". Examples of waterways in cities like Paris and Amsterdam were more common in the research, being cited in several selected works. Based on research by Janjevic and Ndiaye (2014), Table 1 lists the relevant practices present in the literature, their stage of implementation, and the authors who show these examples.

TABLE 1 - URBAN RIVER DISTRIBUTION PRACTICES TREATED IN THE STUDIES STUDIED

City	Waterway for Urban Distribution Practices	Situation	Scientific publications
Brussels (Belgium)	Modal transfer for the distribution of immediate consumption goods palletized using barges. With the transfer to fluvial distribution, the most outstanding advantages are expanding palletized volumes and economic efficiency in the capital.	study	Mommens, Lebeau, and Macharis (2014)
Paris (France)	Franprix - deliveries of consumer goods in supermarkets across the River Seine - swap bodies are used from a warehouse outside the city to a port inside Paris.	implemented	Leonardi et al. (2014), Janjevic and Ndiaye (2014)
Utrecht (Netherlands)	Beer Boat - Delivery to local stores, hotels, and restaurants bringing benefits in costs, traffic, and emissions and serving between 65 and 70 end customers.	implemented	Macharis and Kin (2017), Leonardi et al., (2014), Van Rooijen and Quak (2014), Janjevic and Ndiaye (2014), Nemoto et al. (2005)
Paris (France)	Vert Chez Vous - deliveries of goods up to 30 kg, the barge consists of 18 tricycles on board that is loaded during navigation on the River Seine, distribute the goods and return to the vessel, 14 tons are transported per day.	implemented	Macharis and Kin (2017), Janjevic and Ndiaye (2014)
Amsterdam (Netherlands)	DHL - Floating distribution center for order delivery. Every morning the boat is loaded with orders and stops at specific points on the main channels.	implemented	Janjevic and Ndiaye (2014)
Tokyo (Japan)	Transport of waste by barge from five collection points on the Arakawa River and branches, two types of transport, mass, and container, are operated.	implemented	Diziain, Taniguchi, and Dablanc (2014), Macharis and Kin (2017)
Paris (France)	A barge transports bulky waste and recycled products over 20 km in the western part of the Paris region (Hauts-de-Seine).	implemented	Diziain, Taniguchi, and Dablanc (2014)
Lyon (France)	In 2011, Compagnie Fluviale de Transport, France's leading river operator, evacuated debris and rocks from the Croix Rousse tunnel in central Lyon by barge. The barges carried a total of 6,000 tons per week, equivalent to 500 to 600 truck movements.	used in 2011	Diziain, Taniguchi, and Dablanc (2014)
Amsterdam (Netherlands)	Mokum Maritiem - deliveries to local stores and waste transportation - barges are cleaned with hybrid engines, equipped to handle different deliveries.	implemented	Van Duin, Kortmann, and Van Den Boogaard (2014), Janjevic and Ndiaye (2014)
London (England)	Sainsbury's - Transporting food by barge to supermarket chain stores, if extended to more stores in the same region, could reduce 350,000 road kilometers per year.	used in 2007	Janjevic and Ndiaye (2014)
Paris (France)	Point.P - Heavy materials packed on pallets, supplies its products to 6 stores in Paris through the navigation on the River Seine.	implemented	Janjevic and Ndiaye (2014), Diziain, Taniguchi, and Dablanc (2014)
Paris (France)	Vélib - self-service bicycle regime makes use of the Seine to transport bicycles and mechanics quickly from one point to another.	implemented	Janjevic and Ndiaye (2014)

Theoretical and Empirical Researches in Urban Management
Volume 16 Issue 1 / February 2021

City	Waterway for Urban Distribution Practices	Situation	Scientific publications
Amsterdam (Netherlands)	Computer simulation to study the use of Amsterdam channels for delivery in stores and restaurants, meeting their needs, and studying the interference to other users of the canals.	study	Van Duin, Kortmann, and Van Den Boogaard (2014)
Amsterdam (Netherlands)	A logistical model was developed for analyzing operations and optimization of the number of hubs and fleets necessary.	study	Van Duin, Kortmann, and Van De Kamp (2017)
Tilburg (Netherlands)	A simulation was performed to implement a new barge terminal in the city to help in decisions related to urban operations.	study	Van Duin and Van Der Heijden (2012)
Amsterdam (Netherlands)	A case study showed the potential of Amsterdam's canals for urban river freight and the introduction of a new distribution layout in the city.	study	Maten, Pielage, and Rijsenbrij (2003)
Vistula (Poland)	A Proposal to create a network of logistics centers was presented at local and regional points of importance to serve commercial entities in the region: electronics, cellulose and paper companies, and packaging.	study	Wisnicki (2016)
Szczecin (Poland)	Study of the possibility of using inland waterways to handle and transport goods within the city of Szczecin.	study	Trojanowski and Iwan (2014)

Some papers are related to more sustainable urban logistics practices in cities, a subject discussed most carefully by the European community. Thus, due to the excellent performance of waterways regarding the environment's issues, examples of urban waterways are present in these papers. Van Rooijen and Quak (2014) studied the CIVITAS program's initiatives, which support sustainable urban mobility with funding from the European Commission. Macharis and Kin (2017) proposed a different classification for innovations in sustainable urban distribution. Janjevic and Ndiaye (2014) investigated the scenario of sustainable urban freight transport measures and the reduction of road transport in Europe, and Vilarinho, Liboni, and Siegler (2019) analyzed papers in river logistics in the last five years, identifying opportunities and challenges in the application of the modal as a sustainable alternative.

