



Comparative study for naval repairs using longitudinal slipway or airbags

Giuseppe Melazzo Filho¹, Pedro Igor Dias Lameira¹, Rodrigo dos Santos Saavedra², Tainã Carvalho Garcia Miranda Filgueiras^{3*} and Lucio Carlos Pinheiro Campos Filho¹

¹Faculdade de Engenharia Naval, Universidade Federal do Pará, Belém, Pará, Brazil. ²Programa de Pós-graduação em Engenharia Naval, Universidade Federal do Pará, Belém, Pará, Brazil. ³Programa de Pós-graduação em Engenharia Mecânica, Universidade Federal do Pará, Rua Augusto Corrêa, 1, 66075-110, Belém, Pará, Brazil. *Author for correspondence. E-mail: tai.filgueiras@gmail.com

ABSTRACT. Ship repair has gained prominence as a service offered at the shipyards following a crisis in the shipbuilding industry, which has seen a fall in demand for new constructions, causing many companies in the sector to stall, especially shipyards. For a repair yard to be economically viable, in times of crisis, cost reduction is essential to make a sustainable business, so this comparative study aims to check the technical and economic feasibility of this change in the type of dry-docking. The present work deals with a comparative study between the use of the longitudinal slipway and the airbags for dry-docking and repair of river barges. The study sought to identify data from the vessels used for this project, to verify the average displacement of these vessels to analyze the airbags' carrying capacity, as well as the size of the winch to perform the dry-docking service. Since most repair yards use leased areas, the flexibility achieved with the use of airbags, as well as the reduced need for investments in the area, are benefits provided by using them. This work presented satisfactory results for the use of river barge docking airbags as a competitive alternative in repair services.

Keywords: dry-docking; longitudinal slipway dry-docking; airbags dry-docking; Amazon; river barges.

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Introduction

Ship repair is an industrial practice that consists of replacing or configuring items that are malfunctioning or corroding. The purpose of the repair is to maintain the same structure as when it was built and to offer several services. The importance of ship repair services is directly linked to the shipbuilding itself, because every vessel, after a certain period needs to be reviewed in all its systems, especially to ensure the operational safety of vessels. According to House (2015), the shipbuilding and repair industries are indispensable to each other, and their coexistence within a market such as the Brazilian one is of great value.

Ship repair service is due to international obligations (Boer, Boer, Schutten, & Zijm, 1997). Maintenance on vessels, if not urgent, occurs seasonally, so maintenance periods are planned over the long term. As far as possible, available manpower and dry-docking capacity are taken into account when planning these maintenance periods. It is important to note that ship repair was highlighted as a service offered at the shipyards after a crisis in the shipbuilding industry, which suffered a fall in demand for new constructions, which led to the stagnation of many companies in the sector, especially the shipyards.

Brazil does not have extensive experience in ship repair processes but has a consolidated shipbuilding industry that has been shaped by the transition of the local economy (Ocampo & Pereira, 2019). In this context, repair and maintenance services emerged as an alternative within the naval production chain, so that the maritime market could stay alive (Lacerda, 2003). According to Srdoč, Bratko and Sluga (2007), the vessel repair process is characterized by a high sharing of information that is sometimes incomplete and unreliable at certain stages of the process, therefore, the quality of the repair is influenced by the quality of predefined decisions. According to Celik, Kahraman, Cebi and Er (2009), selecting a suitable shipyard for repairs against many criteria such as ship position, the reputation of the shipyard organization, previous shipyard experience, size of work required, shipyard limitations, yard equipment capacity, among other factors, it is necessary to create a wide range of market research and detailed analysis for a final decision.

Corroborating this, it is necessary to study more efficient dry-docking modes for the region. The most used method today is the longitudinal slipway dry-docking which consists, as the name suggests, of an inclined ramp with fixed rails for the vessel to be removed from the water (Krug, 2012), with this more traditional method being marked by high-cost structure but with great operational experience in the region. Another method used, mainly in Eastern shipyards, is dry-docking by airbags, consisting of a series of industrial airbags arranged over calculated distances, in turn, this methodology does not require a large expense in construction, being, at the same time, safe and easily absorbed.

