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Sustainability of Passenger Waterway Transportation under Demand and Service Level Constraints: A case study in Belém, Brazil

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***Abstract*— Waterway transportation is a very ancient mobility solution. Amazon region represents a good case study, where waterway transport played and is still playing a very important role. Nevertheless, passenger waterway transportation lacks economic models that help in designing and implementing strategies towards sustainability. In this work, a cost model of passenger waterway transportation was developed based on the assumptions of activity-based costing and used linear programming for cost optimization under demand and service level restrictions, with an objective-function of profit maximization of service. The model was applied in a passenger waterway transportation company to three crossings in Belém city - Brazil, for passengers and cargo, and vehicle transportation, operating on trips between Belém and Marajó Island. Different simulations in order to explore the opportunities and conditions of operational cost reductions were made. The search was for the best relation between cost and profit, i. e., model parameters include variable cost, profit and maximum number of possible trips. On results, cost reduction alternatives were established in order to reach the maximum profit and number of trips. The model proved to be useful for the design of sustainable waterway transportation services through the analysis of feasible and effective cost reduction strategies.*

I. INTRODUCTION

Waterway transportation services have been using notably seas and rivers, lakes and canals to transport people where the natural conditions are favorable or where no other alternatives are feasible or represent a better economic solution. Using the water to travel and to transport was the first type of transportation to employ an energy source other than human or animal power; i.e., wind [1]. More recently, the development of the steam engine revolutionized water transportation because the energy source resulted more constant and reliable. In certain regions, waterway transportation systems are still fundamental but face many challenges to be sustainable from several perspectives.

In general, a waterway transportation system is composed of a navigable channel, navigation equipment and an operational plan. Depending on the demand and planning and control restrictions, to which the service is subject, there is a defined operational arrangement, whether for passengers or cargo, and a specific price. Among its main characteristics and advantages, it is seen as a lower cost and less polluting alternative to other transportation systems, with the possibility of wide use in places of water potential. In addition, water has become a vector of penetration and occupation of regions, defining flows by settlement locations and influencing the supply and distribution of cargo, as well as passengers.

Worldwide, cases of waterway transport are notable from various perspectives. In Asia, several studies show the social and economic importance of waterway transportation for the regional development highlighting also operational and service level difficulties. Such studies, typically, focus on descriptive analysis of historical data series [2]-[4]. In Europe, despite the existence of research on waterway passenger transport, approaching particularly modal integration and intermodality in metropolitan areas, studies are more comprehensive in the case of waterway cargo transport, exploring port infrastructure and operational issues. Likewise, the role of public policies and governments is strongly discussed, focusing on sustainable transport development.

Methodologically, analytical methods are among the most used, as well as techniques of data analysis and simulation, which complement econometric methods and economic evaluation approaches [5]-[7]. In North America, characterized by great seaworthy rivers, several surveys studied waterway transportation of passengers and freight, with predominance in terms of modal integration and logistics analysis. Some studies use operational research techniques and descriptive data analysis, and also econometric models and investment appraisal approaches [8]-[10].

Passenger waterway transportation should be understood considering economic but also political, environmental and social perspectives. Brazil can be viewed as a good case study. Indeed, all these perspectives should be considered to have a full understanding of this phenomenon. There are companies of passenger waterway transportation that operate under the regime of public concessions having, in the interstate and international sphere, activities and sales prices regulated by the National Agency of Water Transportation and, in the state sphere, by the Service Regulation Agencies of each State. Considering that, companies of this type can have little influence on the fares and the demand (number of passengers) that make up their passenger billing, due to the regulation, and excluding from this situation the revenues earned from the transport of parcels. Furthermore, due to requirements from the Brazilian Navy, they also have crew scale restrictions, which affect the desired results, and business sustainability.

Particularly, in the Amazon region, companies of passenger waterway transportation performing their activities through public concessions present some economic difficulties. This fact can be verified through the existing competition between the activity of passenger waterway transportation and other modes, such as air transportation for longer distances, which is practicing prices closer and closer to the fares charged in such waterway transportation systems. In other cases, waterway transportation needs to compete also with road connections and the use of private vehicles, particularly in short journeys [11].

Political aspects and options of public policy are also important to understand the context of waterway transportation services. Similarly, to what happened in other towns of the Amazonia region in the middle of the 20th century, the Metropolitan Region of Belém was populated in order to guarantee the political control of the region and waterway transport played a very important role in the social and economic development of the region. However, its importance has declined since the middle of the 20th century due to the advent of road transport, which is the current prevailing mode of transport in the region. As a result, the territorial occupation patterns in the region have changed as well.

Furthermore, the environmental impacts of waterway transport systems might be felt at local level in three dimensions – physical, biological and human. These impacts can have short, medium- or long-term lasting effects that might start right after the new transport system is put into operation. Namely, it might contribute to ease heavy traffic congestion of road transport system and to intensify the socioeconomic activities that are dependent on urban waterway transport. Other benefits include opening of new markets, increased mobility of the islanders because of improved access to transport services, and changes in land use and occupation patterns in the planning areas.

Nevertheless, passenger waterway transportation lacks economic models that help in designing and implementing strategies towards sustainability from both a financial and an economic perspective, i.e., considering both the investors and the society. All economic, social and environmental issues should be taken into account, but such sustainability must begin to be financial, because without viable companies there is no service in free market conditions, public concessions or state-owned industries. Passenger waterway transportation is characterized by restrictions imposed by the market and by law, i.e., from one hand, intermodal competition and market demand in terms of service level; from the other hand, by the existence of a regulatory environment of public concession and institutional restrictions.

