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CONCLUSION PROJECT OF THE COURSE INLAND WATERWAYS & MULTIMODAL TRANSPORT

STUDENTS: CLÁUDIA BORGES

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MADEIRA RIVER: A STUDY OF THE SOCIOECONOMIC-ENVIRONMENTAL SCENARIO OF THE REGION BETWEEN PORTO VELHO (RO) AND ITACOATIARA (AM)

BRASÍLIA – BRAZIL

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ABSTRACT: THIS WORK AIMS TO DRAW A BRIEF HISTORICAL PANORAMA AND THE MAIN CHARACTERISTICS THAT INVOLVE THE MADEIRA RIVER BASIN, FOCUSING ON THE STRETCH BETWEEN PORTO VELHO (RO) AND ITACOATIARA (AM). SOME OF THE OBSTACLES TO THE DEVELOPMENT OF THIS RIVER AS A WATERWAY WILL BE EXPOSED AND POSSIBLE WAYS TO OVERCOME CURRENT DIFFICULTIES ARE PRESENTED IN ORDER TO POINT OUT FUTURE SOLUTIONS FOR A BETTER USE OF THE RIVER IN A COMMERCIAL, SOCIAL AND ENVIRONMENTAL WAY.

KEY WORDS: MADEIRA RIVER; WATERWAYS; NORTH OF BRAZIL.

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SUMMARY

1. INTRODUCTION

The Madeira river has proved, over the years, to be a crucial route for transporting cargo in the North Region. In addition, it has also emerged as an important alternative for the flow of cargoes from other regions of Brazil.

This is because the Madeira river is part of the Brazilian logistics system called *Arco Norte*, made up of ports located above the 16th parallel: including ports that go from Porto Velho (RO-Rondônia), through Amazonas (AM), Amapá (AP) and Pará (PA), which have been standing out as an alternative for the flow of cargoes from the central region of Brazil to the ports in the South and Southeast.

This study presents an analysis of the Madeira river and seeks to propose some plausible ideas and solutions to recurrent problems with the aim of bringing a leap in quality to the operations that depend on this waterway. Its intention is to boost the development of this corridor – already widely used locally – as a perennial waterway and a real sustainable option for economic exchanges in the region. In addition, it aims to transform it into a connection, through intermodality between producers and exporting zones, facilitating and optimizing the transport of cargoes involved in these exchanges. It is not expected to exhaust the discussions, but rather to stimulate the greater production of studies and greater visibility for inland navigation in Brazil, which has historically been so neglected in the country.

1.1. THE MADEIRA RIVER

The Madeira river is 3.240 km long, it rises in the Andes Mountains and is the main tributary and mouth of the Amazon River on the right bank. Crucial for the development of the North Region, the Madeira river receives its name after the confluence of the Beni and Mamoré rivers at the height of the municipality of Nova Mamoré-RO, on the border between Brazil and Bolivia. The navigable stretch of the Madeira river begins in the city of Porto Velho and goes to the mouth of the Amazon River, totaling 1.086 navigable km.

FIGURE 1 – MADEIRA RIVER

Source: Eduardo Duarte – Madeira River, Rondônia, Amazonas (Personal Archive)

On the route between Porto Velho (RO) and its mouth, corresponding to the stretch of study, the Madeira river configures a plain river, with favorable characteristics for navigation due to its smooth and regular slope, with a total difference in level of about 19 m, over a length of 1.086 km, resulting in an approximate average slope of 1.7 cm/km (DNIT – Departamento Nacional de Infraestrutura de Transportes).

On the other hand, due to its sedimentary morphodynamics, the riverbed undergoes an intense mobilization of sediments with frequent migrations of sandbanks that form in the outflow of tributary water bodies and in regions of low hydrodynamic energy, such as curves and backwater areas and the variation in the water level between the rainy and dry periods. Despite being a river with fast waters, with a speed of up to 2.5 m/s or 9 to 10 km/h (DNIT), it has a high degree of sand deposition, and soil that falls off its banks, which makes it need periodic intervention to allow safe and unrestricted navigability at any time of the year.

1.2. NAVIGATION ON THE MADEIRA RIVER

The Madeira river, in the part that comprises the stretch between Porto Velho (RO) and Itacoatiara (AM), as a waterway, which will have a historical overview presented in this work in order to complement its social, economic and cultural importance, as well as some specific characteristics of the Madeira river will be pointed out.

The type of material in the bed of a plain river directly influences its navigability conditions. Bed rivers with the presence of stones favor the maintenance of a narrower stable channel, while rivers with a mobile bottom, with the presence of sand, silt[1] or clay, tend to form sinuous and unstable channels, with migration of sand banks and processes of erosion and silting of the margins.

During most of the year, the lower Madeira (a region comprising Porto Velho-RO and surrounding regions) is more than a thousand meters wide and has many islands along its course. During the dry season (normally between May and October), sandbanks emerge (which change position during the flood season) and *baixios*[2] that force pilots to reduce the speed of the vessels.

In general, the Madeira river has no problems with sinuous sections, since the sinuosity indexes along its route do not exceed values of 1.3[3] (ratio between the radius of the channel curve and its width), without sudden funnels.

The segment between the mouth of the Madeira river and Humaitá (AM) has minimum depths of 3m, while between Humaitá (AM) and Porto Velho (RO), the minimum depths can reach 2m. During the dry season, due to the low depths, some natural obstacles can lead to greater navigation difficulties, however, even at that time, there is navigation of large convoys, with up to 18.000 tons. In periods of flooding, average depths can reach 25m.

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[1] Silt is granular material of a size between sand and clay and composed mostly of broken grains of quartz. Silt may occur as a soil (often mixed with sand or clay) or as sediment mixed in suspension with water. Available in: https://en.wikipedia.org/wiki/Silt . Accessed on: November 10th 2022.

[2] *Baixios* are sandbars or rocks covered by a small amount of sea or river water. Available in: https://www.dicionarioinformal.com.br/baixios/#:~:text=%5BGeo.%5D%20Banco%20de%20areia%20ou%20rochedo%20coberto%20por,%C3%A1gua%20do%20mar%20ou%20de%20rio%3B%20baixias.%202. Accessed on: November 11th 2022.

[3] The following classification has been suggested, based on 4 types of sinuosity: <1.05 (straight); 1.05-1.3 (sinuous); 1.3-1.5 (moderate meandering) and >1.5 (meandering form) (HORACIO, 2014).