In addition to discussions about sustainability, some papers focused on exploring technical alternatives, economically viable and profitable, that reduce the impacts in the urban environment, with discussions about waterways as an alternative to the modal transfer. This approach was observed in the studies by Leonardi et al. (2014), which presented the best European urban freight practices. Nemoto et al. (2005) discussed the interactive relationship between transport and intermodal logistics in cities, and Macharis et al. (2016) studied alternatives for the urban movement of construction materials and their impact.

Discussions focused on studies and alternatives for river logistics in urban areas are treated by the authors to solve their development. It is an alternative to optimize logistics operations, reducing congestion, energy consumption, and other logistics dilemmas in the urban environment. Studies with this

focus were found by Diziain, Taniguchi, and Dablanc (2014), which compared waterway practices and examples in Japan and France. Janjevic and Ndiaye (2014) reviewed recent experiences in urban navigation. Caris et al. (2014) identified efforts to integrate waterways in the supply chain and their support for the urban distribution network. Maten, Pielage, and Rijsenbrij (2003) developed a discussion about the potential use of the distribution of urban goods by water.

In the papers, some research are still found in which studies or models are carried out on the feasibility of implementing new plans related to the use of waterways in specific cities or regions. In this context, the paper by Wiśnicki (2016) was found, which studied the feasibility of transport on Poland's Vistula river. Diziain, Ripert, and Dablanc (2012) discussed opportunities to take the river logistics to Paris. Trojanowski and Iwan (2014) suggested using inland waterways to move goods in the city of Szczecin - Poland. Raimbault, Andriankaja, and Paffoni (2012) studied the diversity of logistics facilities and their processes in the Paris region. Mommens, Lebeau, and Macharis (2014) analyzed the transport of fast-moving goods palletized by barges in Brussels. Van Duin and Van Der Heijden (2012) studied a barge terminal in the Dutch city of Tilburg, and Van Duin, Kortman, and Van De Kamp (2017) and Van Duin, Kortmann, and Van Den Boogaard (2014) developed a discussion on the urban distribution of goods on the Amsterdam canals.

The research analyzed current practices and studies demonstrating the waterway's benefits as a promising alternative and can mainly replace road vehicles and deliver goods a more sustainable activity. The examples described show that the distribution of small orders, consumer goods, and even collecting waste can be carried out efficiently through inland navigation. Electric vehicles and small trucks can assist operations as a complement to the waterway. In some cases, these alternatives' implementation does not depend on significant changes in the existing infrastructure.

4.2. Brazilian cities with waterway potential

Brazil has an excellent waterway potential as described in the Introdution, but consolidated practices have not been found of urban distribution by waterways, compared with the international examples described. However, there are several practices in cities with an extensive river network that, for the most part, often occur precariously and even clandestinely.

In the cases of Manaus, São Paulo, Recife, Santos, and Rio de Janeiro, studies were found to implement an urban waterway network. However, in most studies, the projects are aimed at passenger transport and have not been implemented or are paralyzed.

The city of Manaus (-3.1019400, -60.0250000) depends on waterway transport. Ferreira (2016) points out that the river does the logistics of people, clothes, food, and other goods. Navigation is marked using

Theoretical and Empirical Researches in Urban Management
Volume 16 Issue 1 / February 2021

ferries that carry different loads, mixed vessels, which mainly move cargo, and people, besides ocean ships. Souza (2009) proposed a river network for the passenger's transportation, integrated with other modes. The alternative is based on the progressive urban congestion, the difficulties of growth of the current road network, and the environment's pollution.

A project called “Hidroanel” aims to use rivers for transport operations in the city of São Paulo (-23.5475000, -46.6361100). According to the Metrópole Fluvial Group (2011), the project consists of a network of navigable canals, formed by rivers and dams located in the Metropolitan Region of São Paulo, for cargo and passenger transportation. Due to the high flow of cargo and people on short routes, the project considers self-propelled vessels powered by an electric or hybrid system.