In this context, the shipyards located in the Amazon region stand out for their privileged position. The Amazon basin patents the largest basin in the world, drained by a river and its tributaries, discharging about one-fifth of the global freshwater supply annually (Kunert et al., 2017; Lameira, Filgueiras, Botter, & Saavedra, 2020; Wohl, 2007). Thus, Amazonian navigation is strategic not only for its efficiency but also for the effective and natural availability that the region delivers. It is also possible to see that the region provides a strategic link with the rest of the world through its waterways and navigable rivers that are close to the European continent, North America, and the Panama Canal. Therefore, ship repair carried out by a shipyard located in this geographical position represents for vessels speedy completion of services and, consequently, a shorter return to operation, a factor that is of significant interest to ship owners or shipowners.

Given the above, this comparative study aims to analyze the possibility of replacing the traditional dry-docking method used in the Amazon region, the longitudinal slipway dry-docking, with dry docking by airbags, preliminarily checking the technical feasibility and analyzing the resulting savings from this change in the type of docking seeking to raise issues such as the transport capacity supported by the airbags and whether it will be more advantageous to exude such a replacement.

To develop the analysis of this research, we identified the data of the vessels used for this study, the average displacement of these vessels to analyze the airbag loading capacity, as well as the sizing of the winch to perform the proposed dry-docking. Finally, economic comparison analyzes will be made between the two types of dry-docking.

Material and methods

Given the above, this research aims, from a technical-economic evaluation, to validate the replacement of the dry-dock method for repairing barges, the method that is currently the most used in the Amazon region, by the method of dock through longitudinal slipway, with the aid of airbags. In addition, this paper focuses on comparing the two methods, using a technical-economic evaluation, in order to define the most suitable docking method to be used for repairs of river barges in the Amazon region. Therefore, this study will bring an investigation of the minimum necessary to implement a perfect technical operation of dry docking methods through longitudinal ramps and airbags, comparing the capital necessary for its implementation and maintenance.

Background

Globalization affects companies in many areas. However, in the area of shipbuilding and repair, global competition compels managers to adapt strategies and positions around markets to maintain continuous operations. The identification of companies' core and middle activities became fundamental in this process.

According to Pintelon and Parodi-Herz (2008), repairs are an important contributor to the intended lifespan of technical capital assets, and repairs are defined as any activity aimed at maintaining a system or restoring it to a condition deemed necessary for acceptable operation. Understandably, capital-intensive and technologically advanced systems (such as trains, ships, and airplanes) have a projected lifespan of at least 25 years (Goossens & Basten, 2015) but when it comes to river barges, the life of properly maintained systems tends to project at least 50 years.

Docking is an activity that needs great attention at the time of your procedure, even if the activity performed is simple. According to Gong, Frangopol and Cheng (2019), the unending inactivity of a vessel entails significant environmental damage as well as major economic loss. As for barges, corrosion from metal loss is a relevant concern for the safe navigation of older vessels. To maintain satisfactory integrity, it is ideal that these barges are dry-docked for inspections at least twice within 5 years.

Dry-docking is usually an expensive process and represents a high maintenance cost over the life of Amazonian vessels (Hansen, 2013). This type of dry-docking can adversely affect the operating schedules of

inland shipping companies, putting vessels out of service. This procedure can be performed for various purposes, in which treatment and cleaning services of the vessel, classifier inspections, replacement and repair of parts are performed, among others. According to Boer et al. (1997), The search for the repair of vessels is due to two factors: A mandatory factor, due to the inspections required to protect the useful life of the vessel that are made periodically, or due to damage to the structure of the vessels, either by accident, breakages or collisions, which generate the need for emergency repair.

