Technical and economic feasibility study for offshore transshipment operation: case study for the port of Vila do Conde / PA

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Abstract

Intercontinental cargo transport is carried out mainly through the waterway modal, increasing the number of vessels and the deadweight of ships. This means that onshore ports cannot stand the cargo demands and, to make them competitive in this reality, a very high investment is needed, and their expansion can produce serious environmental impact. Thus, it is necessary to search for alternatives that facilitate the flow of vessels in the regional and world scenario. Hence, the present work conducts a technical and economic feasibility study of a direct offshore transshipment operation of solid bulk cargo of vegetable origin at the Organized Port of Vila do Conde, in Brazil, using the Net Present Value (NPV) methods, Internal Rate of Return (IRR) and Payback. In the study, three scenarios were considered, each of which had its particularity related to the operating life and the amount of cargo handled. Therefore, it was noted that offshore transshipment is more viable in two scenarios – the project's useful life is up to 14 years, so that the investment of capital in an onshore installation is more viable. Furthermore, it was found that, only in the worst-case scenario, offshore transshipment overlapped the other activity in any period of its useful life.

Keywords: Offshore transshipment, onshore port, economic feasibility floating crane, barge to ship

1. Introduction

Brazil is one of the world's largest suppliers of agricultural products and, according to the Brazilian Agricultural Research Corporation (EMBRAPA, 2013), reference company of agricultural research in country, grain production rose from 50 million tons in 1977 to almost 250 million tons in 2018, factor responsible for the transition of the country from an importer into of the world's largest grain producers and exporters. In addition to this growth, the movement of solid bulk cargo of vegetable origin has increased significantly in the maritime environment because of the high worldwide demand for this product. According to National Port Logistics Plan (PNLP, 2017), the national plan of ports logistics, through long-haul shipping, a 127% growth in grain demand is projected, going from approximately 147 million tons in 2017 to 334 million tons in 2060.

Thus, it is noted that, due to the high transport of solid bulk cargo of vegetable origin in the maritime environment, there is a high movement of this merchandise in port facilities in Brazil, which begin to show weaknesses due to the high demands and problems related to its structure and management. The intense use of these facilities can lead to vessel congestion, making them wait in line for later mooring at berths, further increasing the costs of the shipowner to carry out the operation. In addition, the increase in the deadweight of ships means that the mooring berths of onshore facilities do not stand such vessels, as they have dimensions that are not in accordance with the capacity of the port. Finally, it is mentioned that the implementation of an onshore port structure requires a very high initial investment and can significantly harm the environment due to the need for a large area for its allocation.

From these obstacles, it can be seen that the port infrastructure is overloaded and saturated, so there is a need for alternatives that minimize the effects caused by the construction of a fixed port structure on land, reduce costs and do not generate high environmental impact. Thus, one of these alternatives is the offshore transshipment activity, which occurs outside the organized port area and may operate with vessels with larger draught, consisting of the transshipment of cargo from one vessel to another using a floating Rane or self-unloading vessels. Such a loading and unloading method does not promote a high environmental impact and does not require a high initial investment cost when compared to the operation in an onshore port complex. Finally, transshipment may commence at the time of arrival of the vessel in the area determined for the anchorage, without needing berths for the beginning of activities.

Considering these factors, the focus of this work is to compare a solid bulk cargo handling operation of vegetable origin between an onshore port structure and an offshore transshipment activity using a floating crane in Organized Port of Vila do Conde (located in northern Brazil), where cargo will be transshipped between a barge train and a Panamax class vessel, considering that three distinct scenarios will be analyzed – the pessimistic, moderate and optimistic scenario – and the lifetime of the project and operation and the amount of cargo to be transshipped are used as variables, in order to determine the operation that has the greatest economic viability over a specific period of time.

2. Theoretical background

2.1 Port facilities onshore and transshipment

According to ROA et al. (2013), ports can be defined as transition points for specialized cargoes between the maritime and land environments, which are provided with infrastructure that allows managing the cargo and keeping the ship in sheltered areas.

According to National Water Transport Agency (ANTAQ), Resolution No. 55 (2012), port areas are served by port facilities, which can be docks, moorings, wharves, bridges and berthing piers, in addition to buildings, land, warehouses, for example. Furthermore, the infrastructure of protection and waterway access to the port is also mentioned as part of the port area, including current guides, breakwaters, locks, channels, among others.

The ports in Arco Norte, notorious region in grains exporting, have become an escape route for the flow of grain produced in the Midwest of Brazil and, as a result, logistical alternatives are needed to overcome the bottlenecks in the region, one of them being the transshipment activity offshore, which consists of a loading/unloading operation of a commodity directly from barges to a long-haul vessel, characterized as a barge-to-ship operation (ARNAUD, AS, FIGUEIREDO, NM, 2019).

According to the company COECLERICI LOGISTICS SPA (2011), as existing port infrastructures are not able to keep up with greater demand for cargo, there is a need for logistical solutions so that the operations of greater loading and unloading keep up with the demand not for cargo transport, it can be used an offshore transshipment operation as an alternative for this, as the depth at the transshipment site can be much greater than that compared to fixed port facilities sites, as it is in an offshore environment, enabling the increase in cargo capacity deadweight of the vessel. In addition, an offshore transshipment operation reduces the vessel's idle time as it can start an operation as soon as it arrives at the designated location for the procedure. For WANG et al. (2016), the development of a greenfield port or the expansion of an existing port involves a high gestation period and high costs, noting that it is not always possible to expand ports, as the available areas are decreasing. In view of this, to keep up with the worldwide demand for bulk cargo, transshipment offshore is used as a solution to problems such as vessel size restriction, operating time and flexibility if there is a need to change the location of the operation.

The authors mention that there are different transshipment configurations, which can be done with the intermediary of a floating crane (Figure 1), by means of unloadable automobile vessels (Figure 2). In addition to these, there is indirect floating transshipment (Figure 3), which occurs with the ship at anchor and a barge with its own cranes and rapids. Finally, there is the floating transshipment in motion (Figure 4), using a barge with its own crane and it is not necessary to anchor the set of vessels, only mooring between them.