According to Araujo et al. (2015), the city of Recife (-8.0538900, -34.8811100) in Pernambuco state, located at the Capibaribe and Beberibe rivers' mouth, has numerous natural water canals in its area, which explains the popularly used name of "Brazilian Venice". The state of Pernambuco government developed and started to implement the navigability project of the Capibaribe River, entitled “Rios da Gente", which aims to use public transport traffic corridors. However, several difficulties resulted in the stoppage of the works in progress (Silva; Mello, 2017).

Porto Alegre (-30.0330600, -51.2300000) has a port that handles cargo such as fertilizers, transformers, salt, grains, and general cargo, being the strategic waterway system in the state of Rio Grande do Sul. CatSul Company offers a crossing passenger service between two points in Porto Alegre and the city of Guaíba, located on the shore of Guaíba lake. The vessels called Catamarans have a capacity of 120 to 170 passengers (CatSul, 2019).

The city of Florianópolis (-27.5966700, -48.5491700) comprises the Island of Santa Catarina, a continental part, and some small islands. “Conceição” pond and “Peri” pond are also located in the municipality. Waterway transport occurs for tourism, fishing vessels, and transport in ponds intended for passengers. The pond lines allow locomotion between “Costa da Lagoa” and the “Rio Vermelho” lake terminal (Coopercosta, 2019).

The city of Rio de Janeiro (-22.9027800, -43.2075000) is famous for the presence of seas, bays, and ponds, and investing in waterway transport could be a solution for reducing road vehicles in urban areas. According to FIRJAN - Federação das Indústrias do Estado do Rio de Janeiro (2017), an increase in passenger waterway transport connections in the Metropolitan Region of Rio de Janeiro would be a cheaper and quicker alternative. It could absorb 272,400 passenger trips per day, equivalent to the circulation of 100,900 cars.

Santos (-23.9608300, -46.3336100) is the largest coastal city in the state of São Paulo. The municipalities of Bertioga, Cubatão, Guarujá, Itanhaém, Mongaguá, Peruíbe, Praia Grande, Santos, and São Vicente, form the Metropolitan Region of Baixada Santista. The Port of Santos marks the region's economic activity. It is the largest generator of revenue and income for the city, being the most important canal of incoming and outgoing cargo in Brazil (Municipality of Santos, 2019). The passenger terminal Giusfredo Santini, marked by sea cruises, is the busiest in the country. CODESP - Companhia Docas do Estado de São Paulo (2019) presented the Baixada Santista Waterway project, a strategic alternative for access to the port complex. The waterway implementation can remove more than 350 trucks that crowd the port surroundings and the interior of the city. The navigation characteristics in the Baixada Santista region are satisfactory, with a high draft that would not require dredging works (CODESP, 2019).

TABLE 2 - COMPARISON BETWEEN THE BRAZILIAN CITIES STUDIED

Brazilian cities studied	Bodies of water on the edge of the city	Bodies of water in the inland city	Urban waterway transport practices	Types of boats used	Types of cargo transported	Main characteristics of waterways
Manaus	X		yes	Barges, speedboats, ocean ships, passenger and fishing vessels	Bulk, containers, general cargo	High draft
São Paulo		X	no			Extension of rivers
Recife	X	X	no	Barges, speedboats, ships, passenger and fishing vessels		Extension of rivers, seaport
Porto Alegre	X		yes	Barges, speedboats, ships, passenger and fishing vessels	Bulk, containers, general cargo	Elevated draft, river extension
Florianopolis	X	X	no	Boats for tourist tours		Elevated draft (sea), presence of lagoons
Rio de Janeiro	X	X	yes	Barges, speedboats, ocean ships, passenger and fishing vessels	Bulk, containers, general cargo	Extension of rivers, seaport, high draft
Santos	X		yes	Barges, speedboats, ocean ships, passenger and fishing vessels	Bulk, containers, general cargo	Extension of rivers, seaport, high draft
Belém	X	X	yes	Barges, speedboats, ships, passenger and fishing vessels	Bulk, general cargo, urban cargo, perishable	Extension of rivers, seaport, medium draft

Privileged for its strategic position, the city of Belém (-1.4558300, -48.5044400) is a predominantly island capital, having 65.64% of its territory composed of islands. The “Rio Guamá” and the “Baía do Guajará”

Theoretical and Empirical Researches in Urban Management
Volume 16 Issue 1 / February 2021

are the main rivers that border the city. Navigation is a frequent practice in the movement of people and loads of many types. The "Ver-o-Peso" complex is the primary supply market in the city, where various products are sold, most of which comes from the metropolitan region, where river transport between islands, districts, and cities prevails (Montenegro, 2011).

Table 2 presents a comparison between the Brazilian cities treated in the present study. According to the sources described above, features related to the position, size, and purpose of waterway transport in each region were considered.