In this context, the ship repair industry in Brazil has taken an important stance in the face of the fall of shipbuilding in the country. However, this repositioning for the maintenance and repair market still corresponds to a small portion in the naval sector compared to the construction market.

Dry-docking methods

Dry-docking through longitudinal slipway

According to Krug (2012), the longitudinal slipway dry-docking method is defined as a fixed pile-up ramp, which is inclined from the water to the ground of the ground where the repairs are to be made. Nowadays, this is the most used method for dry-docking and launching vessels and barges in the Amazon region.

Wiek (1981) reports that this method utilizes a mobile or fixed boat ramp apparatus comprising a structure with means for supporting a vessel. The structure is supported for central movement between a horizontal position when the vessel is supported and a tilted position to facilitate docking or launching through the ramp into or out of the water. This frame is mounted to be freely rotated about support axes, including a blade mounted for longitudinal movement along the length of the ramp.

Dry-docking through airbags

Airbags, made of reinforced rubber, are widely used for cargo transportation and their use is very efficient in dry-docking vessels through longitudinal ramps (Rashkovskiy, 2014). Sugeng et al. (2020) says that the use of airbags is based on changing the rolling frictional force on the airbags. It is important to note that the rolling coefficients of airbags and soil depend on the soil situation and rolling forces applied to airbags, so sandy soil such as Amazonian soil is ideal for using the method.

Airbag dry-docking and airbag launching is a technique that is becoming increasingly popular in the shipbuilding industry. This is due to the overcoming of the restrictions imposed in the most traditional dry-docking methods. The increasing use of this method by yards is strictly based on its economic advantages, high flexibility, and excellent safety.

This dry-docking method simplifies vessel preparation and docking technology work. Their use is sometimes synonymous with reduced maintenance costs due to small ramp reconstructions, making the method highly sustainable, allowing to control the docking speed of the vessel and providing a safe and reliable process. Another significant advantage of this is the low requirements for the ramp surface (metal, concrete, wood, shrapnel, sand), which allows a great economy compared to the means of reconstruction of the vessel's construction zone.

Following the line of reasoning of Rashkovskiy (2014), the rolling friction of the dry-docking airbags is much lower compared to the slipway friction, indicating that there is a need for a lower inclination for method application. As a benefit, compared to the longitudinal slipway dry-docking method, airbags have a smaller contact area with the bottom of the ramp, making the runway less pressure during docking. This factor culminates in a higher carrying capacity than a traditional ramp, and can also save on the investment made to build the ramp.

Other types of dry-docking

The method known as drydock is the most basic form of the docking technique, where the ship is maneuvered into the dock and rests on the beams, where the gates are closed and water is released from the ship. According to Harris (1945), These dikes are built on land near the mooring area, using concrete to construct walls, blocks, and gates.

Floating dikes, in turn, are used specifically for vessels that have been damaged in the middle of the sea or any type of operation. Korotaev, Pantiushin, Serikova and Anisimov (2016) say in his work that this docking method uses a U-shaped structure that, filled with water, submerges the dike helping the vessel dock. Once

the vessel is protected and brought into the repair area, water is pumped out of the structure, causing the dike to rise and expose underwater parts of the vessel. Both methods do not have widespread employability in the Amazon region.

Study area

As said by Lameira, Braga and Moraes (2015), The most commonly used barge model in rivers inserted in the Amazon basin region is the so-called 'Mississippi type' whose main characteristics are demonstrated by the Table 1. This definition is determined by the restriction of the Amazonian waterways, which have locks whose internal dimensions are 210m x 33 m, the main factor in determining the main design dimensions of the barges that traverse these routes. The pusher craft and barges are classified as river convoys because their configuration allows several unpulsed barges to be coupled to a boat that moves them across the river.

Table 1. Barge dimensions.