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Figure 1. Transshipment with floating crane

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Figure 2. Transshipment with Handymax

Font: Bayan Resources

Figure 3. Typical indirect floating transshipment

Font: Wang (2015)

Figure 4. Typical moving floating transshipment

2.2 Cash-flow analysis tools

A project, when being elaborated, must have as its initiative projections of several factors that would lead to profits and costs, which, when determined, can enable it, determining its final quality. Among these items, there is the cost of construction and development, in addition to the value of sales, taxes, terms and curves for payments and receipts (GUIMARÃES, 2012).

For the analysis of an investment, it is necessary to use indicators that can guarantee such a project. One of these indexes is the Minimum Attractiveness Rate (MAR), which, according to SILVA and JANNI (2021), should be considered a reference when carrying out a financial feasibility study and can be understood as the minimum rate that an investor wants to get by putting money into a business. This rate is made up of a basic interest rate, so that the investor does not go through so many risks and that he has a compensation for the risk of investing his capital.

In addition to the minimum attractiveness rate, another important component for the feasibility analysis of a project is the Net Present Value (NPV), which, according to the ENERGY STAR (2008), is one of the main methods used in engineering for the analysis of investments, being able to provide the cash flow values from the useful life of the investment to the present, being possible to predict whether the investment is viable or not, where there is only feasibility if the result is greater than zero.

Furthermore, another important method used for the analysis of investments is the Internal Rate of Return (IRR), which, according to ALPCAN (2019), is the discount rate that aims to support the viability of the business, it is the discount rate that equals the NPV to zero. The IRR must be compared with the minimum attractiveness rate, where the internal rate of return must be higher than the MAR for it to be accepted, otherwise it must be rejected.

Moreover, one very important factor for the viability of an investment is the payback time. According to the American Association of Port Authorities (AAPA), the payback period is the time required for a certain investment to be fully reimbursed for the investment to generate some profit from then on.

Lastly, the profitability index is considered, which is the association between the investment cost and the cash inflow and outflow values and is intended to provide the return in relation to the investment capital brought to the present value (Schorr, 2015). For the analysis of the profitability index, it is necessary to consider that, if the result found is above one, the project must be accepted. For an index equal to one, the project is indifferent, and for a profitability index below one, the project is not accepted.

3. Methodology

The methodology used in the feasibility analysis can be seen summarized in the flowchart of the Figure 5:

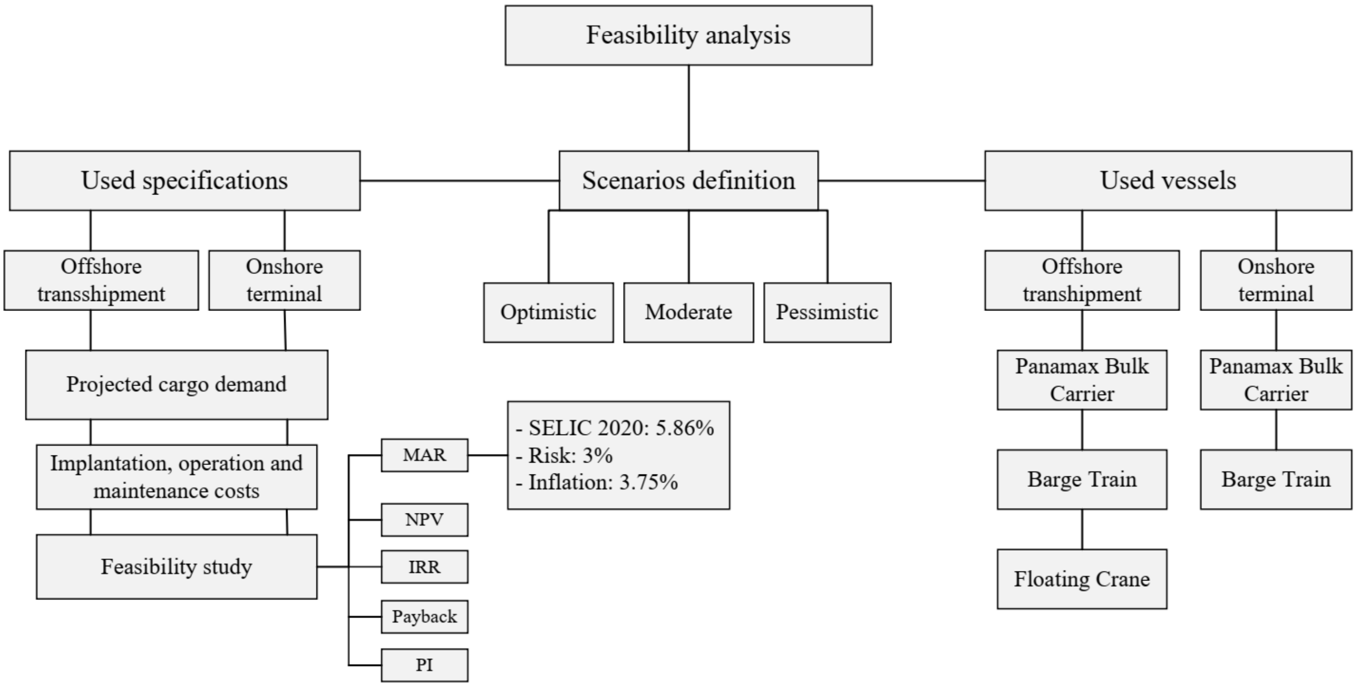


Figure 5. Flowchart of the steps used in this research. (Author, in press).

As can be seen in Figure 5, the feasibility study was initially carried out with the determination of the Minimum Attractiveness Rate, which was defined based on the 2020 SELIC rate, in addition to the risk rate and the inflation rate, the which totaled 12.61%. Based on the MAR result, the initial premise about the investment is made, as it defines the minimum expected investment of capital and, with this amount, the feasibility study can be continued.