Based on bibliographical research on Brazilian cities with characteristics conducive to urban navigation, and through the comparison between them, Belém was the one with the most significant potential to receive urban waterway logistics practices. The practices that already happen in the city are closer to international cases, where several products, mainly of regional origin, are delivered and dispatched by the river. Also, most of these products are sold on the river bank itself. The existing infrastructure and the problems faced in the urban center of Belém, regarding the high number of activities and road cargo vehicles, reinforce the importance of efficient and sustainable solutions.

5. WATERWAY PRACTICES IN THE CITY OF BELÉM (PA)

5.1. Belém characterization

The estimated population of Belém in 2020 was 1,499,641 inhabitants, and the Gross Domestic Product (GDP) per capita in 2015 was R$ 21,191.47 (IBGE, 2020). The Metropolitan Region of Belém (RMB) is composed of seven municipalities: Ananindeua, Belém, Benevides, Castanhal, Marituba, Santa Bárbara do Pará and Santa Isabel do Pará. According to information from the Municipality of Belém (2020), the municipality has some districts (Figure 3), that are four islands with different characteristics:

- Mosqueiro Island: a fluvial island located on the eastern coast of the Pará River, in the southern arm of the Amazon River, in front of Baía do Guajará. The distance to the center of Belém is 70 km, and the route was made only by ships, but currently, the Sebastião R. de Oliveira bridge with 1,457.35 meters is the primary access;
- Icoaraci: with a population of approximately 167,035 inhabitants, it is considered an industrial district that employs a large portion of its residents in fishing, lumber, pottery, joinery, palm hearts, among others;
- Caratateua Island: bathed by fresh, turbid and muddy waters, coming from Baía do Guajará, the island is located at a distance of 18 km from the capital with several tourist beaches. The island

has 2,000 permanent inhabitants, but this population is much higher in the season, like in the summer.

- Cotijuba Island: it is an Environmental Protection Area, which makes the use of motor vehicles prohibited for the protection of its fauna and flora. Near Belém, access to the island is done by boats.

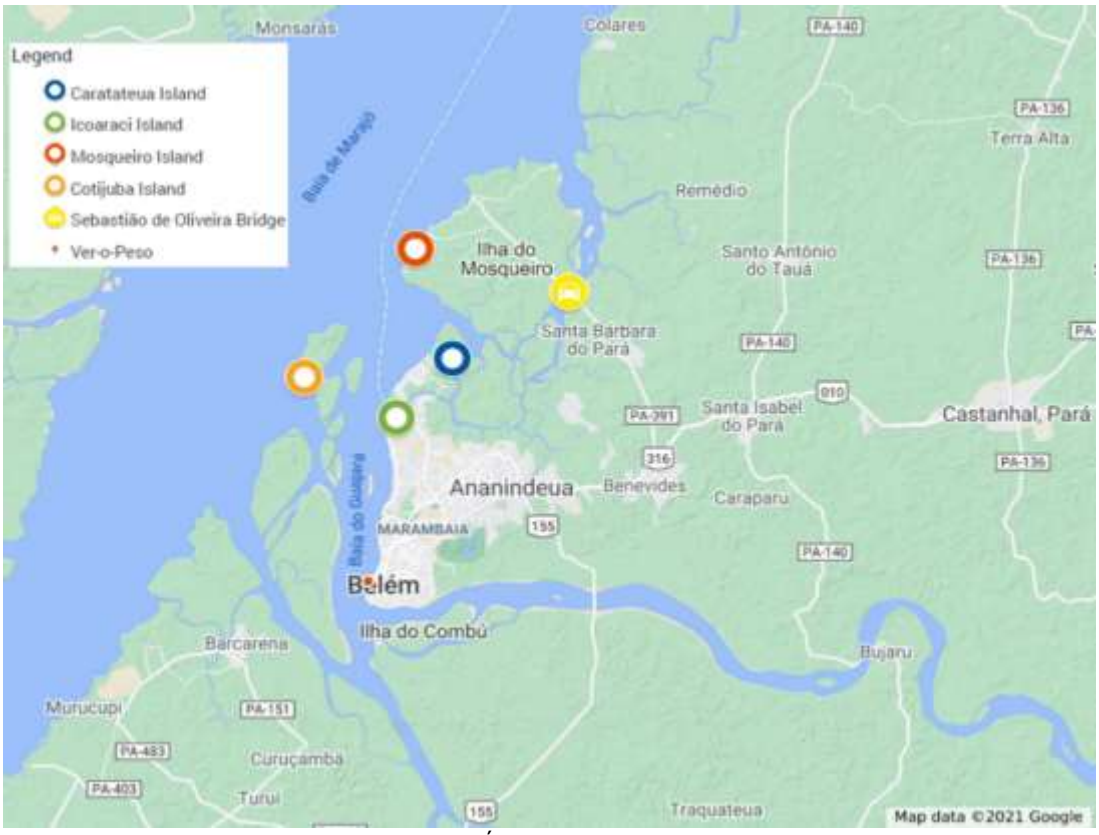

FIGURE 3 - BELÉM REGION AND DISTRICTS
SOURCE: Google MyMaps

The Ver-o-Peso complex is a historical point and the city's primary supply market. This complex comprising about 1,250 boxes in 19 sectors, including the "Mercado do Ferro", "Pedra do Peixe", “Mercado de Carne” and “Feira do Açaí” (Montenegro, 2011). Due to its importance, this market impacts the city's economy, selling various types of products, including fish, fruits, handicrafts, and mainly açaí, a local fruit.