Characteristics	Barges
Total length	60.00 m
Molded Depth	10.67 m
Beam	4.51 m
Project draught	3.50 m
Lightweight	285 ton

Technical feasibility analysis

To reach the expected results, firstly, the Mississippi type barges (Table 1) were designed for longitudinal dry-docking through a longitudinal slipway. Two scenarios will be simulated:

- Based on the calculation of a single slipway mechanical docking, considering a slope set at a value of 6.5° , the average slope of the region's riverbanks, for the displacement value of 285 tons for the standard Mississippi Box barge;
- In the case of dry-docking with the use of airbags, the calculation was analogous, using an estimated friction coefficient as shown in the literature.

To know certain characteristics of the vessel to be docked, it is necessary to know some elements to perform the dry-docking calculation, for example, in the slipway calculation, only two necessary elements were taken into consideration, where the first one consists in the slope of the repair slipway where a value of 6.5° is stipulated and the second element, the light displacement of the standard Mississippi Box barge, adopted a value of 285 tons, as presented by Lameira et al. (2015).

The sketch, shown in Figure 1, illustrates the simplified arrangement for docking calculation of a vessel:

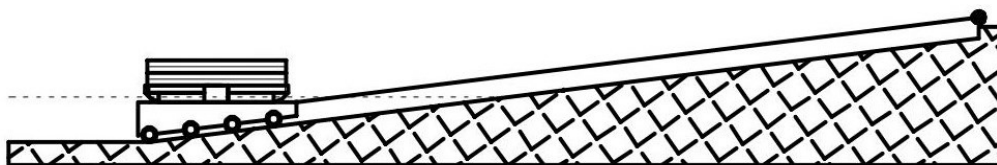


Figure 1. Docking sketch.

According to Bruce and Eyres (2012), conventional slipways are relatively solid and reinforced, with sufficient quantities to allow them to support the weights of boats built or repaired on them. During this process, keel blocs receive the largest percentage of the vessel's weight, the remainder being carried by shores and bilge blocks.

Strictly, a slipway for dry-docking is a machine and the rail support beams are part of that machine (Alexander, 2016). The central issue is the construction of reinforced concrete tracks and underwater beams to support the rails to the required tolerances. Constructions methods are an essential subject. The general trend is construction in dry conditions and above-water dam and prefabricated elements installed below water.

It is common to allocate slots in the beams at their place of use and once installed, the beams are filled with concrete in these slots so that only the railhead protrudes. According to Alexander (2016), This fill continues to support the railhead, even when there is a greater incline.

The recommended by House (2015), the slipway would be deployed near the locality with a draft of 6 meters, where the barge could be pulled with maximum safety. Thus, the ramp length calculation is calculated according to Equation 1.

$$L := \text{sent}(t) \cdot Hr \quad (1)$$

Where L is the horizontal extension of the ramp, t is the slope angle of the ramp and Hr the total height of the ramp.

To calculate the required power of the barge winch is considered the weight of the barge, desired speed, drum diameter, amount of cable-layers accumulated around the drum, and ramp dimensions. The engine power formula shall consider the possibility of a wheel being locked by water entering a bearing as a safety feature. The coefficient of slip friction of the braked, inflated, and wet tire varies between 0.25 and 0.7. For a 4-wheel race, as only 25% of the weight will be on a braked wheel, the value of 0 is taken, 15 to determine the tensile force (Ft), which is the resisting force to be overcome.

According to Fevereiro (2014), for the calculation of tensile force, Equation 2 is used:

$$Ft = G \cdot \frac{H}{L} + G \cdot 0.15 \quad (2)$$

G is the weight of the barge plus the trailer, H the height of the ground about the water level, and L the length of the ramp.

Then, it is proposed to carry out the load capacity sizing in the airbag dry-docking system. Shipbuilding Industry Standard (1999) says the ramp used for dry-docking using airbags should not have a slope greater than 7° . Over the entire length of the ramp, the shape of the airbags can be varied in various ways by matching the boat's inclination line. However, the bottom of the boat should not contact the ground even when the airbags are at their lowest possible height.