In this context, a proper management of costs is of particular importance. However, traditionally, cost models and cost management practices have been focused only on reducing operations costs, in order to keep low prices and gain market competitiveness. Thus, strategic cost management emerges as one of the instruments that can be used to obtain, analyze and optimize the company's costs in accordance with its strategy, the optimized use of resources and the efficiency of activities performed [12]. Traditional costing systems also do not adequately translate the value creation process that relates resources consumed, activities developed and products or services produced for different categories of customers. This reality has motivated the emergence of new costing models, focused on the analysis of the activities that support businesses processes, e.g., such as Activity Based Costing – ABC [13].

Therefore, in this research project, a cost model was developed based on ABC principles namely; assigning resources to the activities and the later to the services provided using proper cost drivers. In an industry were revenues drivers (both number of passengers and price) are conditioned by laws, rules and regulations controlled by several agencies, a good cost management plays a very important role in the sustainability of the business.

Indeed, facing demand and service levels restrictions, cost optimization is indispensable for the sustainability of the service. Such optimization can be supported on simulation models, cost optimization techniques, sensitiveness analyses and searching minimum costs. Different approaches can be undertaken, both deterministic and stochastic. In this exploratory work, a deterministic approach was followed, considering a stability in the system, highly regulated in terms of fares and passenger capacity per trip. The system objective is to maximize the profit and the sustainability of the service provided.

Thus, a linear programming model [14] was developed where the objective-function maximizes the profitability of the waterway transportation services under revenues and cost restrictions, service level conditions and return on investment expectations. The optimization model relies on a cost model that relates resources-activities-services, i.e., resources are consumed by the activities and of later support the different crossings. The mathematical relationships established between these elements through appropriate cost drivers turn the model much more reliable and useful, particularly, for optimization purposes.

This model can help companies and public agencies, in the analysis of the internal cost structure of waterway transportation, towards the design of effective cost reduction strategies, the analysis of potential new markets or new services, to establish new partnerships, to support investment decisions, or to recommend public policies.

The model was applied considering the cost structure of a typical passenger transportation company located in the Amazon River in Belém, State of Pará, Brazil, and three different crossings. From this case study, it was possible to understand the cost structure that support the waterway transportation, namely, the costs of the main activities and of the most relevant cost objects. In order to compute profitability margins, identify cost reduction opportunities and the conditions of competitive advantage related to the different strategic options that can be pursued namely, cost leadership, differentiation or segmentation [15].

The paper is structured as follows. Section 2 presents and discusses the main concepts that supported the development of the cost model and the optimization approach. The case study is presented in Section 3 and the results are presented and discussed in Section 4. The main conclusions, final remarks and opportunities for further research are presented in the last section

II. MATERIAL AND METHODS

The current business environment, which is based on information, requires adequate management tools to manage and measure accurately costs, revenues and performance. In this context, strategic cost management is fundamental to obtain, analyze and optimize the company's costs in accordance with its strategy, the optimized use of resources and the efficiency of activities performed [16]. Strategic cost management consists of the use of cost information to develop and identify superior strategies that will produce a competitive advantage [17].

The use of cost models based on activities proved to be more useful than traditional costing models for the understanding of cause-effect relationships that explain the costs of products and services. The Activity-Based Costing (ABC) method considers that to produce a product or service it is necessary to perform certain activities that, in turn, consume resources. Thus, in an ABC costing system resource costs are assigned to activities, firstly, and such costs are allocated to cost objects using appropriate cost drivers [18].

Cost drivers are fundamental in this approach because they represent the cause-effect relationship between resource use, activity performance and cost objects [19]. The information extracted from the ABC model allows us to identify activities that add value and those that do not the latter could be reduced or eliminated; without compromising, the value created from the customer perspective [20].

The ABC method seeks to answer which activities are being executed by the organization; how much does it costs to be executed; and, how much of each activity is necessary for the products and services, considered as cost objects. In short, in ABC, the cost of a product or service results from the sum of the direct costs and the cost of all the activities necessary to produce the product or service [21]. The ABC is applied through two main steps: the first, in which the costs of resources consumed are allocated to the various activities of the organization.

In this step, resource drivers are used to distribute the costs consumed over more than one activity. Second, the costs of the activities are allocated to the cost objects based on their consumption of the activities. This allocation is done using activity cost drivers. Finally, direct costs are added to the cost objects in order to compute the total cost of the product or service. The use of ABC provides relevant information for both operational and strategic cost analysis, identifying what generate costs, and helping in the design of plans towards reducing total costs in a sustainable manner.

There are just a few works on cost and economic models and economic analysis in waterway transportation, and some a literature review on waterway transportation modelling through case studies [22]. In some studies, environmental, social, economic, financial, operational and technical aspects were considered. Waterway transportation has been analyzed using the cost-benefit analysis method and the Analytic Hierarchy Process [23]-[24], and Monte Carlo simulation, using dynamic and linear programming [25].

Some studies made the evaluation of investments considering the cash flow and sensitivity analysis [26]-[27]. The use of these different methods depends on the reliability of the data available and of the independent and dependent variables used. In this work, the passenger waterway service cost model was structured as it is presented in TABLE 1.