Belém followed the panorama of other Brazilian cities, marked by uncontrolled growth, and despite being in a preservation zone, the commercial center suffers from visual pollution. According Moraes et al. (2003) the motorized land vehicles' traffic influences the commercial area of Belém, with noise levels that exceed the indices stipulated in the standards. Brabo and Miyagawa (2014) measured atmospheric pollution

Theoretical and Empirical Researches in Urban Management
Volume 16 Issue 1 / February 2021

levels in massive traffic points. They concluded that pollutants' levels are below the primary and secondary standards according to the current resolutions, harming people's health.

Municipal Decree No. 66,368 of March 31, 2011, from Belém, establishes restrictions on truck traffic in the city. On several streets in the commercial area, cargo vehicles' passage is not possible due to the existing infrastructure and the occupations of informal traders. In the Belém region, various vessels sail between the islands and the continent, small and precarious vessels, and large vessels (Tobias, 2007). The cultural issue is difficulty in the development of river transport. The popular imagination considers a link between the modal and the low social position. The precarious waterway transport infrastructure reinforces the modal's negative image, which contributes to the resistance regarding its development (Borges; Cardoso; Neves, 1999).

Among the products sold on the shore of Baia do Guajará, the açaí is the most notable. The açaí is distributed throughout the country through trucks and is exported too. During the night, the movement in "Feira do Açaí" (Açaí fair) is intense, with several types of vehicles. Figure 4 shows the commercializing açaí practice, which involves everything from the product's extraction (phase 1 and 2), Inland waterway transport (phase 3 and 4), commercialization (5, 6, and 7), and, finally, açaí can be sold to the local population, as shown in phases 8 and 9 of the figure, or sold and transported to other states and countries. Waterway transport drives this process and, despite the current difficulties, fulfills its function by making the açaí arrive at the fair and continue to the final consumer.

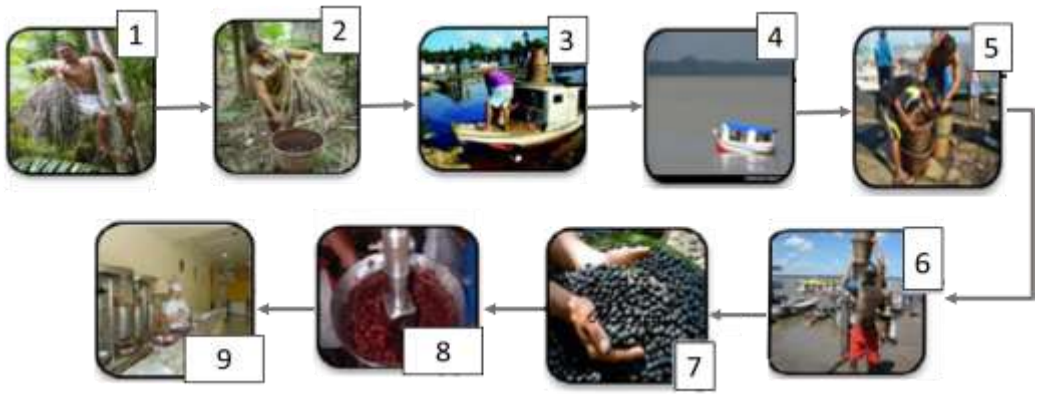

FIGURE 4 - SEQUENCE OF THE AÇAÍ PRODUCTION CHAIN ADOPTED BY THE COMPANY PONTO DO AÇAÍ
SOURCE: Adapted from Souza and Bahia (2010)

5.2. Field research

To better understand the activities of supplying goods by waterway, its interaction with the city, and the search for information that supports the planning of consolidated waterway urban logistics practices, and information survey from field observations were carried out in Belém.

The field study addressed the main trade routes in the center and the Ver-o-Peso complex, as shown in Figure 5. In the study area, some streets have impediments to the circulation of vehicles. In most of the roads in the studied area, informal commerce and the available infrastructure, typical of a historic center, prevent the passage of road vehicles.

FIGURE 5 - STUDY AREA IN THE BELÉM COMMERCIAL CENTER
SOURCE: Google MyMaps

The main problems identified in the commercial center of Belém are: lack of official loading and unloading spaces, narrow streets that result in a lack of space for trucks to park near the establishments served, heavy vehicle traffic on the streets, state of conservation the streets and sidewalks that make it difficult for walkers to pass and load goods, lack security and workers' complaints about cargo theft.