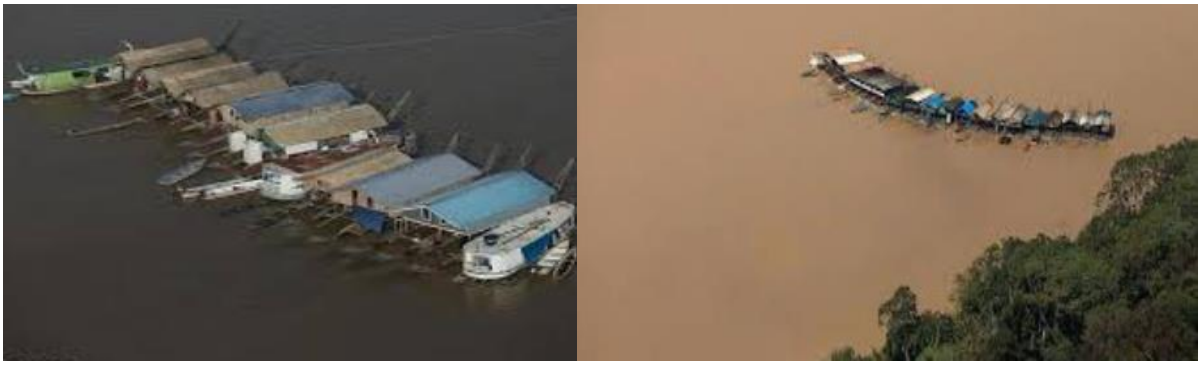
The natural and seasonal event mentioned above ends up causing a phenomenon specific to this river that directly impacts its navigability. The process of drought and subsequent flooding of the river causes the flow of a large number of tree trunks, called toothpicks (*paliteiros*), from the process of river erosion of the banks due to the flood/ebb, a phenomenon known as fallen land (*terras caídas*). This material flows down the Madeira river causing risks and damage to vessels and people, causing great concern for users.

FIGURE 2 – TOOTHPICKS (*PALITEIROS*)

Source: Personal Archive

During the dry season, mining activity, carried out in some stretches of the Madeira river, promotes changes in the configuration of the bottom and the banks of the river. In addition, the mining rafts congest the navigable riverbed, increasing navigation difficulties.

FIGURE 3 – GARIMPO (GOLD MINING) RAFTS ON THE RIVER BED



Source: Personal Archive

Complementing the navigation characteristics of the Madeira river, there are power generation plants along its course which, as they do not have a system of locks or diversions, constitute the relevant physical obstacles to the navigation of this waterway, preventing the connection of the mouth of the Madeira river to the mouth of the Beni river and the Mamoré and Guaporé rivers.

1.3 SOCIO-ECONOMIC POTENTIAL

Currently, approximately 16 million tons of cargoes are transported, adding both directions of navigation – Porto Velho/Manaus and Manaus/Porto Velho. The largest amount of cargo is in the Porto

Velho/Manaus direction, due to the large volume of solid bulk, such as soy and corn produced in the northwest of Mato Grosso and in crops in the state of Rondônia, whose destination is export. There is also a considerable volume of general cargo to supply the states of Amazonas and Roraima, in addition to the export of sugar and soy oil to Peru and containerized cargo. In the opposite direction, the largest volume is liquid bulk, corresponding to oil derivatives to supply the states of Rondônia, Acre and northwest Mato Grosso. There is also a load of products from the Manaus Free Trade Zone and fertilizers.

For all these reasons, cargo navigation on the Madeira River plays a fundamentally important role in supplying the states of Amazonas, Roraima, Rondônia, Acre and Mato Grosso, as well as for the flow of wealth produced and exported, being essential for the integration and development of the region.

The Madeira river is of vital importance for the integration of the communities located along its banks, some accessible only by navigation, being the only means of transporting passengers between the different locations and the production of riverside communities, which is sold at fairs in the most important cities in this route, such as Porto Velho (Rondônia), Humaitá (Amazonas), Manicoré (Amazonas), Novo Aripuanã (Amazonas), Borba (Amazonas), Autazes (Amazonas) and Nova Olinda do Norte (Amazonas) (LOPES E MAGALHÃES, 2018).

2. THEORETICAL REFERENCE

2.1. BRAZILIAN WATERWAYS: HISTORICAL PERSPECTIVE

The incipient navigation of the Madeira River, which began in the mid-nineteenth century, was mainly due to an agreement between Brazil and Bolivia, a landlocked country, and according to that agreement, Brazil would build a railroad linking the locality of Guajará Mirim, on the banks of the Mamoré River, on the border with Bolivia, with the city of Porto Velho.

After frustrated attempts to build the railroad around the year 1865, the so-called *Estrada de Ferro Madeira Mamoré* was finally built between the years 1907 and 1912. From then on, commercial navigation on the Madeira river increased with the transport mainly of latex extracted from rubber trees and chestnuts, whose major production at that time was in Bolivian soil.

With the advent of the 2nd World War, the production of latex became of great importance, and in that period the local economy experienced an important growth. Possibly, the interconnection between the Madeira-Mamoré Railroad and the navigable section of the Madeira river constituted one of the first examples of modal integration in transport in Brazil.

From the second half of the 20th century, with the construction of the BR-364 highway, which connects the state of Rondônia to the states of the Brazilian Midwest, logistics integration became between road and water transport, since around the year of 1972, the Madeira-Mamoré Railroad was deactivated due to the construction of a highway between the cities of Guajará Mirim and Porto Velho. During this period, cargo from other states or from production in the state of Rondônia began to be transported along the Madeira river, destined for Manaus, in the state of Amazonas and for the state of Roraima.

In this way, the rivers began to be used to transport the production of the interior areas of Brazil, however there was no real plan for adapting and developing inland navigation, that is, transport was carried out in the way that was possible for the need of disposing of products. Over the years and developments in the world of transport, around the 19th century, the railway modal became the one with the greatest investments, even replacing some river interconnections that were used at the time, giving way to the railways (POMPERMAYER, CAMPOS NETO AND PEPINO DE PAULA, 2014).

The first concessions are also a hallmark of this Brazilian imperial era, where the implementation of projects was the responsibility of the private sector – in fact, it can be said that concessions are common in Brazilian political/economic practice since the Hereditary Captaincies, where land administration distributed throughout the territory was 'privatized' (LIMA NETO ET AL., 2001).

2.2. BRAZILIAN WATERWAYS: ECONOMY

The strong population concentration on the coast of the country – added to the expressive condensation of the largest economic centers on the coast – made, in the maritime modal, cabotage navigation to be prioritized in order to meet the demands of the big cities and help in the development of the Brazilian ports. The river modal, more important in the interior areas of the country, was left in the background, but has, in recent years, regained greater attention, mainly because it is intrinsically connected to the great producing areas of the country. More and more, people are thinking about

ways to facilitate, make cheaper and expand the connections between the producing region and the consuming and exporting areas, especially since it is a country that mainly exports agricultural products, which come, on a large scale, from inland locations in Brazil, permeated by rivers and possibilities of connections through the river modal (LOPES E MAGALHÃES, 2018).