Table.1: Key-elements of the activity-based costing model

Resources	Cost accounting information was obtained from a typical waterway company for the years 2017, 2018 and 2019, in a monthly basis; namely, equipment depreciation, salaries, cleaning and security, electricity, fuel, maintenance, etc.; some resources were assigned directly to the respective activity and other were allocated to several activities, according to the consumption relationship resource-activity, having as main resource cost driver the fuel consumption, because this one is highly correlated to the number of journeys, nautical miles traveled, maintenance expenses, etc.
Activities	Activities were classified as primary, directly assigned to the cost objects and secondary or support activities, which were allocated to the other activities. Activities' costs were allocated to the crossings considering the number of journeys made.
Cost objects	Documents analysis, on-site observations and interviews allowed to identify the most relevant costs and respective cost drivers; only the crossings were considered cost objects; direct resources (e.g., fuel consumption was allocated directly to the cost objects) and indirect costs were allocated through the activities.

Source: authors (collected from the company).

Thus, the cost model us built on the principles of ABC turning it more sophisticated, accurate and relevant for decision making, than previous models used in this context. The deterministic use of the cost model allowed us to compute the costs and margins by cost object, overall profitability, return on investment and to analyze the cost structure and value creation process relating resources, activities and cost objects. An optimization model can be used for cost optimization purposes and profit maximization through the analysis of cost reduction opportunities and potential strategies as well as the global impact of such changes in the service under certain constraints. The use of ABC allows an effective strategic cost analysis of the business processes, identifying the relevant cost drivers and the cause-effect relationships, which help decision makers to know where and how much can be reduced in total costs in a sustainable manner.

On the other hand, Linear Programming (LP) provides the simulation of scenarios under certain restrictions, in order to seek the best use of resources. Some studies on transportation were found using Linear Programming (LP): to optimize operational arrangements of transport system components [28]; in multi-objective routing problems of vehicles [29] and in the analysis of performance improvement opportunities [30]. Recently, in urban transport networks studies [31] and for exploring challenges and opportunities of sustainable development of logistics networks [32].

Linear programming model belongs to the mathematical programming field that supports the optimization (maximization or minimization) of one or multiple objectives, which can be linear or non-linear [33]-[35]. Linear programming, in general, is the simplest case to solve in mathematical programming. A linear programming problem is described by linear functions of decision variables. Nonlinear programming is very common in practical cases, being composed of an objective function, general restrictions and variables, where at least one function is nonlinear, which can be the objective function or one of the restrictions.

$$\begin{aligned} &Max \quad z = c^T x \\ &s.t. \quad Ax = b \\ &x \geq 0 \end{aligned} \tag{1}$$

Where *A* is a matriz *m x n*, (all linearly independent lines). Wet can decompose vector c into its basic and non-basic components, $c = (C_b, C_R)$, assuming that the existing viable basic solution is represented by a vector $\bar{x} = \begin{pmatrix} B^{-1} \\ 0 \end{pmatrix}$, whose associated value is given by the:

$$z_0 = c\begin{pmatrix} B^{-1} \\ 0 \end{pmatrix} = (C_B, C_R)\begin{pmatrix} B^{-1}b \\ 0 \end{pmatrix} = C_B B^{-1} b. \tag{2}$$

We can present the vector x, depending on the basic and non-basic variables, as follows:

$$\bar{x} = \begin{pmatrix} x_B \\ x_R \end{pmatrix} \quad e \quad b = Ax = Bx_B + Rx_R \tag{3}$$

Multiplying by B^{-1} the expression of z_0 is given by

$$\begin{aligned} x_B &= B^{-1}b - B^{-1}Rx_R \\ &= B^{-1}b - \textstyle\sum_{j\in J} B^{-1}a_j x_j \end{aligned} \tag{4}$$

In this way, we can rewrite the expression. $z = cx$, as follows:

$$\begin{aligned} z &= cx \\ &= c_B x_B + c_R x_R \\ &= c_B\left(B^{-1}b - \textstyle\sum_{j\in J} B^{-1}a_j x_j\right) + \textstyle\sum_{j\in J} c_j x_j \\ &= z_0 - \textstyle\sum_{j\in J}(z_j - c_j)x_j \end{aligned} \tag{5}$$

Where $z = c_B B^{-1} a_j$ for each non-basic variable.

The convergence criterion considered for the model is:

$$z - \hat{z} = (c_R^T - c_B^T B^{-1})x_R > 0 \tag{6}$$

$$\bar{R}_k = B^{-1}R_k \;\; e \;\; x_{R,k} = min\left\{\frac{\hat{x}_{B,i}}{\bar{R}_{k,j}}, \;\; \bar{R}_{k,j} > 0\right\} \tag{7}$$

III. CASE STUDY

The case study was developed in a company with three crossing services by waterway transportation in the Metropolitan Region of Belém, for passengers and cargo, and vehicle transportation. The services are the following:

1. Belém-Camará crossing: daily frequency passengers´ service, authorized by state entity. The crossing is of 30 nautical miles long and it can be used two different equipment: a ship for 600 passengers and a boat for 137 passengers. There is a competitor company with similar equipment and, another one, which operates in this crossing with a ferryboat.
2. Belém-Arapari crossing: daily frequency, transport of passengers' vehicles and cargo, authorized by state entity. The journey begins in the south bank terminal of Belem and ends at the Arapari terminal, in the southeast of the State of Pará. The crossing is 10 nautical miles long and it can be done using two types of equipment: a pusher and a ferry, which adds up to an average of 50 standard capacity vehicles. There are three companies competing in this crossing.
3. Belém-Cotijuba crossing: daily frequency, for the transportation of both passengers and cargo, through a concession contract with the Belém City Hall. The crossing is 10 nautical miles long with one equipment: a ship for 350 passengers.