Then, the methods of Net Present Value and Internal Rate of Return were used to assess the viability of the business to, later, define the payback and verify its profitability index. These methods were used as a result of several studies using the same mechanism. Thus, Table 1 aims to show some studies that used the same methods and their results.

For the feasibility analysis between an onshore port facility and an offshore operation, scenarios with a useful life of 5, 10, 15 and 20 years were considered for the scenarios: optimistic, which considers the operation will occur at its maximum projected capacity for 20 years; moderate, considering 80% of the amount of cargo handled in its useful life and pessimistic, a scenario where only 50% of solid bulk is considered.

Initially, the type of port on land was defined and, based on studies carried out in various works, the costs of implementation, operation and maintenance of the terminal were addressed for subsequent comparative analysis. In addition, it was necessary to determine the “standard” vessels that are used in an offshore transshipment operation, the operational arrangement used during cargo handling and the components present in the ship's anchorage system. Then, all the costs involved in carrying out an offshore operation were discussed and, finally, the calculations performed for the feasibility study of such investments are presented.

Year	Authors	Description
2021	FIORITI, D.; BACCIOLI, A.; PASINI, G.; BISCHI, A.; MIGLIARINI, F.; POLI, D. and FERRARI, L.	LNG regasification and electricity production for port energy communities: Economic profitability and thermodynamic performance
2020	COLAROSSI, D. and PRINCIPI, P.	Technical analysis and economic evaluation of a complex shore-to-ship power supply system
2020	GÓMES-FUSTER, J. M. and JUMÉNEZ, P.	Probabilistic risk modelling for port investments: A practical approach.
2019	QIU, Y.; YUAN, C.; TANG, J. and TANG, X.	Techno-economic analysis of PV systems integrated into ship power grid: A case study
2019	ALPCAN, O.	Efficiency and competitiveness analysis of port of Izmir
2019	MELLICHAMP, D. A.	Profitability, risk, and investment in conceptual plant design: Optimizing key financial parameters rigorously using NPV %
2015	JAYANTHI, G. D. and DAMAYANTI, S. M.	Feasibility analysis of new prior port project phase 2 of Indonesia Port Corporation II

Table 1. Publications that used similar analysis methods

As the study deals with the movement of solid bulk cargo of plant origin, it was decided that the type vessel used for the study will be the Panamax Bulk Carrier, which is 225 meters long; 32.2 meters of beam; 19.15 meters in depth; 13.82 meters of draft, a block coefficient of 0.865 and a dead weight of 75,122 tons, according to the document “Dry Cargo Bulk Carriers” of the “NEDA MARITIME AGENCY” of the ship “MARINA”. This document shows that the vessel has a displacement of 85,838 thousand tons to the local draft. However, the displacement will not be considered for the study, as there are restrictions in the organized port that allow the movement of vessels with a draft of up to 13.7 meters. Thus, an Equation (1) was used to determine the volume displaced to the allowed draft.

$$\nabla = L \, x \, B \, x \, D \, x \, Cb \tag{1}$$

Where, L is equal to length; B is the beam; D is the depth and Cb the vessel's block coefficient.

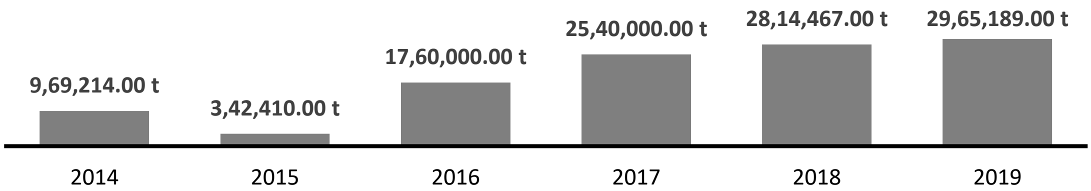
After the replacements, a displaced volume of 85,838 m^3 was obtained and, as the density of fresh water (where the operation will take place) is equal to 1 t/m^3, the displacement will be 85,838 tons. From that, it is necessary to deduct the lightweight of the vessel and weights that should not be considered in determining the carrying capacity, such as fuel. After such considerations, a load capacity of 66,221 tons was defined.

3.1 Onshore Port Facility Specifications

According to SNIZEK JÚNIOR et al. (2017), as the state of Mato Grosso is the largest national producer of grains, it is necessary that alternatives be defined to enable the flow of such goods, since the ports in the south/southeast are already overloaded. A solution for this is to transport the cargo for future export through the ports present in Arco Norte.

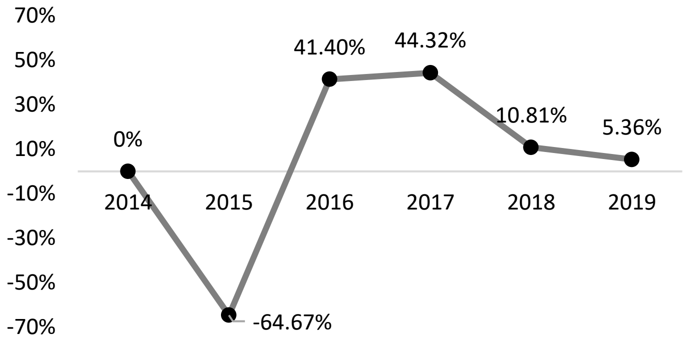
In view of this, as a basis for the study, the Privative Terminal of Vila do Conde Port, was used to consider the "type terminal" for the loading/unloading operation of solid bulk of plant origin. The terminal has a total area of 316,505 m² and did not require any shelter works, as its location already favors against the presence of waves as it is far from the Brazilian coast.

According to the Environmental Impact Report (RIMA) and data from ANTAQ, this terminal began operating in 2014 with a handling of 969,214 tons of cargo, reaching, in five years of operation, a quantity of 2,965,189 tons of solid bulk handled, and the terminal's maximum handling capacity is 4,000,000 tons. Thus, Graph 1 shows the amount of cargo handled at the terminal from 2014 to 2019.