It is worth emphasizing here that navigability on rivers is something that needs studies and projects, since it involves extensive knowledge of the characteristics of the courses – seasonality, type of bottom, natural obstacles to navigation, etc. – so that interventions are correctly designed to develop navigability with the least possible natural impact. This 'formalization' - bringing the formulation of navigation charts, signaling and infrastructure - of waterways is essential for the recrudescence of the use of this modal in an intense and safe way by companies willing to invest in inland navigation.

Another point of relevance for the development of inland navigation in Brazil, in a more expressive way, is that transhipment facilities are implanted in strategic places of the production flow routes. These transhipment locations promote intermodality, essential to facilitate the variation of modals applied, in order to complete cargo transportation. It should be noted that the greater the distances involved in transport – in Brazil, the distances are, at least, considerable –, the greater the need for integration and promotion of possibilities for changing modes. This lack of internal connectivity makes cargo transportation more expensive and slows it down in the country.

De Langen and Sharypova (2013) reinforce this idea by exposing that intermodal connectivity should be an indicator for assessing the performance of a port; it may even extend this conception and think that this integration should be an indicator of a country's economy. The internal connections between producing and consuming/exporting regions should be seen as a key factor in measuring the development of the national economy.

2.3. BRAZILIAN WATERWAYS: A NATIONAL NEED

As relevant as it is a driver of the favorable trade balance as a result of a country's exports, internal logistics must be modeled with a focus on internal development as well. In this way, one must think about the development of waterways beyond facilitating the flow of products to be exported, that is, beyond a need focused on international trade; but as a national need, for economic as well as social improvement.

This becomes even more expressive when taking into account the moment of 'Globalization transition', marked by the gain in importance of regional exchanges to the detriment of the global one; and where knowledge also takes on a preponderant status in measuring the power of countries (LUND ET AL., 2019).

The advent of new technologies drives the development of tools and solutions for the most diverse existing obstacles, increasing productivity and logistical efficiency. This search for models that overcome challenges and resolve internal bottlenecks with a focus on national development generates greater confidence, which leads to risk mitigation, increased performance and reduced total costs (CRISTOPHER AND LEE, 2004).

By making a connection with the Brazilian waterways, a parallel can be drawn that greater investment and a real project are needed for the use and viability of the waterways in a constant and sustainable way. To this end, public entities - Federal and state governments involved - should

encourage the organization of inland navigation corridors, as this will result in a greater level of confidence for users - companies installed in the region - to use waterways as viable and safe alternatives in order to to reduce risks and optimize product exchanges in the country.

In a country of continental dimensions and marked by significant regional inequalities, waterways can be elements of connections and able to resolve discrepancies, in addition to boosting economic exchanges throughout the national territory and facilitating the flow of products to be exported. Intermodality has to be pursued in order to achieve greater and better results in the national economy, updating it to a more sustainable model and more connected to international markets, which live an eternal search for optimization - in terms of time and money - of operations/exchanges.

3. ECONOMIC AND FINANCIAL ASPECTS

3.1. CURRENT LOAD FLOW

The state of Rondônia is a passageway for part of the grain production in the state of Mato Grosso (MT) and Santarém (PA). The list of products includes, in addition to soy and corn, soy complex products such as soy bran and soy oil. Completing the list, are containers of various products, sugar and vehicles, which, without the option of highways, travel on vessels to the large cities of the state of Amazonas. On the return journey (up the Madeira river), the vessels bring consumer products, natural gas, gasoline and diesel oil, raw materials, vehicles, and all other products and equipment used by companies based in Rondônia.

The city of Porto Velho has 4 bulk terminals. The rest of the embarkation and disembarkation takes place in the city's river ports, which are extremely precarious and without an infrastructure equal to the importance of river navigation on the Madeira river.

This port movement projection study is based on an econometric analysis of the movement bases recorded in ANTAQ's (Agência Nacional de Transportes Aquaviários) statistical yearbook (Yearbook 2020) which includes the movements carried out in Brazilian ports between 2010 and 2020, detailing the ports of origin and destination of each movement, the transported loads, the movement direction (embarkation/disembarkation), the volumes moved, as well as the year of the movement.

The Porto Velho port complex handled, in 2020, a total of 9.62 million tons, among which agricultural solid bulk corresponds to the main cargo profile, responsible for 83.78% of the volume transported in 2020, followed by general non-containerized cargo (GNCC) with 4.79%, other solid mineral bulk with 4.22%, liquid bulk with 4.2% and general containerized cargo (GCC) with 3.01% according to Table 1.

TABLE 1 - CARGO HANDLING (THOUSAND TONS) BY INLAND NAVIGATION AND CABOTAGE - PORTO VELHO PORT COMPLEX

Profile	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Total
Agricultural Solid Bulk	**3.089**	**2.436**	**3.683**	**4.445**	**3.674**	**4.324**	**5.072**	**7.312**	**7.349**	**7.642**	**8.057**	**57.083**
Soybean in Grain	2.553	2.035	2.713	1.954	2.359	2.211	3.796	4.075	4.826	5.041	5.140	36.703
Corn in Grain	487	386	926	1.740	1.193	2.058	1.235	3.202	2.515	2.586	2.841	19.169
Brans	16	0	5	695	17	10	4	3	0	1	6	757
Sugar	33	14	39	57	105	45	36	31	8	14	70	454
Liquid Bulk	**344**	**320**	**233**	**372**	**596**	**395**	**455**	**494**	**486**	**539**	**404**	**4.637**
Diesel oil	301	277	189	321	536	317	352	383	386	458	330	3.851
Natural Gas	41	42	45	50	51	52	63	68	11	0	0	423
Ethanol	2	0	0	0	8	19	28	27	31	55	42	213
Biodiesel	0	0	0	0	1	7	6	11	49	21	15	110
Petrochemicals	0	0	0	0	0	0	6	5	9	5	16	41
General Non-Containerized Cargo (GNCC)	**484**	**383**	**384**	**484**	**657**	**448**	**387**	**222**	**320**	**364**	**460**	**4.593**
General Containerized Cargo (GCC)	**238**	**197**	**774**	**323**	**202**	**111**	**118**	**245**	**650**	**231**	**290**	**3.378**
Other Solid Mineral Bulk	**197**	**142**	**100**	**68**	**150**	**43**	**170**	**352**	**365**	**348**	**406**	**2.341**
Total	**4.351**	**3.477**	**5.175**	**5.692**	**5.279**	**5.321**	**6.201**	**8.625**	**9.170**	**9.124**	**9.617**	**72.032**