The company also has a replacement equipment, a ship for 238 passengers and, shares a ferryboat as replacement equipment with three other companies that operate in the Belém-Arapari crossing. The three crossings have some specific resources and share some operational and administrative resources, too. The mission of the company is to meet the needs of the demand efficiently, at the lowest possible cost. Fig. 1 shows the different crossings.

The empirical study was made in three different phases. A documental analysis phase was carried out for the general characterization of the company and the services offered, and data about the cost structure was obtained to identify the value chain of the service and the resources employed. At this stage, empirical observations of the service were made, notes were taken of the activities

developed in the various sectors and several interviews were conducted at the company. It was also possible to identify the drivers of the activities and the structure of the value chain. A reasonable level of aggregation was also sought, considering the difficulties that defining each activity would bring to the information system.

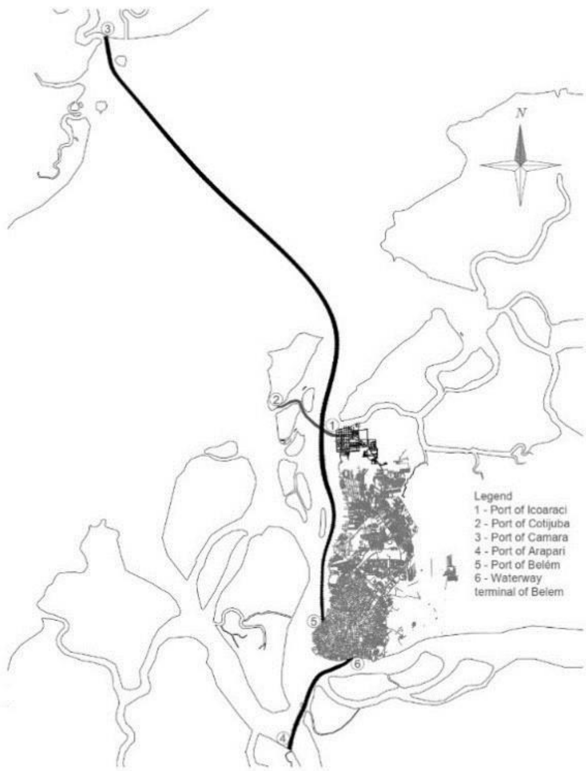

Fig. 1 Caption: map of Belém metropolitan region and Marajó Island, both in Brazil, at the mouth of Amazon River with the Atlantic Ocean. The legend identifies six ports: number 1 – Port of Icoaraci; number 2 - Port of Cotijuba; number 3 - Port of Camará; number 4 - Port of Arapari; number 5 - Port of Belém and; number 6 - Belém waterway terminal. The figure shows the waterway transport routes from Belém (from port number 1) to the Port of Camará at Marajó Island (port number 3), with interconnection with another waterway transport route from the Port of Cotijuba, number 2. It also depicts the waterway transport route connecting number 4 and 5 ports.

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In sequence, there was a second phase, composed by interviews conducted with the company's employees, since the experience acquired can provide reasonable estimates of the consumption of resources by the different activities, as well as to establish the cause-effect relationship between the consumption of resources and their activities. Finally, defined the activities, the resources that each activity consumed were allocated to them.

In an interview with the company's board of directors, the following main challenges were identified:

- The out-of-date tariff for the Belém-Camará and Belém-Arapari crossings, in the last 20 years, and without any perspective of adjustment by the regulatory agency;
- The high rate of seasonality of the service, where only in two months of the year it is possible to have the capacity filled;
- The large number of equipment of competitors in the Belem-Camará and Belém-Arapari crossings and, in the Belem-Cotijuba crossing, and the competition from informal transport;
- Shortage of skilled labor;
- Conflicts of operational nature and financial adjustment with competing companies;
- Inefficiencies resulting from predominantly family-based management models without professional management.

Indeed, it is challenging for companies operating in this context. There is a revenue growth restriction, because the government regulates the tariff and, costs are committed by the seasonality of the demand – the company in only two months of the year operates at full capacity. Cost drivers are miles travelled and the type of equipment used, both impact in the fuel consumption, the main variable cost. Labor costs are also important but are mainly fixed costs.

The optimization of both fixed and variable costs asks for continuous improvement, conversion of some fixed costs in variable ones, and expense reduction; as well as, optimization of the number of journeys and the reduction of idle capacity, sharing resources or using such available capacity (e.g., in terms of maintenance) to perform other activities that can result in additional revenues. The restrictions in terms of demand (both quantity and price) does not allows increasing revenues, thus profit maximization implies a cost optimization approach.

IV. RESULTS AND DISCUSSION

The analysis of the case study was initially done by modeling the cost structure, following the principles of ABC. Subsequently, a cost optimization analysis was made using a linear programming model. A sensitivity analysis and several simulations were carried out for the three crossings. There are two companies operating in the Camará crossing, four companies in the Arapari crossing and only one company operates the Cotijuba crossing.