Graph 1. Solid bulk handled from 2014-2019 at the Privative Terminal of Vila do Conde Port

From these values, a graph was obtained, which shows a variation, in percentage, each year, as shown in Graph 2:



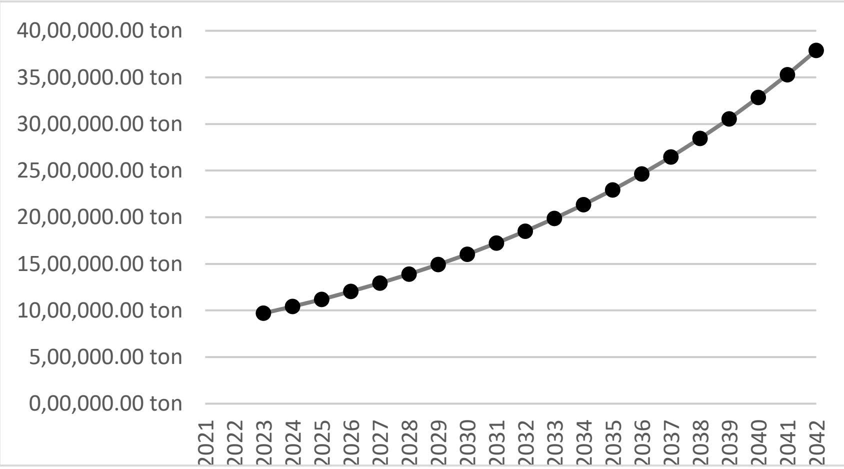
Graph 2. Percentage variation annually

Based on the percentage variation each year, the average variation over the years indicated was calculated and a positive variation of 7.44% was obtained. Thus, for the study in question, the amount of cargo handled in the first year of operation of the privative terminal used as a basis was considered and based on that, the percentage average found each year was applied. It is known that the useful life of an onshore terminal is, on average, 30 years, and that of the barge to ship operation 20 years. Hence, for the feasibility analysis between the two operations, a useful life of 20 years was considered for the terminal on land and for the operation offshore. In this way, the first two years will be determined for construction and the subsequent years for operation. Thus, Table 2 shows the projection of cargo handled over 20 years.

YEAR	DATE	CARGO HANDLED IN 20 YEARS	YEAR	DATE	CARGO HANDLED IN 20 YEARS
0	2021	CONSTRUCTION	11	2032	1,848,901.08 ton
1	2022	CONSTRUCTION	12	2033	1,986,459.32 ton
2	2023	969,214.00 ton	13	2034	2,134,251.89 ton
3	2024	1,041,323.52 ton	14	2035	2,293,040.23 ton
4	2025	1,118,797.99 ton	15	2036	2,463,642.43 ton
5	2026	1,202,036.56 ton	16	2037	2,646,937.42 ton
6	2027	1,291,468.08 ton	17	2038	2,843,869.57 ton
7	2028	1,387,553.31 ton	18	2039	3,055,453.46 ton
8	2029	1,490,787.27 ton	19	2040	3,282,779.20 ton
9	2030	1,601,701.85 ton	20	2041	3,527,017.97 ton
10	2031	1,720,868.46 ton	21	2042	3,789,428.11 ton

Table 2. Projection of movement in the terminal

From the projection presented in Table 2, it is possible to visualize better the movement of cargo over the years in Graph 3.



Graph 3. Projection of handled cargo Privative Terminal of Vila do Conde

The analysis of the cargo projection is essential for the feasibility comparison, since from the amount of cargo handled, it is possible to obtain the operating costs each year, as well as the revenue, that is, the smaller the cargo movement, the lower the operating costs and lower revenue.

For the costs feasibility analysis, two terminals for handling solid bulk of plant origin were considered: privative terminal of Santarém – where the implementation costs were obtained from the Technical, Economic and Environmental Feasibility Study (EVTEA, 2015) of the enterprise – and the Outeiro terminal, which also had its investment costs determined from its EVTEA (2012). Thus, their investment costs are shown in Table 3.

Terminal	Costs	
Privative Terminal of Santarém	US$	138,037,648.70
Outeiro	US$	29,353,047.99

Table 3. Terminal investment costs

Based on these costs, the areas of each terminal were analyzed to obtain a cost/m². The area of the Privative Terminal of Santarém terminal is 502,788 m² and the Outeiro terminal is 226,975.84 m². Thus, it was found that the cost/m² of Santarém privative terminal was US$ 274.55 and that of the Outeiro terminal was US$ 129.32. From this, an average was made between the two values, and it was obtained that the cost considered for the hypothetical onshore terminal was US$ 201.93 per square meter. Thus, as the Privative Terminal of Vila do Conde has an area of 316,505 m², the estimated total costs of implementation for the terminal were US$ 63,912,928.09.

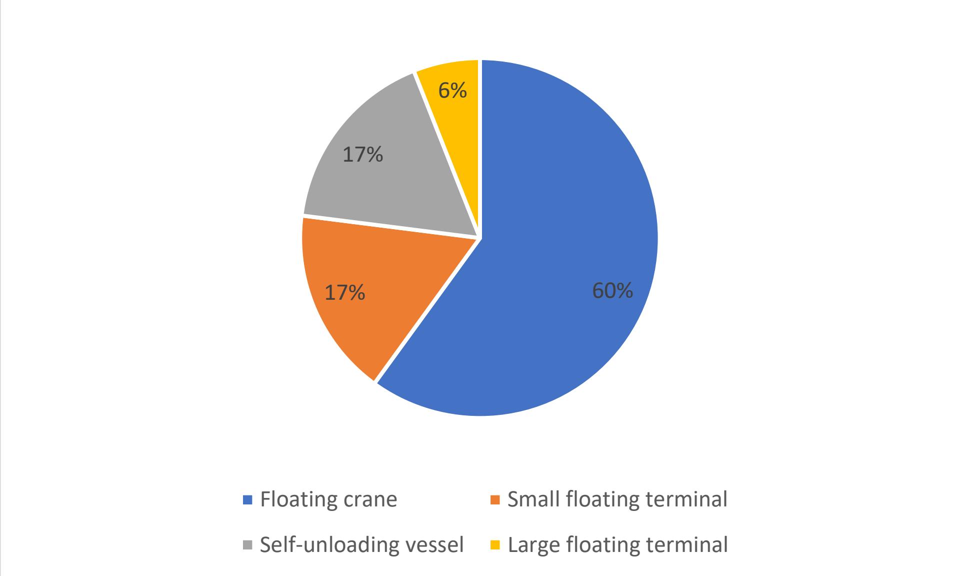
In addition to the investment cost for the implementation of the terminal, operating costs are extremely important for the feasibility analysis. These costs were defined from the Outeiro terminal's EVTEA, where a relationship was made between the amount of cargo handled per year in relation to its total operating cost. Thus, for the Vila do Conde terminal, an operating cost of US$ 2.65 per ton handled was determined.