The large quantity and diversity of products sold in the center, including perishable foods that supply supermarkets, and the high stock turnover, make deliveries practically daily. The lack of official parking spaces forces the cargo vehicles to stop on roads far from the establishments and often in prohibited places. The supply is made through "wheelbarrows", which increases the delivery time and damages the goods. Workers moving wheelbarrows find difficulties because the streets and sidewalks were not built for this type of vehicle, in addition to the weight of the goods on them. Some large vehicles, mainly trucks coming from other states, remain parked on the roads for an entire day or evenmore, due to the time to reach the establishments' doors.

With the Kernel Density tool available in ArcGIS Software, the heat map presented in Figure 6 was built for the study area and surroundings. The locations that appear in warmer colors (red, orange) are the most critical, where there is a large concentration of parked cargo vehicles. The region close to and even inside the Feira do Açaí is the most affected. The trucks use the space during the day to carry out loading

Theoretical and Empirical Researches in Urban Management
Volume 16 Issue 1 / February 2021

and unloading of goods in general since the movement is more significant in the area during the first areas of the morning when the boats dock with the açaí. Other regions of the map also point to cargo vehicles' presence (areas in yellow and blue), but in less concentration, which also impacts the traffic of vehicles and walkers on these roads.

Despite the water potential surrounding the studied area, trucks are still the primary source of trade supply. Large trucks contribute to traffic jams, pollution, accidents, infrastructure degradation, and other problems faced. Implementing waterway practices as an aid to urban logistics could increase the interest of those involved in transport and commerce and, consequently, reduce the number of road vehicles in the area.

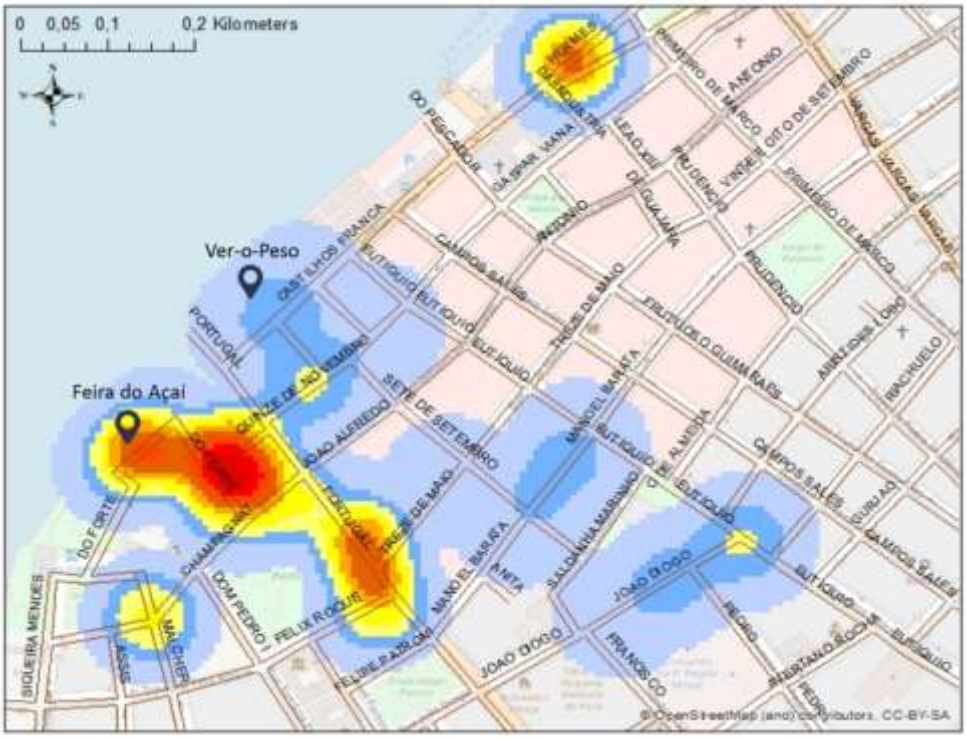

FIGURE 6 - HEAT MAP OF THE TRUCK PARKED POINTS IN THE BELÉM COMMERCIAL CENTER
SOURCE: Software ArcGIS

5.3. Main international practices implemented and possibilities for Belém

Among the best practices found in the literature, some have already been implemented and obtained satisfactory urban logistics results. The examples are in France and the Netherlands, being used to deliver goods by the river, as a complement to other modes or for the collection of urban waste. These practices are described below for comparative analysis and identification of possibilities for the Bélem city (Table 3):