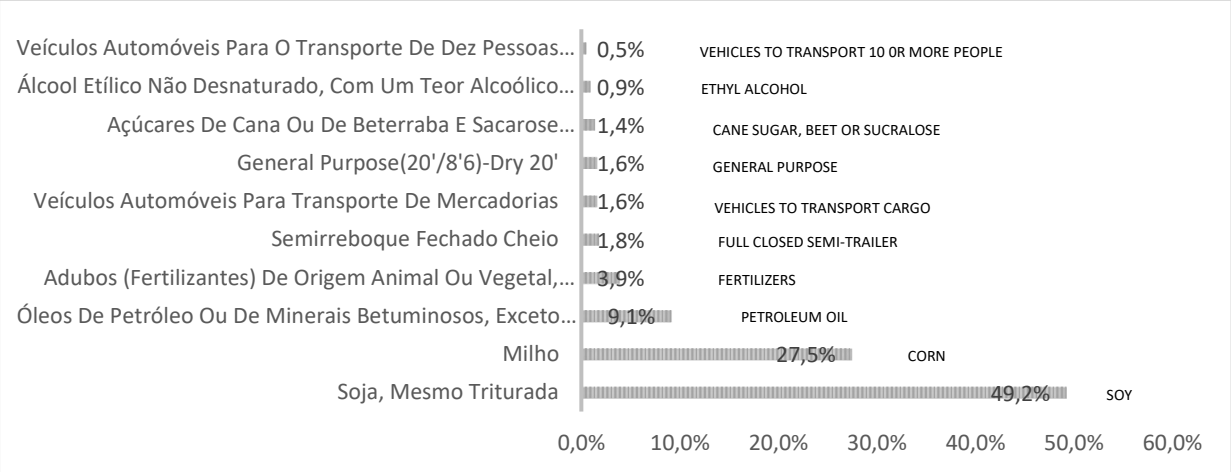
Source: Self elaborated with ANTAQ's data (2020).

Based on Table 1, there is a persistent growth trend in the movement of soybeans and corn along the Madeira river between 2010 and 2020. Also noteworthy is the growth curve in the movement of corn in grain as the second main product, which came from a movement of 487 thousand tons in 2010 and, in 2020, reached a movement of 2.84 million tons, which represents an average annual growth of 19.75%.

Additionally, it appears that the Port Complex grew, on average, 13% per year, during the period from 2015 to 2020. This change represents an 81% growth in cargo handled in the period, out of an amount of 5.3 million from tons transacted in 2015 to 9.62 million tons transacted in 2020. The cargo profile that grew the most in the period under analysis was other solid mineral bulk, represented mainly by fertilizers, followed by general containerized cargo and soy in grain, respectively.

In Graph 1, within the agricultural solid bulk group, it is observed that the two main commodities transported by the Madeira River are soy, with 49.2%, and, secondly, corn with 27.5%, both produced in the states of Rondônia and Mato Grosso.

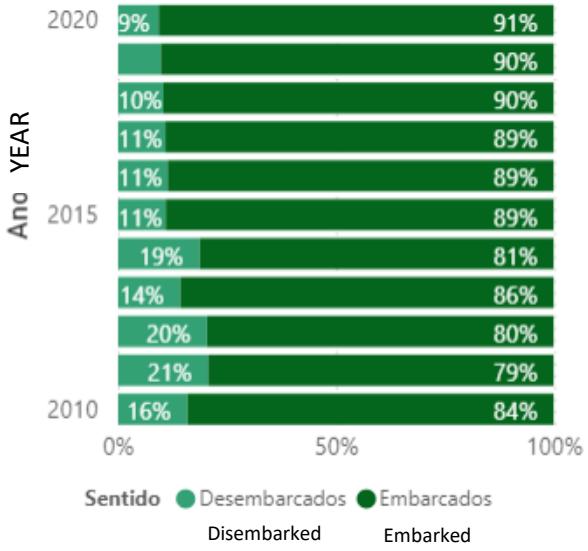
GRAPH 1 - HANDLING OF THE PORT COMPLEX IN 2020 BY TYPE OF CARGO



Source: Self elaborated with ANTAQ's data (2020).

With regard to the direction of movements, according to Graph 2, it is observed that around 86% of them are destined for shipment, which demonstrates the export vocation of the Madeira River.

GRAPH 2 - CARGO HANDLING BY NAVIGATION DIRECTION IN %



Source: Self elaborated with ANTAQ's data (2020).

In terms of landing navigation at the port complex of Porto Velho, the main products are petroleum derivatives, which supply the states of Rondônia, Acre and the northwest of Mato Grosso. It should be noted that products from the Manaus Free Trade Zone, which arrive in Porto Velho from Manaus, go to other national destinations, through modal integration between the waterway and road segments.

3.2. GROWTH POTENTIAL

In order to add value to the present study, having a vision of the projected demand for the Port Complex of Porto Velho is important as a vision of the future for the use of the Madeira River. Thus, with 2020 as the base year, a table prepared by the Public Logistics Company (EPL) with data from ANTAQ (2020 Yearbook) is presented below in a time period between 2020 and 2035, both in terms of shipped products and in terms of sense of disembarking.

TABLE 2 - CARGO DEMAND PROJECTION (IN TONS) AT THE PORTO VELHO PORT COMPLEX BETWEEN THE YEARS 2020 (OBSERVED) TO 2035 (PROJECTED)

Profile	CARGO	DIRECTION	TYPE OF NAVIGATION	2019	2020	2025	2030	2035
Solid Bulk	Fertilizers	Embark	Interior	198	856	226	242	254
	Fertilizers	Disembark	Interior	347.397	222.252	230.798	247.063	258.979
	TOTAL		**Interior**	**347.595**	**223.108**	**231.024**	**247.305**	**259.233**
Profile	CARGO	DIRECTION	TYPE OF NAVIGATION	2019	2020	2025	2030	2035
Liquid Bulk	Petroleum Derivatives	Embark	Interior	1.249	3.576	5.798	5.672	5.574
	Petroleum Derivatives	Disembark	Interior	809.743	691.977	733.670	718.139	706.348
	Ethanol	Embark	Interior	82.903	94.535	99.349	109.865	119.853
	Ethanol	Disembark	Interior	457	1.956	371	412	453
	Biodiesel	Embark	Interior	20.614	15.124	46.685	54.120	59.753
	GLP	Disembark	Interior	0	15.506	83.986	83.988	83.992
	TOTAL		**Interior**	**914.966**	**822.674**	**969.859**	**972.196**	**975.973**
Profile	CARGO	DIRECTION	TYPE OF NAVIGATION	2019	2020	2025	2030	2035
GNCC	Others GNCC	Embark	Interior	242.385	212.955	229.405	237.022	242.495
	Others GNCC	Disembark	Interior	5	2.018	7.042	7.064	7.079
	Semi-Trailer	Embark	Interior	136.846	154.384	166.310	171.831	175.799
	Semi-Trailer	Disembark	Interior	47.761	64.908	69.922	72.243	73.912
	Vehicles	Embark	Interior	145.232	69.363	59.295	57.266	55.898
	Vehicles	Disembark	Interior	34.607	15.574	13.338	12.881	12.574
	TOTAL		**Interior**	**606.836**	**519.202**	**545.312**	**558.307**	**567.757**
Profile	CARGO	DIRECTION	TYPE OF NAVIGATION	2019	2020	2025	2030	2035
General Containerized Cargo (GCC)	Others GCC	Embark	Interior					
	Others GCC	Disembark	Interior	3.146	36.123	71.861	74.527	76.426
	TOTAL		**Interior**	**3.146**	**36.123**	**71.861**	**74.527**	**76.426**
Profile	CARGO	DIRECTION	TYPE OF NAVIGATION	2019	2020	2025	2030	2035
Agricultural Solid Bulk	Soy in Grain	Embark	Interior	5.041.506	5.139.705	6.312.354	7.112.647	7.758.928
	Corn in Grain	Embark	Interior	2.615.116	2.867.152	3.554.742	3.924.722	4.333.211
	Sugar	Embark	Interior	93.461	141.734	67.008	61.403	57.608
	Brans	Embark	Interior	18.768	23.405	17.548	18.200	18.666
	Brans	Disembark	Interior	75	473	629	653	670
	TOTAL		**Interior**	**7.768.926**	**8.172.469**	**9.952.281**	**11.117.625**	**12.169.083**