4.1 Cost model

Considering the passenger waterway transportation cost structure presented in Section 2, it was collected information on the costs of the resources that support the crossings, as well as, the cost drivers for each activity. Finally, once the costs of the activities were computed, they were allocated to the cost objects (i.e., the three crossings), for the years 2017, 2018 and 2019. The activity costs, which were assigned to the crossings, were computed in a monthly basis and on average per year, as shown in TABLE 1. TABLE 2 shows that fleet maintenance and equipment operation activities are the main primary activities and, the maintenance of the company headquarters the secondary activity that consumes more resources. Fleet maintenance and the maintenance of the company headquarters are activities explained mainly by labor costs and costs related to the equipment operation, being fuel consumption costs the most significant one. Camará crossing has higher costs in all activities as shown in TABLE 3.

It is important to point out that transportation services ask for a considerable amount of resources and direct costs, particularly fuel and labor, and the main cost driver for these activities is nautical miles. Likewise, maximum revenues were obtained considering the number of journeys established by the State Regulation Agency, which regulates the service. Furthermore, demand seasonality turned possible to calculate the revenues per month. TABLE 4 shows the *status quo*, highlighting the average monthly profit. Notice that Camará crossing presents a negative profit. This situation leads the company to have losses of US$ 508,30 per month. Since revenues cannot be increased and the number of journeys cannot be reduced significantly, there is a need to reduce costs and increase the profit margin to achieve the desirable return on investment, which is considered in the industry to be around 10% of the revenues. This situation leads to an optimization model of profit maximization through cost reduction strategies.

4.2 Optimization model

A scenario of 10% overall and by journey profitability over the total revenues was set up and the maximum allowed average costs for each crossing was established. Fuel costs, which are variable and dependent on the number of journeys, were also considered. The results are presented in TABLE 5. Camará and Arapari crossings have similar costs, excepting depreciation costs, since the company operates with ships in the Camará crossing and with a ferryboat in the Arapari crossing.

Table 2: Activities costs per crossing on average per month (values in US$)

	Operational	Primary Activities Costs		
		(1)	(2)	(3)
1	Administrative support at the port	4,904.42	3,433.10	1,471.33
2	Ticket Sales (ticket manufacture/refund/distribution and card costs)	5,005.99	5,074.76	3,113.41
3	Release of the fleet and crew (equipment preparation and crew scale)	1,337.72	192.67	79.89
4	Fleet maintenance (personnel/storage and equipment)	7,374.20	6,052.13	2,669.43
5	Equipment operation (inputs and crew)	45,555.70	24,501.62	10,093.89
6	Equipment operation (depreciation)	4,468.20	3,025.79	745.03
	Non-operational			
1	Advertising and marketing	269.01	63.32	40.47
		Secondary Activities Costs		
1	Maintenance of the company headquarters	6,022.59	4,618.17	2,176.50
2	Administrative Activities	3,351.18	2,345.83	1,001.28
3	Accounting and Finance Services	103.85	103.85	103.85
4	Other Activities*	7,480.72	4,815.02	2,202.63

*Other Activities: pro-labore board, company advertising, bank/loan charges/employer's union monthly fee.
Crossing (1) – Belém – Camará; Crossing (2) – Belém – Arapari; Crossing (3) – Belém – Cotijuba.
Source: authors (collected from the Company).

Table 3: Current scenario - monthly financial results (values in US$)

Crossings	(average by month)			
	Revenues	Journeys	Costs	Profit
Camará	71,258.14	112	85,873.59	14,615.45
Arapari	67,891.36	231	54,226.25	13,665.11
Cotijuba	24,139.74	123	23,697.70	442,04
Total	163,289.25		163,797.50	-508,30

Source: authors (collected from the Company).

Table 4: 10% Profit scenario (values in US$)

	Operational	Primary Activities Costs (on average per month)			
		(1)	(2)	(3)	Resource Costs
1	Administrative support at the port	14,84	11,96	43,72	9,808.85
2	Ticket Sales (ticket manufacture/refund/distribution	21,94	25,32	44,63	13,194.16
3	Release of the fleet and crew (equipment preparation	0,83	0,65	11,92	1,610.28
4	Fleet maintenance (personnel/storage and equipment)	26,16	21,71	65,74	16,095.76
5	Equipment operation (inputs and crew)	43,05	60,81	137,54	32,865.50
6	Equipment operation (depreciation)	13,08	6,06	39,83	8,239.02
	Non-operational				
1	Advertising and marketing	0,27	0,33	2,40	372,80
		Secondary Activities Costs (on average per month)			
1	Maintenance of the company headquarters	19,96	17,70	53,69	12,817.27
2	Administrative Activities	10,14	8,14	29,88	6,698.29
3	Accounting and Finance Services	0,45	0,84	0,93	311,56
4	Other Activities	20,81	17,91	66,69	14,498.37
	Maximum Cost	234,41	192,71	765,59	146,960.32
	Fuel	62,86	21,27	268,60	47,285.71

Crossing (1) – Belém – Camará; Crossing (2) – Belém – Arapari; Crossing (3) – Belém – Cotijuba

Source: Authors (collected from Company under study).

Table 5: Optimization scenarios, maximum profit and number of journeys

Simulations	Constraints	Maximum Profit (US$)	Journeys		
			Camara	Arapari	Cotijuba
1	With 10% profit, considering information presented in Table 4 date and the PL model.	14,931.77	90	231	120
2	Considering the sensitiveness analysis made in the first simulation, and a cost reduction in Camara crossing,	16,269.41	110	231	120
3	Cost reductions in all crossings, proportional to the weight of activity costs in each crossing.	16,161.44	110	231	123
4	No cost reductions, sharing the costs of Administrative support at the port and Fleet maintenance in the Camara	16,008.62	107	231	120
5	Cost reductions in the Camara Crossing and sharing the costs of Administrative support at the port and Fleet maintenance in the Camara crossing (with two	16,266.66	111	231	123

Cotijuba crossing, with the highest monthly costs, is made with only one ship, having a low frequency of journeys (only two journeys per day). The service is still subsidized and operated by just one company.