Finally, there are the fixed costs of the terminal, which considers all the administrative labor, as well as the costs arising from shipping and storage. In addition, you need to consider the insurance value of the terminal. From the data provided by EVTEA, a relation of the fixed cost with the area was made and it was obtained that the annual fixed cost of the Vila do Conde terminal is US$ 664,467.41, but a rate of 6 % per year in value was considered due to inflation.

3.2 Specifications of the offshore transshipment operation

As previously mentioned, the offshore transshipment operation has numerous advantages, among them the possibility of transshipment of cargoes in areas with greater depths, allowing the presence of ships with a more considerable draft, in addition to reducing the waiting time for start of operation and generate little environmental impact compared to the onshore port installation.

Initially, the composition of vessels that would be used for the offshore transshipment operation was defined, according to WANG (2015), the procedure can be performed using a floating crane, with the presence of large or small floating terminals or with vessels with own loading/unloading capacity. For the author, Graph 4 represents the main type of offshore transshipment used in the world.



Graph 1. Composition of the offshore operation

As in the world scenario most transshipment operations offshore are carried out with the presence of a floating crane, the study will also use this method for cargo handling. Thus, Table 4 mentions the vessels that will be necessary for the procedure to be carried out.

Vessels	Quantity
Panamax Bulk Carrier	1
Floating Crane	1
Barge Train with 25 barges and 1 towboat	1

Table 4. Vessels used in operation

The floating crane considered for the offshore transshipment operation was the "Crane Barge 6324" from "Damen Shipyards Group" due to the availability of a product sheet supplied by the company. Table 5 shows the main characteristics of the vessel.

Main characteristics	
Length overall	63.00 m
Breadth	23.50 m
Depth	4.50 m
Draft	2.50 m

Table 5. Main characteristics of the floating crane

The vessel does not have its own propulsion and for its allocation at the place of operation it is necessary to use harbor towboats. When positioned alongside the ship, it will be able to operate when mooring to the ship is complete. The floating crane can move 1,000 tons of solid bulk per hour and 24,000 tons per day. Considering the selected vessel, as it has the capacity to transport 66,221 tons of solid bulk, the transshipment operation from floating crane to the vessel will last just under 3 days. However, it was determined that the complete operation will take place in 7 days due to the use of only two barges at a time, causing the towboat to have to keep moving to join the unloaded barges to the barge train and take the loaded ones to the transshipment operation.

Both for the onshore operation and for the offshore transshipment activity, a river barge train with 25 barges and the towboat will be considered. The barges considered will be of the Mississippi standard, with the Rake and Box types, with their characteristics expressed in Table 6 and Table 7, respectively.

Main characteristics	
Length overall	60.96 m
Breadth	10.67 m
Depth	4.27 m
Draft	3.66 m
Deadweight	2100.91 t

Table 6. Rake Barge

Main characteristics	
Length overall	60.96 m
Breadth	10.67 m
Depth	4.27 m
Draft	3.66 m
Deadweight	2230.285 t

Table 7. Box Barge

Analyzing the load capacity for each of the barges, considering that the barge train will have 5 rake type barges and 20 box type barges, its total load capacity is 55,110.25 tons of cargo. Thus, for the ship to be fully loaded, a train must be unloaded and another 4 rake-type barges and 5 box-type barges.

To carry out the offshore operation, it is necessary to implement an anchorage system for both the ship and the barge train to ensure the safety of the operation. The ship's anchoring system will have a frame of buoys (Figure 6), which are anchored by means of moorings, anchors and poles where the cost of concrete from SINAPI and anchors and moorings from the catalog of the company QINGDAO WANCHENG ANCHOR CHAIN CO., LTD., was considered. Furthermore, a unit cost per kg of steel was considered as US$ 18.00. From this, the costs composition for the ship and barge anchorage system was performed, which can be seen in Table 8 and Table 9, respectively. In addition, from the analysis of the cost of acquiring a ferry and a crane, it was considered that the estimated price for the floating crane was US$ 8,353,982.3 and the cost for implementation considered was US$ 675,970.92. Hence, the total costs are presented in Table 10:

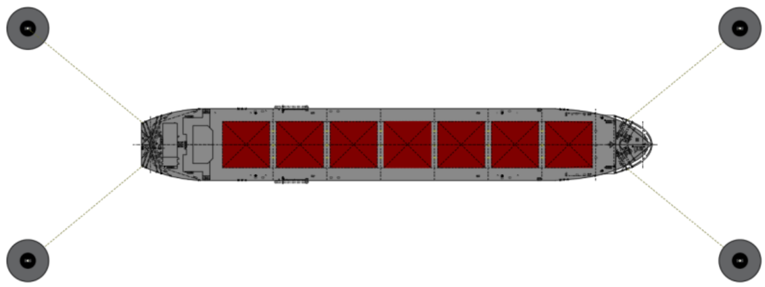


Figure 6. Ship with frame of buoys

Type	Quantity(unit)	Total per unit	Total
Buoy	4	US$ 101,994.61	US$ 407,987.44
Mooring blocks	15	US$ 22,477.20	US$ 337,157.98
Moorings	4	US$ 354,897.85	US$ 1,419,591.39