Source: Self elaborated with EPL and ANTAQ's data (2020).

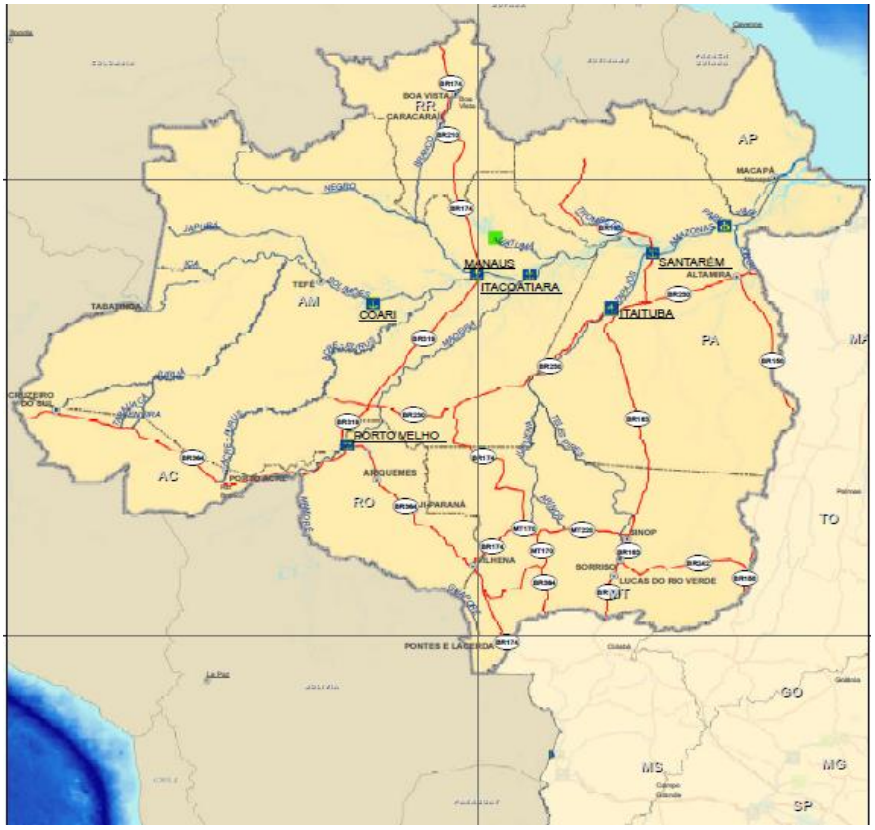
In 2035, in the projected scenario, it is estimated that the demand for the Porto Velho port complex will reach a value of 14.36 million tons handled, which is equivalent to an average growth rate of 2.88% per year. In Table 2, the share of the agricultural solid bulk cargo profile remains as the cargo with the highest relative share, increasing its share by 3% compared to the base year 2020, reaching a share of 84.75%. The second most relevant cargo profile is liquid bulk, with 6.80%, followed by other non-containerized general cargo (3.95%), containerized general cargo (2.70%) and mineral solid bulk (1.81%).

Given the predicted potential for transporting cargo on the Madeira river, with large volumes of bulk cargo and the long distances to be covered, an opportunity is identified for the development of this inland transport route. The production of soy and corn, two of the main agricultural commodities in Brazil, tends to continue expanding until 2035, the horizon shown in the table above. Fertilizer imports will also grow, as well as inland waterway transport of chemicals, oil, coal, and Ro-Ro transport will increase significantly.

3.3. PASSENGER TRANSPORT

The transport of passengers by waterways, in Brazil, has a greater relevance in the regional/local context, with passengers being transported, in general, for short distances from (and to) cities located in the vicinity of rivers. According to ANTAQ (2020 Yearbook), the Amazon region is the one in which passenger transport by rivers is most used. With slightly different characteristics from the other regions of the country, currently, six million passengers travel long distances and a 40% increase in the population transported on waterways in the region is expected by 2031. Short distance services (ferries) are also important in that area, with an equal number of passengers. Long-distance transport in this region is directly related, on the one hand, to the density of the naturally available river network, and, on the other hand, to the limited reach of the road network. Figure 4 below shows the limited number of highways that connect Porto Velho to the main cities in the region: Manaus, Itacoatiara, Santarém and Itaituba.

FIGURE 4 – HIGHWAYS FROM PORTO VELHO TO MANAUS, ITACOATIARA, SANTARÉM AND ITAITUBA



Source: ANTAQ (2020 YEARBOOK)

BR-319 is a Brazilian federal highway, which connects the cities of Manaus (AM) and Porto Velho (RO), in the North Region of Brazil and is the only road connection available between Manaus and the state of Rondônia. It is the main access to several cities in the south of Amazonas, such as Humaitá, Lábrea, Manicoré, Careiro, Manaquiri, Autazes and Careiro da Várzea. Its length is 880.4 km, of which 859.5 in Amazonas and 20.9 in Rondônia. The BR-319 was inaugurated in 1973, during the Brazilian military government, within the context of the colonization of the Amazon. Due to lack of maintenance, the highway has become impassable, and most of its length is currently unpaved.

The other highway in the region is the *Transamazônica* Highway (BR-230), designed and built also during the military government, it is the third largest highway in Brazil, with 4.223 km in length, connecting Cabedelo, in Paraíba to Lábrea, in Amazonas, cutting seven Brazilian states: Paraíba, Ceará, Piauí, Maranhão, Tocantins, Pará and Amazonas. It was planned to better integrate the North region with the Northeast region of Brazil, however it is not paved for most of its stretch, which makes traffic on the *Transamazônica* Highway impractical during the rainy season in the region (between October and March).