The LP model used in this work was defined as follows: the objective-function (*z*) considers the maximization of the profit of the company; the decision variables x_1, x_2 *and* x_3 are the number of journeys of the three crossings: Camará, Cotijuba and Arapari, respectively. The restrictions consider the costs of the different activities and direct costs (i.e., fuel consumption); c_i represents the profit coefficients vector for each journey; a_{ij} the coefficients´ matrix and b_i the vector of the coefficients available for each restriction. The resources available for each activity are presented in the last column. From these results, it was developed a linear programming model presented in Eq. (8).

$$\text{Max } z = 63{,}53x_1 + 19{,}3x_2 + 19{,}63x_3 \quad (8)$$

$$\begin{aligned}
\text{s.t. } 43{,}72x_1 &+ 14{,}84x_2 + 11{,}96x_3 \le 9{,}808.85 \\
44{,}63x_1 &+ 21{,}94x_2 + 25{,}32x_3 \le 13{,}194.16 \\
11{,}93\,x_1 &+ 0{,}83x_2 + 0{,}65x_3 \le 1{,}610.28 \\
65{,}74x_1 &+ 26{,}16x_2 + 21{,}71x_3 \le 16{,}095.76 \\
137{,}54x_1 &+ 43{,}05x_2 + 60{,}81x_3 \le 32{,}865.50 \\
39{,}83x_1 &+ 13{,}08x_2 + 6{,}06x_3 \le 8{,}239.02 \\
2{,}40x_1 &+ 0{,}27x_2 + 0{,}33x_3 \le 372{,}80 \\
53{,}69x_1 &+ 19{,}96x_2 + 17{,}70x_3 \le 12{,}817.27 \\
29{,}88x_1 &+ 10{,}14x_2 + 8{,}14x_3 \le 6{,}698{,}29 \\
0{,}93x_1 &+ 0{,}45x_2 + 0{,}84x_3 \le 311{,}55 \\
66{,}69x_1 &+ 20{,}81x_2 + 17{,}90x_3 \le 14{,}498.37 \\
756{,}59x_1 &+ 234{,}41x_2 + 192{,}71x_3 \le 146{,}960.32 \\
268{,}60x_1 &+ 62{,}86x_2 + 21{,}27x_3 \le 47{,}285{,}71 \\
x_1 & \le 112 \\
x_2 & \le 231
\end{aligned}$$

After this initial round of cost optimization, five optimization scenarios were simulated (TABLE 6). In order to find these reductions, several simulations were made seeking the best relationship between cost and profit.

Parameters include variable costs, profit and maximum number of possible trips.The simulations 2, 3 and 5 resulted in the best relations between the maximum profit and the largest number of trips. It was possible to establish cost reduction alternatives, keeping values very close to the maximum profit and the number of trips, so that the company could assess which of these would be better, or easier to be carried out. Since Camará crossing is the one that presents the highest costs, it received most of the attention of the cost reduction analysis. From Table 6, we can observe that Simulation 5 is the one that fits better the required level of service, defined by the Regulatory Agency. It also offers the best level of profitability.

Table 6: Reduced cost per activity for Camará, Arapari and Cotijuba crossings (in %)

	Operational	Simulation 2	Simulation 3 (1)	Simulation 3 (2)	Simulation 3 (3)	Simulation 5
	Primary Activities					
1	Administrative support at the port	9 %	14 %	9 %	4 %	4 %
2	Ticket Sales (ticket manufacture/refund/distribution	8 %	8 %	8 %	5 %	4 %
3	Release of the fleet and crew (equipment preparation	35 %	38 %	6 %	2 %	9 %
4	Fleet maintenance (personnel/storage and equipment)	22 %	12 %	9 %	4 %	4 %
5	Equipment operation (inputs and crew)	20 %	11 %	8 %	5 %	4 %
6	Equipment operation (depreciation)	1 %	17 %	12 %	2 %	4 %
	Secondary Activities					
1	Maintenance of the company headquarters	21 %	12 %	9 %	5 %	4 %
2	Administrative Activities	25 %	14 %	9 %	3 %	4 %
3	Accounting and Finance Services	17 %	6 %	6 %	6 %	3 %
4	Other Activities	25 %	5 %	9 %	5 %	4 %

Crossing (1) – Belém – Camará; Crossing (2) – Belém – Arapari; Crossing (3) – Belém – Cotijuba

Cost reductions can be reached by sharing some activities with other companies eventually, competitors. Cost reduction strategies should do not compromise the service level as well as maximizes the profit and the company's return on the investment, globally and by crossing.

V. CONCLUSION

In Amazon region, passenger of waterway transportation companies working under public concessions present some economic difficulties, as the case study presented here. The transportation system is regulated by the government (e.g., tariff and service level in terms of number of passengers per crossing) and the Navy sets some significant costs, such as salaries. Thus, profit maximization is constrained in terms of revenues, what implies a strong optimization of the resources used. Such optimization asks first for an accurate allocation of the costs to the activities because are these which can be optimized through efficient strategies such as, for example, sharing equipment and infrastructure.