For the quantification of airbags used in maneuvers, one must calculate using Equation 3 (Shipbuilding Industry Standard, 1999).

$$N = 1.3 \cdot \frac{Q \cdot g}{C_b \cdot R \cdot L_d} + N_1 \quad (3)$$

Where N is the amount of rolling airbags to be used; Q is the weight of the vessel to be docked (ton); g is the acceleration of gravity (m s^{-2}); C_b is the block coefficient of the vessel to be docked; R is the permissible rolling force of the airbag (kN m^{-1}); L_d is the contact length between the bottom of the vessel and the body of the airbag in the midship section, and N_1 is the number of airbags to be reset in continuous operation (usually used between 2-4 units).

In the case of the minimum distance between two neighboring airbags, the needs for the hull structure must be known, also avoiding the overlap of rolling airbags. As a rule, the distance from the center can be verified using Equation 4 (Shipbuilding Industry Standard, 1999):

$$\frac{L}{N - 1} \leq 6 \quad (4)$$

Where L is the length of the vessel to be docked; and N is the number of rolling airbags to be used. For vessels with thin ends, the length L is the total length subtracted by the length of the thin ends that are not suitable for cushioning with airbags. If the vessel does not have special hull structural strength needs such as river barges, the central distance between two neighboring airbags can be arranged according to real conditions.

As for airbag carrying capacity, the lowest capacity of a supplier was used, as airbags are sized for vessels sailing in the open sea and are therefore oversized for docking and launching river barges. Airbag specifications are shown in Table 2, using the airbag with a load capacity of $153,87 \text{ ton m}^{-1}$.

Table 2. Airbag specifications.

Diameter	Pressure	L Effective	Height	Airbag Loading Capacity			
				kN m ⁻¹	ton m ⁻¹	kN m ⁻¹	ton m ⁻¹
2	16	0,1	0.8	188.5	19.23	3015.94	307.75
			0.9	172.79	17.63	2764.61	282.1
			1	157.08	16.03	2513.28	256.46
			1.1	141.37	14.43	2261.95	230.81
			1.2	125.66	12.82	2010.62	205.17
			1.3	109.96	11.22	1759.3	179.52
			1.4	94.25	9.62	1507.97	153.87

Economic comparison analyzes

One of the most important phases for project development success is its economic analysis, which is often overlooked or inadequately performed (Keeling, 2000). For the most part, within economic analysis, the finance manager relies on project risk assessment, potential value, and suitability for investment or financial support. In the economic analysis, the calculation of the acquisition/implementation costs of the slipway and the airbags were made considering the purchase values of the products to build the docking and launching methods.

The variation in costs obtained from both analyses, longitudinal slipway, and airbags deployments, was performed taking into account values obtained through regional market research, expressed and translated into Brazilian reais (R\$). Both results were subjected to market analysis at a 10% price fluctuation.

Results and discussion

The first dry-docking method analyzed was the longitudinal slipway dry-docking, thus, it was found as a horizontal extension of the ramp a value of 56 meters for proper use of the longitudinal slipway. For the calculation of winch sizing, as a safety margin, 75% of the wheels of the trailer in operation were considered. It was found by calculating the tensile force, a value of approximately 62 tons. Therefore, the winch had to have a load dimensioning of at least equal to the summation result plus the margin. For this purpose, a winch of 80 tons was used as the basis, given that the minimum value of 62 tons was considered.

For airbag sizing, it was found that the capacity of only one airbag from the contacted supplier (Table 2) can withstand 50% of the lightweight displacement of the standard Mississippi Box barge adopted for this study. For the light displacement of the barge, the average value of 285 tons was used. However, even with the use of only one airbag supporting 50% of the barge, it needs balance, so an average of eight per docking is used. The adequate amount of 11 barge docking airbags used was found using Equation 6, respecting the safety margins.