The third road that passes through Porto Velho is the BR-364. It starts in Limeira-São Paulo (SP), at km 153 of the SP-330, entering the SP-310 until km 292, where it enters the SP-326 going to the border with Minas Gerais, then passes through Goiás, Mato Grosso, Rondônia and Acre , ending in Rodrigues Alves, in the far west of this state, thus being a highway of fundamental importance for the flow of production from the entire North and Midwest region of the country. Commodity production from the states of Rondônia and the northwest of Mato Grosso, which is destined for the Porto Velho port complex, arrives through this highway. Here we have an important intermodal connection for the flow of production in this region of the country.

There are no railroads in this part of the country and the vegetation cover of the Amazon rainforest is important from an environmental point of view, as well as the characteristics of its soil, making any initiative to open a railway line unlikely. Thus, due to the precarious conditions of road access, and in some cases due to the absolute lack of it and the railway, navigation on the Madeira River plays a fundamental role in social and economic integration for communities and municipalities that are located on the river channel, whose water supply consumer goods, medical care and transporting people between one location and another depends essentially on the river.

4. SUSTAINABLE DEVELOPMENT

The main objective regarding this theme that is becoming more and more important in society is: to use resources better, no more, no less. This means, according to Elkington (2001), that resources must be consumed in order to optimize the quality of the process, eliminating waste of all kinds.

Another way of understanding sustainable development was defined in the 1970s, according to Almeida (2002), at the first meetings of the UN (United Nations), which defines it as collective planning to meet the needs of the current generation, without compromising the future of upcoming generations

With regard to the Madeira river, there is a factor that is essential to sustainability, which is its maintenance of continuous water flow, in order to ensure minimum depths throughout the year that guarantees the maintenance of vessel drafts suitable for the transport of large volumes of loads and the control of erosion processes that may lead to the silting up of its bed.

Almost every year, there are disturbances during the dry season, when vessels run aground on various stretches of the river, which directly impacts the maintenance of jobs associated with the logistics of products that use the river as a means of transport.

As a consequence of this anthropic action, deforestation in areas of high declivity, and/or in areas of great susceptibility to erosion, appears in the first place. Deforestation, in addition to favoring erosive processes and, consequently, the silting up of watercourses directly affects the hydrological cycle, negatively influences the recharge of aquifers that feed rivers and streams during the dry season, when groundwater has an important role.

Another negative anthropic action is the mining activity for gold and cassiterite in the beds and banks of the main course and some tributaries, in territories of the three countries where the basin is located, as well as the extraction of sand through the dredging process.

Despite deforestation being a problem of great impact for the region, other activities related to deforested areas should deserve the attention of environmental authorities due to the great impacts they cause and which have compromised important waterways in our country and in other regions. These activities are irrigation and mechanization of crops, which are being introduced both in Rondônia and in the south of Amazonas, without any study related to environmental aspects, such as the characterization of soil susceptibility to erosion and water balance, with the potential to increase the silting up of rivers and streams.

In this scenario, there is a population of approximately 780.916 inhabitants (IBGE 2010) living along the stretch of the Madeira river that lack quality of local health and education infrastructure, which increases the relevance of navigation on the Madeira. The companies that maintain their operations there do not find specific and qualified labor in the region, and it is common to bring in from outside or invest in the training of local labor. Most subsistence products that are traded in the region are affected in their prices by transport logistics, since many are not produced locally, coming from other regions.

5.0. CORRIDOR INTERCONNECTIVITY

5.1. CORRIDOR INFRASTRUCTURE

The definition of logistics, according to Coelis (2017), is to provide or make available a range of products or services in accordance with the deadline, place of delivery, quantity and, above all, quality.

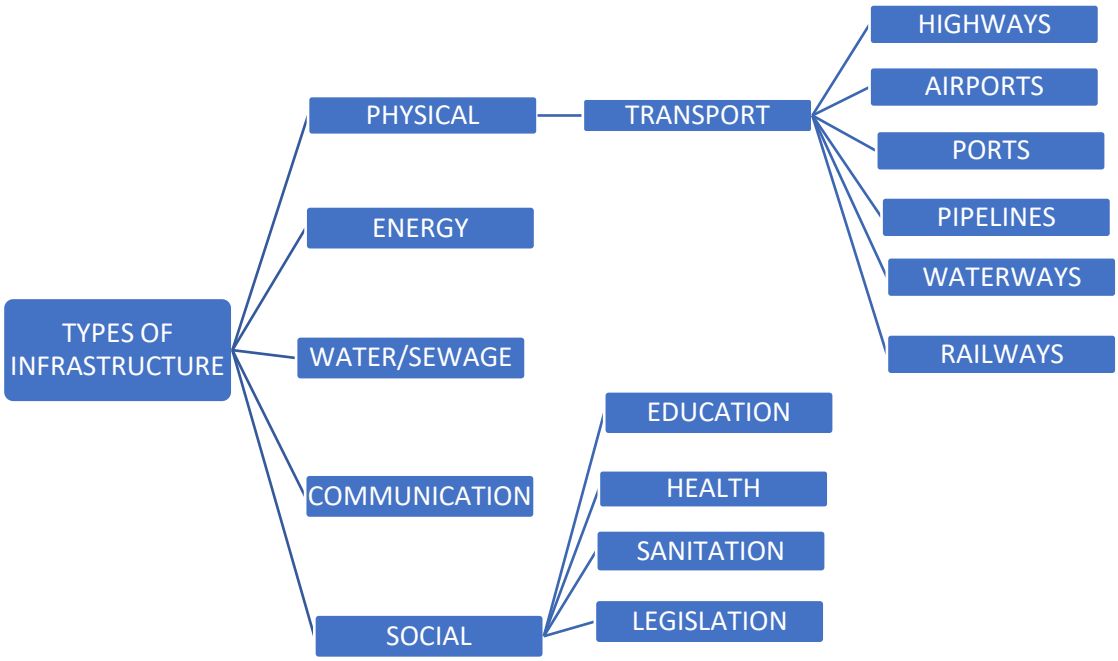
Investments in infrastructure are fundamental for the commercial integration between producer and final consumer, and in a highly complex context where the costs of this operation are quite representative, a region with adequate, modern and accessible infrastructure, reduces costs and increases the productivity of the entire logistic chain (FLEURY, 2000).

5.1.1. CLASSIFICATION OF TYPES OF INFRASTRUCTURE

Infrastructure can be classified into two types: physical and social. The physical one is made up of investments in roads, railways, airports, ports, waterways, bridges, subways, dams and canals, pipelines, water purification and treatment plants, drinking water supply, electrical energy sources and their distribution networks, oil and gas pipelines, sanitation and sewage facilities, health and housing services, urban services, communication and telecommunications networks (KUMARI and SHARMA, 2017).

The social infrastructure, on the other hand, is composed of the quality of services available to the population of the region and that allows serving the region with educational structures, health care, sanitation and the current legislation.