The cost structure of the service, namely the relevant activities and resources, and respective cost drivers was analyzed considering three years of operation. Fuel and labour are the most significant resources and nautical miles the cost drivers of most activities. There is a cross-subsidy between crossings. However, some facts interfere in this regularity; whether punctual or derived from demand characteristics. For example, due to the seasonality of demand, which only peaks in two months of the year (July and December), implying that equipment are fully used in only two months of the year.

The seasonality of the service is a problem that might be mitigated with more passengers in high season periods, in order to cover the low season. In addition to seasonality, the company faces competition, which further contributes to an over-supply of the service, and to the existence of an operational deficit. In addition, this deficit is also due to the tariff gap, because fares have not been updated in the last years.

In order to explore the opportunities and conditions of operational cost reductions, simulations were made. It was applied a linear programming model followed the premise of a deterministic approach, considering the stability of the system, highly regulated in terms of fares and passenger capacity per trip. Some aspects can be highlighted: the current business model can be optimized through effective and sustainable cost reductions such as partnerships and collaboration among competing companies, e.g., sharing costs of some activities. Indeed, several costs can be reduced if the infrastructure and land labor (port and maintenance) are shared. Furthermore, there are economies of scale to be explored in the acquisition of resources, particularly, fuel; in which supports Scenario 5.

Finally, there are some research opportunities, which could be explored, e.g., the model and optimization approach developed can be replicated in other similar waterway transportation companies. Further studies could be to developed to extend this research, including the impact of seasonality, risk and uncertainty, or assuming demand seasonality and the analysis of the breakeven point. Operational characteristics as speed and capacity of the boats, which can reduce significantly fuel consumption. Furthermore, it is imperative to study the design of tariff models, which, for example, include the impact of services free-of-charge granted for seniors and students.

The model and approach proposed here extends the previous literature on cost and economic models and economic analysis in waterway transportation and offers a basis for further developments with practical and theoretical relevance. In addition to unveiling a reality present in the Amazon region and other regions worldwide where waterway transportation is important.

REFERENCES

[1] Cutler J. C. & Morris, C. (2014). *Handbook of Energy: Chronologies, Top Ten Lists, and Word Clouds.* (1st ed.). Elsevier Science: Amsterdam. https://doi.org/10.1016/C2013-0-00172-7.

[2] Tuan, A. V. (2011). Making Passenger Inland Waterways a Sustainable Transport Mode in Asia: Current Situation and Challenges. In: *8 Proceedings of the Eastern Asia Society for Transportation Studies*. https://doi.org/10.11175/eastpro.2011.0.23.0

[3] Duan, S., Yu, G., Xing, H. & Wu, Z. (2010). Inland Waterway Transport in China: Situation and Problems. In *ICLEM - International Conference of Logistics Engineering and Management*. https://doi.org/10.1061/41139(387)54.

[4] Li, J. Y., Notteboom, T. E. & Jacobs, W. (2012). China in transition: institutional change at work in inland waterway transport on the Yangtze River. *Journal of Transport Geography*, 40, 17-28. https://doi.org/10.1016/j.jtrangeo.2014.05.017.

[5] Seidenfus H. S. (1994). Inland waterway transport in the federal Republic of Germany: Situation and problems. *Transportation Research Part A: Policy and Practice*, 28(6): 511-515. https://doi.org/10.1016/0965-8564(94)90049-3.

[6] Mihic, S., Golusin, M. & Mihajlovic, M. (2011). Policy and promotion of sustainable inland waterway transport in Europe – Danube River. *Renewable and Sustainable Energy Reviews*, 15 (4), 1801-1809. https://doi.org/10.1016/j.rser.2010.11.033.

[7] Kaup, M. & Łozowicka, D. (2018). The concepts of inland passenger transport in the Oder river basin. *New Trends in Production Engineering*, 1 (1), 349-356. https://doi.org/10.2478/ntpe-2018-043.

[8] IPEA – Instituto de Pesquisas Econômicas e Aplicadas. (2014). *Hidrovias no brasil: perspectiva histórica, custos e institucionalidade*. Brasília: IPEA.

[9] Massara, M. V. (2012). Brief Synopsis of the Brazilian freight and future development. *Journal of Infrastructure Development*, 4 (2), 77-90. https://doi.org/10.1177/097491130612465191.

[10] Tobias, M. S. G., Moraes, H. B. & Figueiredo, N. (2019). The role of ports in Amazonia cities for sustainable urban development: The case of Belem - Brazil. *WIT Transactions on the Built Environment*, 188, 11-21. https://doi.org/10.2495/CC190041.

[11] Castro, N. (2003). *Transporte rodoviário de passageiros: estrutura, desempenho e desafios regulatórios.* Faculdade de Administração da UFRJ. Rio de Janeiro. Retrieved from https://anaiscbc.emnuvens.com.br/anais/article/viewFile/394/394/

[12] Shank, J. K. (1989). Strategic Cost Management: New Wine, or Just New Bottles? *Journal of Management Accounting Research*, 1 (fall), 47-65.

[13] Cooper, R. & Kaplan, R. S. (1991). Profit priorities from activity-based costing. *Harvard Business Review*, 69 (3), 130-135.

[14] Vanderbei, R. J. (2014). *Linear Programming: foundations and extensions*. (4th ed.). New Jersey Princeton. https://doi.org/10.1007/978-1-4614-7630-6.