- Franprix - Paris: urban distribution of consumer products - the company's products are transported through boxes from a warehouse outside the city to a port inside Paris. The goods are transferred to specifics trucks that deliver to 100 stores in the city. The company can better serve consumers and reduce the impact of restrictions in urban areas. There is also a reduction of 450,000 km that would be covered by road transport and 37% less CO2 emissions (VNF, 2017);
- Mokum Maritiem - Amsterdam: deliveries to local stores and waste transport - The group of logistics services operates in the transport of freight with barges called City-Supplier and Power Supplier, with hybrid energy (electric and biodiesel), "intelligent" because of their lack of idle rotation, silent and do not release odors. City-Supplier is equipped to handle different types of deliveries using a hydraulic crane. The Power Supplier is a multifunctional barge designed to transport heavy materials, but it can become a floating platform and even a stage for events. For hotels and restaurants, the route includes the delivery of goods, as well as the waste collection (Janjevic; Ndiaye, 2014);
- DHL floating distribution center - Amsterdam: package delivery - the Dutch Ministry of Transport has allowed DHL Express to launch a floating distribution center for central Amsterdam deliveries. Every morning the boat is loaded with orders and parked at specific points of the main canals. There is a daily reduction of eight cargo vehicles on the congested streets, being used only two a day (Janjevic; Ndiaye, 2014);
- Vert Chez Vous - Paris: goods weighing up to 30 kg - Vert chez Vous uses a barge with 18 tricycles on board that is loaded during navigation on the River Seine. The barge dock to each port in Paris, and the tricycles distribute the goods, then return to the vessel. Around 14 tons are transported per day, 15 heavy road vehicles are reduced, reducing 207.9 kg of CO2. Figure 7 shows the barge and tricycles used (Diziain; Taniguchi; Dablanc, 2014);

FIGURE 7 - BARGE AND TRICYCLE USED BY VERT CHEZ VOUS IN PARIS
SOURCE: Diziain, Taniguchi, and Dablanc (2014)

Theoretical and Empirical Researches in Urban Management
Volume 16 Issue 1 / February 2021

- Beer Boat - Utrech: delivery of drinks: in Utrecht, the "beer boat" is electric and has been distributing goods through the city's canals since 2010, as shown in Figure 8. The barge supplies stores and restaurants along the center urban, with a loading capacity of up to 20 tons. The products transported can still be refrigerated and frozen.

FIGURE 8 - BEERBOAT IN UTRECHT, NETHERLANDS
SOURCE: Gemeente Utrecht (2018)

Based on the described international examples of waterway urban logistics practices and Belém commercial center's current scenario, it is possible to carry out a comparative analysis to identify possibilities for improving the distribution of goods. Table 3 lists the primary international consolidated practices and the possibilities of implementation in Belém, together with assessing implementation difficulties, based on data collected in the literature and field observations.

The possibilities identified as easy to implement, when compared to the others, could be realized from the infrastructure and activities already existing in Belém. As described, one possibility would be to use regions close to "Baía do Guajará" to store products, such as districts, and to supply markets in the "Ver-o-Peso" region by the river (based on the practice Franprix - Paris). This practice could use facilities in the Port of Belém, for example, close to the shopping center. Mainly, appropriate vessels would be necessary for the products transported and organization of loading operations in the districts and unloading in the urban area. Small vehicles could deliver to the door of establishments that are not located on the river bank.

Like the company Vert Ches Vous (Paris), the waterway use in conjunction with cargo tricycles would be interesting for the region studied. The narrow and busy roads could receive tricycles without significant impacts on the activities carried out. Goods brought by the river could be distributed in the commercial

center using tricycles. Adapted to the reality of Belém, the loading of tricycles could be done in a parking lot in a predefined location. Existing vessels could be used in operations.