FIGURE 5 – TYPES OF INFRASTRUCTURE



Source: Self elaborated

5.2. LOGISTICS INTERCONNECTIVITY

The importance of seeking a scenario with a high degree of logistical development is aimed at allowing exchanges between existing modals. This has numerous advantages that can be mentioned:

• Increased service flexibility: in this case, both in a need for greater speed, and to divert from a modal unavailability (accidents/breakage);

• Increase in the number of possible origins and destinations of loads throughout the entire system: allowing entry and exit from the central route at points closer to the origin/Destination;

• Lower total cost: allowing to evaluate the best modal combination for each operation (volume X time).

In the same way that logistical interconnection brings important advantages for the development of a region, its absence is closely associated with the scenario of operational risks, which translates into higher costs and low flexibility as it reduces the number of logistical partners.

In an extreme case, where there is only one logistical means of connection between regions, it jeopardizes not only the flow of production, but also the supply of basic items in the interior, in addition to making the entire region more sensitive to the occurrence of extreme natural events, or even major accidents at connection ports.

5.3. CORRIDOR LOGISTICS MODELS

The Madeira river logistics corridor presents an operational scenario that is still distant when compared to reference operations of the same size, as in the case of waterways in Europe. Another relevant point is that there is no infrastructure of other modals overlapping or interconnecting the regions where the operation on the Madeira river serves, as it is the only option for the entire region between Rondônia and Amazonas, which, according to Caixeta-Filho (2001), is far from the ideal for a large logistics operation.

The Madeira river is not a waterway, but a navigable river. This fact is relevant to reinforce that, despite being the only means of transport between large producing and consuming regions in the North of Brazil, there is no formal management of this operation aimed at safety, maintenance, navigability, information management basic for operators and communication along the river.

Another point about the access points to the Madeira river is that, due to the absence of more loading/unloading terminals along its length, most of its cargo travels between two pre-existing fixed points. In this way, the service of the entire region along its extension needs to move to one of these points, a very harmful fact which Caixeta-Filho (2001) reinforces that increases logistical costs and the total time of operations.

5.4. PUBLIC POLICIES FOR THE CORRIDOR

Understanding the macro scenario in which the Madeira river is inserted, its natural and political restrictions, with a large population demanding improvement in logistic quality and cost reduction at the same time as its importance as the main channel for the distribution of commodities in the Center-North region in the country, it is necessary to prioritize infrastructure investments for the region.

Creating the Madeira river waterway is important to improve the management of the operation, as it will take a lot of time and financial investment to seek to implement another logistical solution such as a railroad or even a highway that serves the region.

In parallel to this, it is necessary to raise the main demands of the region to direct solutions, whether with respect to safety, maintenance of the navigable region (signalling/dredging/etc.), communication along the river, salvage, among others, to directing to the public power what can be met with a government plan, and what can be absorbed by private entities in a structured way.

6.BARRIERS THAT HARMFUL THE DEVELOPMENT OF THE WATER MODAL ON THE MADEIRA RIVER

Before listing the bottlenecks that navigation in general (cargo and passenger) needs to overcome, it is necessary to demystify the idea that there is a waterway on the Madeira river. It is understood that the term “waterway” should not be used, as the Madeira river is only a navigable river. The condition of navigability in part of its route is due to the natural conditions of the river, which from Porto Velho to the mouth of the Amazon River is typically a plain river, with no rapids or rock formations that prevent navigation. Here, a caveat should also be made with regard to rock formations, which, during the period of ebb of the river, which occurs between the months of May and October, tend to appear, and which are even causes of navigation incidents.

The main bottlenecks of the Madeira river are listed below:

1) Lack of Investments

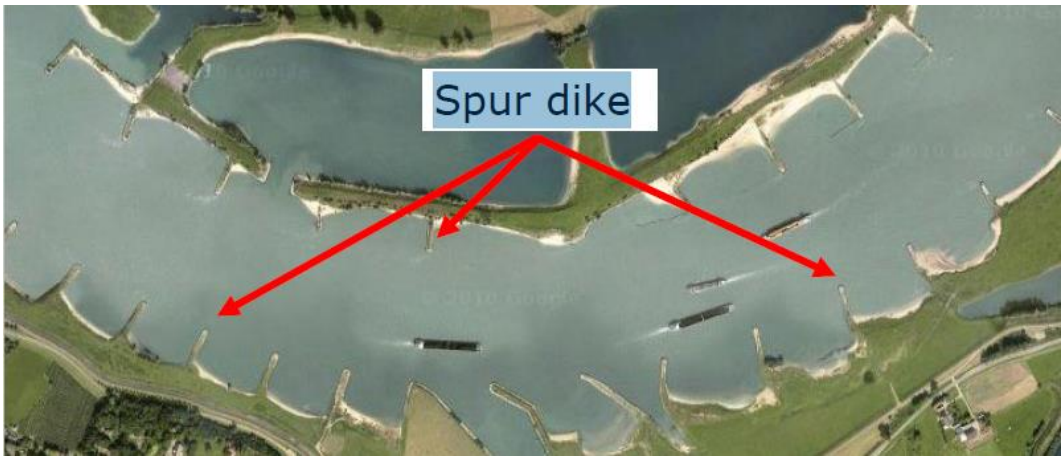
Despite the importance of navigation on the Madeira river, there is a lack of a State policy for the sector. As a result, we do not have, on an ongoing basis, investments in infrastructure, such as signs, beaconing, dredging or rockfall.

In this sense, the Madeira river lacks permanent dredging services, notably during the ebb period, when the level reaches critical points, with dozens of points where vessels suffer passage restrictions, even with a reduction in draft and cargo volume. Dredging services are performed punctually, which is no guarantee that a vessel leaving Porto Velho will reach the mouth of the Amazon river without mishap. Strandings and collisions with stones are constant during this period.

2) Navigation Security

An important issue regarding the improvement of navigation safety on the Madeira River is the implementation of a digital platform that concentrates data such as the height of the water depth of the river, dangers to navigation along the river, meteorological conditions, operating conditions of the system of beaconing and signaling, level of asset security, incident management, traffic ordering and other data that are important to assist the navigator in planning and safely executing the sailing.

FIGURE 6 – SPUR DIKE



Source: Personal Archive

As previously reported, the Madeira river is characterized by a large transport of sediments, which constantly changes the navigation channel. Thus, as possible solutions to make the navigation channel more uniform, it is necessary to maintain the width and depth of the channel through the use of techniques such as the construction of spur dikes and current breakers.

3) Lack of ordering of gold mining in the riverbed

Although prohibited in many places, prospecting activity in the Madeira river bed is commonplace, putting the safety of vessels at risk, which sometimes are unable to navigate due to the accumulation of dredgers operating in the navigation channel. Despite the importance of mining activity for the local society, it is understood that the delimitation of sites for such exploration is crucial, and that the free movement of vessels is guaranteed, safely and with the consequent reduction of the risk of accidents. The problem takes on dimensions that exceed normality, if we consider that more than 4.000 mining dredgers operating between Porto Velho and the mouth of the Amazon river have already been identified.