[15] Porter M. E. (1989). From Competitive Advantage to Corporate Strategy. In: Asch D., Bowman C. (Eds), *Readings in Strategic Management*. London: Palgrave. https://doi.org/10.1007/978-1-349-20317-8_17.

[16] Blocher, E. J., Stout, D. E. & Cokins, G. (2010). *Cost management: A strategic emphasis*. New York: McGraw-Hill College.

[17] Mowen, D., Hansen R. & Heitger, D. (2017). *Managerial Accounting: The Cornerstone of Business Decision-Making.* (7nd ed.). Boston: Cengage Learning.

[18] Kim, J. (2009). Activity-based framework for cost savings through the implementation of an ERP system. *International Journal of Production Research*, 47 (7), 1913–1929. https://doi.org/10.1080/00207540701663508

[19] Cooper, R. & Kaplan, R.S. (1997). *Cost & Effect: Using Integrated Cost Systems to Drive Profitability and Performance*. Boston: Harvard Business School Press.

[20] Baykasoglu, A. & Kaplanoglu V. (2008). Application of activity-based costing to a land transportation company: A case study. *International Journal of Production Economics*, 116, 308-324. https://doi.org/10.1016/j.ijpe.2008.08.049.

[21] Tseng, L. & Lai C. (2007). The relationship between income smoothing and company profitability: an empirical study. *International Journal of Management*, 24 (4), 727-833. https://www.proquest.com/docview/233228753?pq-origsite=gscholar&fromopenview=true.

[22] Assis, T. F., Lopes, D. M. M., Pedro, L. M. & Silva, M. A. V. (2017). Systematic review of feasibility studies on transport: a contribution to waterway transport. *Gestão da Produção, Operações e Sistemas*, 12 (4), 1-31. https://doi.org/10.15675/gepros.v12i4.1728.

[23] Sarkar, P., Mathur, V., Maitri, V. & Kalra, K. (2007). Potential for Economic Gains from Inland Water Transport in India. *Journal of the Transportation Research Board*, 2033, 45–52. https://doi.org/10.3141/2033-07

[24] Rahman, M. A., Jaumann, L., Lerche, N., Renatus, F., Buchs, A. K., Gade, R. & Geldermann, S. (2015). Selection of the Best Inland Waterway Structure: A Multicriteria Decision Analysis Approach. *Water Resources Management*, 29 (8), 2733–2749. https://doi.org/10.1007/s11269-015-0967-1.

[25] Baroud, H., Marquez-Ramirez, J. E., Barker, K. & Rocco, C. M. (2014). Stochastic Measures of Network Resilience: Applications to Waterway Commodity Flows. *Risk Analysis*, 34 (7), 1317–1335, 2014. https://doi.org/10.1111/risa.12175.

[26] Panigrahi, J. K. & Pradhan, A. (2012). Competitive maritime policies and strategic dimensions for commercial seaports in India. *Ocean and Coastal Management*, 62 (11), 54–67. https://doi.org/10.1016/j.ocecoaman.2012.03.008.

[27] Cantasano, N. & Pellicone, G. (2014). Marine and river environments: A pattern of integrated coastal zone management (ICZM) in Calabria (Southern Italy). *Ocean and Coastal Management*, 89, 71–78. http://dx.doi.org/10.1016/j.ocecoaman.2013.12.007.

[28] An, F., Hu, H. & Xie, C. (2015). Service network design in inland waterway liner transportation with empty container repositioning. *Eur. Transp. Res. Rev.*, 7 (9), 1-11. https://doi.org/10.1007/s12544-015-0157-5.

[29] Yan, Q. & Zhang, Q. (2015). The Optimization of Transportation Costs in Logistics Enterprises with Time-Window Constraints. *Discrete Dynamics in Nature and Society, 2015*. http://dx.doi.org/10.1155/2015/365367.

[30] Nyrkov, A., Shnurenko A., Sokolov, S., Chernyi, S. & Korotkov, V. (2017). Some Methods of Increasing the Efficiency of River Transport System. *Procedia Engineering*, 178, 543-550. https://doi.org/10.1016/j.proeng.2017.01.106.

[31] Vakulenko K., Kuhtin, K., Afanasieva I. & Galkin, A. (2018). Proceedings of the Designing Optimal Public Bus Route Networks in a Suburban Area. *Transportation Research Procedia*, 39, 554–564. https://doi.org/10.1016/j.trpro.2019.06.057.

[32] Vilarinho, A., Liboni, B. L. & Siegler, J. (2018). Challenges and opportunities for the development of river logistics as a sustainable alternative: a systematic review. *Transportation Research Procedia*, 39, 576-586. https://doi.org/10.1016/j.trpro.2019.06.059

[33] Dantzig, G. B. (2002). Linear Programming. *Operations Research*, 50 (1), 42-47. https://doi.org/10.1287/opre.50.1.42.17798.

[34] Luathep, P.; Sumalee, A.; Lama , Lam, W.H.K.; Li, Zhi-Chun, Lo & Hong K. (2011). Global optimization method for mixed transportation network design problem: A mixed-

integer linear programming approach. *Transportation Research Part B: Methodological*, 45 (5), June, 808-827. https://doi.org/10.1016/j.trb.2011.02.002.

[35] Datta, D. & Figueira, J. R. (2013). A real-integer-discrete-coded differential evolution. *Applied Soft Computing*, 13 (9), September, 3884-3893. https://doi.org/10.1016/j.asoc.2013.05.001.