For the economic comparison, the deployment costs for the airbag in Table 3. for the longitudinal slipway model in Table 4, and its costs have been found through marketing research and industry experts. Materials such as piles, 30 Mpa reinforced concrete block, and L and T beams were found through research with experts in the field. The winch and rails were found through market research. The rail is ASTM A 36 of A 6"x3/8" grade steel.

It is possible to verify from the results of the tables that the number of objects to build a slipway is much higher compared to the airbag, and consequently, the cost of deployment will be higher. The savings achieved by deploying airbags at the repair yard are approximately 40%. Variations of 10% were also used, up and down, due to market fluctuations for the prices considered, which proved to be an excellent economy even with variations. So, it was considered that the use of airbags would be an interesting docking model to implement in the ship repair industry.

Table 3. Airbag deployment costs.

Object	Amount	Measure	Unit value	Total value
Airbags	11	Unity	R\$ 26,110.35	R\$ 287,213.85
Airbag pressure gauge	8	Unity	R\$ 141.75	R\$ 1,134.00
Hose	50	m	R\$ 12.10	R\$ 605.00
Winch 80 tons	1	Unity	R\$ 40,000.00	R\$ 40,000.00
Total				R\$ 328,952.85
Variation (+)				R\$ 361,848.14
Variation (-)				R\$ 296,057.57

Table 4. Longitudinal longitudinal slipway deployment costs.

Object	Amount	Measure	Unit value	Total value
Piles	50	Unity	R\$2,665.00	R\$133,250.00
Reinforced concrete block 30 Mpa	50	Unity	R\$2,347.00	R\$117,350.00
Beam L 25 x 60	200	m	R\$526.20	R\$105,240.00
Beam T 25 x 60	200	m	R\$526.20	R\$105,240.00
Rails (2 x 210 m)	60	m	R\$102.66	R\$43,117.20
Winch	1	Unity	R\$40,000.00	R\$40,000.00
Total				R\$544,197.20
Variation (+)				R\$598,616.92
Variation (-)				R\$489,777.48

Also, we can see that the results are consistent with the existing literature, since Ozkok and Cebi (2014) in their work, which aimed to make a general analysis of all types of launching methods from of a SWOT analysis, multicriteria decision methods (MCDM) and fuzzy logic, concluded that dry dock and airbag options are considered the most appropriate launching methods in terms of cost, performance and risk factors. The authors further state that the airbag method is emerging in far east shipyards and it is believed that those who prefer the use of dry dock or airbag launching will benefit from a substantial gain related to competitive power.

Conclusion

By analyzing the presented aspects and considering the relevance of the repair of vessels in the scenario of the Amazonian naval industry, because of the retraction in the shipbuilding market, we tried to verify how the naval repair with the use of airbags can be shown as an economical alternative to dry-docking.

The objective of the study was to analyze the possibility, from a technical and economic comparison, of replacing the current dry-docking model for river barges most used in the Amazon region by airbag dry-docking. Some restrictions were used for a hypothetical shipyard in the Amazon region, such as the 6.5° land angle, river barges with similar displacement averages and the soil was considered to be low, but compact.

Given the above, it is concluded that it is technically and economically feasible to replace the dry-docking model using the longitudinal slipway with the model using airbags, with savings of approximately 40% compared to its implementation. It has also been shown to have flexibility achieved with the use of airbags and can be used in different locations and companies when compared to the implantation of docking carried out by a longitudinal slipway. Also, such a dry-docking method has been shown to have flexibility achieved with the use of them and can be used in different locations and companies, when compared to the implementation of docking made by the longitudinal slipway. This advantage, in particular, is essential in the study region as most of the region's yards are located on leased land. Finally, this work presented satisfactory results, which show a great advantage in the use of airbags for river barge docking in the Amazon region, as a competitive alternative in naval repair services.

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