FIGURE 7 – GOLD MINING DREDGERS ALONG MADEIRA RIVER

Source: Personal Archive

4) Acts of Piracy – Absence of security forces on the river

Different from what happens on a highway or even in the streets of a city, where police forces permanently act in a preventive and repressive way against theft and theft of vehicles and cargo, on the Madeira river there is an absence of police force action, leaving free and fertile space for criminal groups to act. Assaults on vessels, crews and cargo thefts are recurrent.

5) Training of waterways' specialists/workers

By law, the Brazilian Navy has the monopoly to train manpower for the sector. The Brazilian Navy, in this context, promotes professional training in two centers, one in Belém (PA) and the other in Rio de Janeiro (RJ). It happens, however, that the number of graduates is far below the need. There is a clear gap between the modernization of the vessels and the knowledge of the crews. The ideal would be to allow teaching institutions to promote the qualification and training of professionals, as is the case in the airline industry, where aeroclubs train pilots; or as in the road sector, where driving schools train drivers, as well as the SENAT (National Transport Learning Service) also perfects and trains professionals, the same could be developed at least for river/inland navigation.

6) Bureaucracy

The excess of bureaucratic demands is one of the factors that stifle water transport. There is a State interference that is responsible for the pace of its transactions, which is still regulated by numerous provisions, some considered obsolete and that do nothing to optimize operations. In addition, there is an excess of norms and regulation, with the activity being subjected to the scrutiny of various regulatory agencies and state bodies, both at the Federal and State levels.

7) Transposition of trunks

The Madeira river gets its name because of the amount of wood trunks that are carried by its waters, especially in the flood season, when the force of the water rips off pieces of ravines and carries trees of all sizes in its current. Since the beginning of the formation of the reservoirs of the Jirau and Santo Antônio (Hydroelectric plants – HPP), these wooden trunks are segregated with the aid of a log boom, and from time to time the trunks are released. The problem faced is due to the fact that the release of trunks, when it occurs, is done without any notice and in huge quantities, causing incidents in port facilities installed downstream of the Santo Antônio HPP, as well as with vessels, including a history of collisions and shipwrecks. As a suggestion, instead of releasing the trunks retained in the dams downstream, that they be removed, processed and benefited on site. For this, an environmental law needs to be approved by the National Congress.

8) Institutional Environment

Waterway transport in Brazil requires actions of an institutional nature, aimed at unlocking the sector through the improvement of its operating rules, as well as the centralization of a public institution as a waterway authority in order to emanate the sector's development guidelines. These actions can only be implemented with the effective action of the Public Power in its various spheres.

The excess of bureaucracy and the high tax burden, combined with the high logistical cost, prevent growth and make the contribution of new resources unfeasible. For there to be a constant expansion of the sector, which accompanies the growth of Brazilian commodities, changes are necessary to guarantee the security of investments and the continuous growth of the sector. In this context, the guarantee of the end of charging for the use of the reflecting pool stands out. This tax, instituted by Ordinance n.404/2014, from the *Secretaria de Patrimônio da União* (SPU), has already been considered illegal by the Judiciary. However, for legal certainty, it is necessary that the prohibition of collection be included in Law n.9636/1998, which provides for the regularization, administration, leasing and disposal of real estate owned by the Union.

The main input to leverage Brazilian inland navigation and help improve the country's cargo logistics requires a reduction in its value. As a solution, the State must guarantee exemption from ICMS tax for fuel used in inland and cabotage navigation, following the example of what is foreseen for long-haul navigation in Law n.9432/1997.

Agility in the analysis of environmental license processes must be part of the government's priority agenda for the growth of the national port infrastructure. The great plurality of environmental agencies hinders the agility of the undertakings and, to a large extent, makes the progress of works for long periods unfeasible. It is necessary that the port bottlenecks are solved for the waterway to grow. As a solution, it is proposed to unify the procedures of the licensing environmental agencies.

9) Cargo Terminals

Multimodal transport is a logistics solution that enables the best use of modals to increase service efficiency by optimizing support activities, storage and cargo handling, making operations more efficient and sustainable.

In this sense, the terminals are essential for the coordination of the logistics chain, as they allow the connection between modals, in addition to offering space for transhipment operations, cargo storage, and this can reduce the cost of companies and industries.

There is a need to modernize the berthing infrastructure, storage structures, equipment for handling cargo and utilities (supply of water and energy, among others) of the port facilities that make up the main port complex on the Madeira river located in the city from Porto Velho.

As a solution to this, it is proposed the installation of multimodal terminals at strategic points for the integration of the transport system between the two modals used in the region, waterway and road. In addition to a correct sizing of the terminal area in order to prepare for the growth perspectives foreseen by the projections, as well as the construction of parking areas for cargo vehicles.

7. FINAL CONSIDERATIONS

Waterway transport on the Madeira river is essential to ensure trade between the main ports in the Amazon Region, with a direct relationship between regional economic growth and the demand for transport across the river, which is the means of transport that provides the best relation cost-benefit for users and positive externalities for society.

It should be noted that the Madeira river is important for regional development, as boats are the main transport for riverside populations. It is located in an area of dense vegetation, therefore, water transport is presented as a less aggressive modal, not only because it emits less greenhouse gases, but also because it represents, in some way, an alternative for the transport of local communities, which reduces the need to build new highways and their larger environmental impacts.

However, there is a small presence of the State in this region of the extreme west of Brazil, as well as the lack of policies to encourage water transport. Among the issues identified that mitigate its development are port inefficiency, high bureaucracy, lack of investment, mining, piracy, toothpick holders and inadequate infrastructure for navigation.

As raised in this work, the Brazilian State needs to invest in improving the navigability of the Madeira river mainly through civil works. These include the demolition of boulders to allow navigation during the dry season. In addition, activities such as dredging and channel regularization are necessary to mitigate and avoid the problems of sediment accumulation along the river, especially during the dry period. Since the problems of sediment accumulation are dynamic, an updated signaling system is necessary to guarantee the safety of navigation.

Considering the various points discussed above, it is understood that it is possible to transform the Madeira river into a waterway, with clear products and services for road users, and thereby optimize the economic, social and environmental performance of the entire context encompassed by the region of influence of the Madeira basin. It is, currently, nothing more than a navigable river with little investment and attention from the state. It needs to be discussed a State policy in Congress and not a government project, which changes once a new President/Coalition takes the power. There is a need to have a regulatory agency leading, coordinating and promoting the development of navigable rivers to make them a waterway that aims to reduce and mitigate the existing problems of each river / waterway in favor of the development of society, economics and the environment. Finally, we understand that this is the first and most important step that needs to be taken, which is the regulatory framework for waterways in Brazil and, from it, other options will emerge such as concession or privatization, that are not the aim at the point we are currently.

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