Table 8. Ship mooring costs

Type	Quantity(unit)	Total per unit	Total
Buoy	3	US$ 138,915.99	US$ 416,747.98
Mooring blocks	8	US$ 40,388.74	US$ 323,109.95
Moorings	1	US$ 411,289.53	US$ 411,289.53

Table 9. Barges mooring costs

Type	Costs
Ship mooring	US$ 2,164,727.82
Barges mooring	US$ 1,151,147.46
Implantation costs	US$ 675,970.92
Floating crane	US$ 8,353,982,30

Table 10. Mooring systems investment costs

From this, a total implementation cost of US$ 12,345,828.50 was obtained, and it is worth noting that inflation costs, the current dollar price and other charges were considered.

For the composition of the operational costs of transshipment offshore, it was necessary to make the composition of costs with all the elements present in the operation. From this composition, it was noted that the operating cost has the value of US$ 4.28 per ton handled. In addition, it was considered that the terminal earns 100% on top of the considered operating cost, thus, the cost charged to obtain revenue is US$ 8.56 per ton of solid bulk of plant origin handled.

The offshore operation, being carried out with 4 ships per month (maximum capacity), being one ship per week, has the maximum capacity to handle 3,178,608 tons of cargo per year. Hence, according to Table 2, the operation only meets the terminal's demand until the 17th year of operation, thus, the last three years will have the movement restricted to the maximum capacity of the operation.

Seeing that the fixed cost in the onshore operation is much higher than the offshore operation due to the number of people involved in the operation. In the onshore operation, you must have control over the storage of the cargo, its movement in the yards, whereas in the offshore operation, these activities are not necessary. Thus, the estimated fixed cost for offshore operations is US$ 265,786.97 per year, with an increase of 6% each year.

3.3 Investment feasibility analysis

To determine the Minimum Attractiveness Rate (MAR), the opportunity cost was considered, which was represented by the 2020 SELIC, as 5.86%. In addition, a business risk rate of 3% was established and the inflation estimate for 2021 was added, which is 3.75%. Thus, the defined MAR is 12.61%.

According to Lameira (2019), the calculation of NPV is determined by the following equation (2):

$$NPV = -I_0 + \sum_{j=1}^{n} \frac{CF_j}{(1+i)^j} \quad (2)$$

Where, I_0 is the initial investment, CFj is the expected cash flow, i is the considered discount rate and j is the considered time interval.

For URTADO et al. (2009), the internal rate of return has the function of zeroing the net present value considering the initial cash flow (investment) and the flow of subsequent years (profit). The formula that represents this method is represented in Equation (3):

$$CF_0 = \sum_{j=1}^{n} \frac{CF_j}{(1+i)^j} \quad (3)$$

For the payback time, the discounted payback formulation (4) was used, which considers that when the NPV is equal to 0, there is the necessary period for the invested amount to be recovered.

$$NPV = -\,CF_0 + \sum_{j=1}^{n} \frac{CF_j}{(1+k)^j} \quad (4)$$

To define the profitability index, it is necessary to use the Equation (5):

$$PI = \frac{\Sigma CF_j}{CF_0} \quad (5)$$

With CFj being the total cash flow and CF_0 equal to the cash flow at the initial moment.

4. Results and discussions

4.1 Optimistic scenario

For the feasibility analysis of the onshore port terminal, all the operational and fixed costs mentioned above were used. From this, the calculation of the income obtained each year was made. For this, a charged amount of US$ 12.39 per ton handled was considered, as explained above. The revenue for each year is presented in Table 11:

YEAR	REVENUE	YEAR	REVENUE
0	US$ -	11	US$ 22,906,739.02
1	US$ -	12	US$ 24,611,000.41
2	US$ 12,007,961.06	13	US$ 26,442,058.84
3	US$ 12,901,353.36	14	US$ 28,409,348.01
4	US$ 13,861,214.05	15	US$ 30,523,003.50
5	US$ 14,892,488.38	16	US$ 32,793,914.96
6	US$ 16,000,489.52	17	US$ 35,233,782.24
7	US$ 17,190,925.94	18	US$ 37,855,175.64
8	US$ 18,469,930.83	19	US$ 40,671,600.70
9	US$ 19,844,093.68	20	US$ 43,697,567.80
10	US$ 21,320,494.25	21	US$ 46,948,666.84

Table 11. Revenue of terminal annually

Then, the cash flow was performed, and the balance was verified each year for further analysis of the net present value, internal rate of return, payback and profitability index.

From this, the NPV for each year was calculated and the sum of the values obtained was made, obtaining a final net present value of US$ 19,442,276.04. Thus, as the NPV is greater than zero, the investment may be viable.