TABLE 3 - URBAN RIVER DISTRIBUTION PRACTICES TREATED IN THE STUDIES STUDIED

Main international practices implemented	City	Papers	Implementation facilities	Implementation difficulties	Difficulty level for implantation
Franprix - deliveries of consumer goods in supermarkets across the Senna River - moving boxes are used from a warehouse outside the city to a port inside Paris.	Paris (France)	Leonard et al. (2014), Janjevic and Ndieye (2014)	Navigation potential of Baia do Guajará and markets close to the shore, RMB cities would support the installation of warehouses close to the river.	Deliveries could not be made directly to the establishment, other forms of transport would need to be used for the final delivery.	
Beer Boat - delivery to local stores, hotels and restaurants, bringing benefits in costs, traffic and emissions - serving between 65 and 70 end customers.	Utrecht (Netherlands)	Macharis and Kin (2017), Leonardi et al. (2014), Van Rooijen and Quak (2014), Janjevic and Ndiaye (2014), Nemoto et al. (2005)	Part of the Ver-o-Peso complex is directly linked to the Baia do Guajará, stalls selling dishes and drinks could use the service.	Just like the Beer Boat, the vessel would need equipment to access the fair, which has an unevenness in relation to the river.	
Vert Ches Vous - deliveries of goods of up to 30 kg, the barge consists of 18 tricycles on board that are loaded during navigation on the Senna River, distribute the goods and return to the vessel, 14 tons are transported per day.	Paris (France)	Macharis and Kin (2017), Janjevic and Ndiaye (2014)	Commercial center near the shore of Baia do Guajará with the sale of the most varied products, RMB cities would include the installation of warehouses close to the river.	Construction of structures at specific points for mooring barges and access to urban roads to facilitate the circulation of tricycles.	
DHL - Floating distribution center for order delivery, every morning the boat is loaded with orders and stops at specific points on the main canals.	Amsterdam (Netherlands)	Janjevic and Ndieye (2014)	Establishments close to the shore would benefit from the floating CD, the Baia do Guajará has large capacity vessels.	Difficulty of access for people who are far from the shore, construction of structures to allow people access to the boat.	
Transport of waste and recyclable products by barge - residents of 16 municipalities in the Paris region can benefit from the service. In 2011 the barge transported around 300 thousand tons.	Paris (France)	Diziain, Taniguchi, and Dablanc (2014)	Large generation of waste and recyclable products, mainly in the commercial center, cities in the RMB and islands that are also located on the banks of the Baia do Guajará.	It would only serve the proximity of the shore, the population's disposition to separate recyclables and travel to the collection point, construction of structures for mooring the vessel and collection of waste.	
Mokum Maritiem - deliveries to local stores and transportation of waste with sustainable barges equipped to handle different types of deliveries.	Amsterdam (Netherlands)	Van Duin, Kortmann, and Van Den Boogaard (2014), Janjevic and Ndiaye (2014)	Commercial center close to the shore with a wide variety of products received and sent, great generation of waste and recyclables.	Construction of structures at specific points for mooring barges, acquisition of hybrid barges, association with other modes for final delivery to establishments far from the shore.	

Subtitle: Low level Medium level High level

Theoretical and Empirical Researches in Urban Management
Volume 16 Issue 1 / February 2021

After deliveries, the small vehicles would return to the parking lot for a new loading. The Feira-do-Açaí region, for example, is located on the river bank and is a place with a high circulation of products. Even açaí, which is destined for the metropolitan region of Belém, could be delivered by tricycles. Applications on smartphones can assist in communication between customers and couriers, avoiding larger vehicles.

5.4. Analysis of results

After gathering information in the field, problems were identified in the Mercado do Ver-o-Peso region related to heavy traffic. This situation is related to other difficulties faced, such as the restricted width of roads, the lack of planning and organization, and cargo vehicles stopped in a prohibited place. Data from INRIX - Global Traffic Scorecard (2018) points to Belém as the 25th most congested capital globally. To minimize these problems, prior planning and simulation of solutions in the affected areas are essential.

The analyzes presented in the field survey and comparison with international practices point to the excellent potential for the city of Belém, as described in Table 3. These proposals aim to increase the interest of those involved in practices for the Belém commercial center, which can help urban logistics in the region.

With the implementation of cargo terminals, for example, and even constructing mooring points on the shore, establishments located in the commercial region or carriers that daily deliver to these establishments, could have use the waterway to access commercial areas. The increasing availability of georeferenced information and GIS software has enabled a better spatial analysis, contributing to planning in urban space.

6. CONCLUSIONS

With the studies carried out on the use of waterway transport as an aid to urban logistics, it is possible to observe great possibilities for an efficient distribution of goods in urban centers and reduce impacts on the life quality population. The international practices identified mainly in cities in France and the Netherlands point out that the waterway use can be an ally in reducing road cargo vehicles in commercial centers, mainly in large cities. Furthermore, it is possible to use the modal when the water bodies do not allow direct delivery to establishments, based on the association between vessels and other vehicle types. This alternative can reduce conflicts in the urban space, contributing to cities' social, economic, and environmental development.

According to the survey of the use of waterways in the Brazilian scenario, it can be concluded that the potential available is not fully used. Projects were identified in cities such as São Paulo and Recife that seek more significant interaction between rivers and urban mobility. However, most of these studies are

aimed at passenger transport and have not been implemented. Cities like Manaus and Belém, which are more dependent on the waterway modal, use rivers to transport cargo and people, even in adverse and complex conditions than European examples.

The comparative analysis carried out shows that the country has cities where it would be possible to use the waterway to aid urban logistics, based on an adaptation of international examples to the Brazilian reality; this is the case of Belém. Observations in the field near the Ver-o-Peso complex point out that there are many points to be improved. With some adjustments, greater waterway modal use would be possible for efficient deliveries and relatively simple changes. Practices such as Franprix and Vert Ches Vous (Paris) were identified as those with greater adherence to reality in Belém.

The participation of all those involved in the distribution of goods is essential for implementing comprehensive measures that help in the solution of urban conflicts. The public authorities' contribution is indispensable for the development of these alternatives, taking as an example again the international practices that were only successful thanks to public investments and incentives.

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