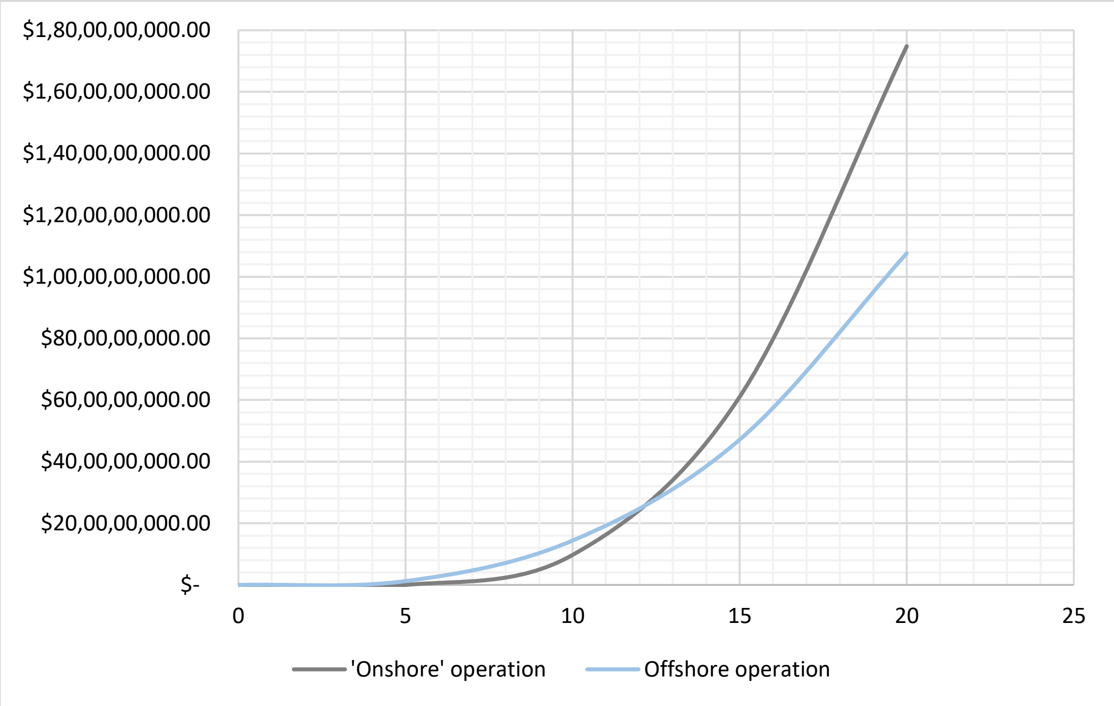
In topic 3.3, a minimum attractiveness rate of 12.61% was defined. This value is important for the feasibility analysis, because, based on it, it is possible to compare the internal rate of return with the MAR and know if the investment is viable or not. Thus, the IRR for the terminal was calculated from Equation (3) and the value of 16% was obtained. As the IRR value is higher than the MAR value, the investment is viable.

By obtaining the cash flow and the net present value, it was possible to calculate the investment's payback, and it was found that in 7.27 years the investment is paid for, and, from that, it starts to make a profit. Finally, a profitability index of approximately 1.31 was obtained, demonstrating that there is feasibility of investing in the business.

For the feasibility analysis of the offshore transshipment operation, the operational and fixed costs mentioned in topic 3.2 were used and based on this, the calculation of the income obtained each year was made considering a movement value of US$ 4.28 to every ton. Then, the cash flow was made, and the balance was verified each year for the calculation of the NPV, where its sum produced a final value of US$ 26,180,054.30. In addition, the calculated IRR presented 30%. Thus, from the analysis of the cash flow and the NPV during the useful life of the investment, it was found that the investment pays for itself in 4.34 years and that its profitability index is 3.12, proving its viability.

From this, the profit of each of the operations was verified for 5, 10, 15 and 20 years of operation and making the comparative analysis between them, it was noticed that for an investment with a useful life of up to 10 years, it is more advantageous to invest the capital in setting up an offshore operation. However, if the useful life of the project is longer than that mentioned, it is more advantageous to invest in an onshore port structure, as shown in the Graph 2:

Graph 2. Profit comparison optimistic scenario



4.2 Moderate scenario

In the moderate scenario, only 80% of the idealized load projection during the useful life was considered and, in addition, the annual fixed cost was reduced by 40% due to the lower demand for work. From this, all the costs adopted in topic 3 were considered and the revenue obtained each year was obtained, then it was possible the cash flow be done to then calculate the NPV each year. Table 12 shows the sum of net present values obtained both in the onshore terminal and in the offshore transshipment:

Onshore terminal	Offshore transshipment
US$ 3,307,404.03	US$ 19,347,936.81

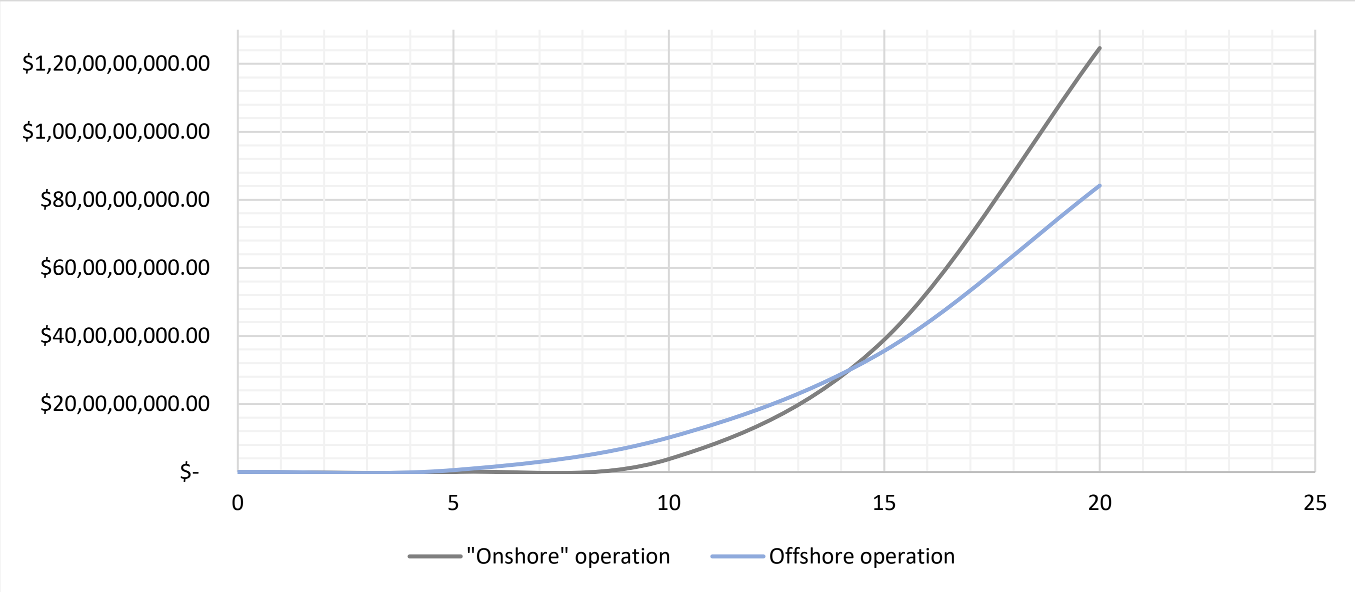
Table 12. NPV comparison for each operation

The difference between the values is due to the very high cost of implementing the onshore terminal, meaning that when there is a significant reduction in the amount of projected cargo, the NPV is not so relevant. This differs from offshore transshipment, which has a much lower implementation cost, so even with a smaller amount of cargo, the NPV is still relevant.) From this, the results of the other variables were obtained for the subsequent comparison between the two types of operation, which can be seen in Table 13, considering both operations.

-	Onshore terminal	Offshore transshipment
IRR	13.17%	26%
Payback	10.71 years	4.62 years
PI	1.06	2.56

Table 13. Results comparison between operations

Having made the comparative analysis between the operations, considering the moderate scenario, it was noticed that the investment in the onshore terminal can be viable, as well as the offshore operation. Graph 6 presents the comparison between the situations and, from it, it can be seen that until the 14th year of operation, the offshore operation is more advantageous and, from that point on, the financial investment in the onshore terminal is more viable.



Graph 3. Profit comparison in moderate scenario

4.3 Pessimistic scenario

In the pessimistic scenario, only 50% of the idealized load projection during the useful life was considered and, in addition, the annual fixed cost was reduced by 50% due to the lower demand for work. From this, all the costs adopted in item 3 were considered and the revenue related to each year was obtained, then it was possible to the cash flow to be done to then calculate the NPV each year. Table shows the sum of the net present values obtained both in the onshore terminal and in the offshore transshipment:

Onshore terminal	Offshore transshipment
US$ - 25,594,607.07	US$ 8,323,469.16

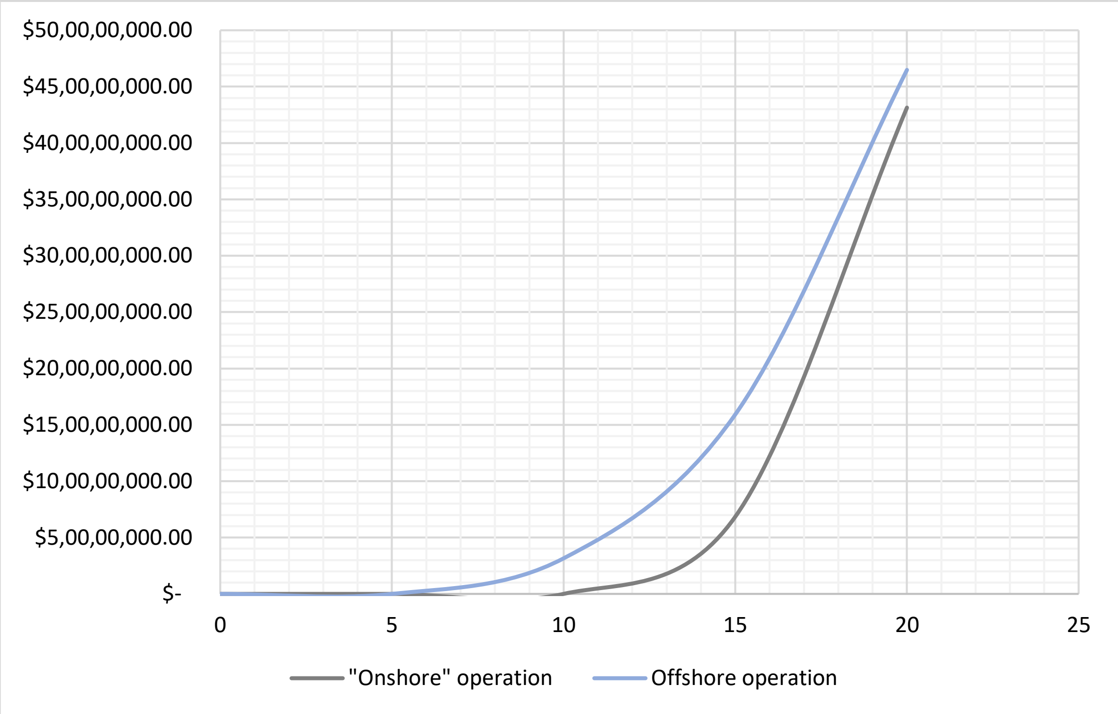
Table 14. NPV comparison for each operation

From this, the other variables were obtained for the subsequent comparison between the two types of operation, which can be seen in Table 15, considering both operations.

-	Onshore terminal	Offshore transshipment
TIR	8%	19%
Payback	15.4 Years	6.75 Years
PI	0.6	1.67

Table 15. Results comparison between operations

Having made the comparative analysis between the operations, considering the pessimistic scenario, it was noticed that the investment in the onshore terminal is very risky, since its NPV is negative and the internal rate of return is lower than the value of the MAR. As for the offshore operation, there is still probability of feasibility even in the most critical scenario, since the operation presented a positive NPV and an IRR higher than the MAR. Graph 4 presents the comparison between the situations and, based on it, it can be seen that at any time during the project's useful life it is more viable to invest in offshore operations.



Graph 4 – Profit comparison in pessimistic scenario

5. Conclusions

Therefore, it was verified that the offshore transshipment operation is becoming more and more present in the north of Brazil, and it was possible to conclude that its use is viable and competitive compared to onshore port facilities, especially when the demand is not so high and when the considered useful life is low. In addition, the versatility of offshore transshipment is a significant influencing factor, since it has no location restriction and allows the operation with ships of greater draft, as there is no depth limitation.Thus, it was noticed that the offshore transshipment activity has the potential to become a more frequent practice over the years due to the lack of availability of large areas close to shoals, the versatility of the operation and the possibility of carrying out the activity with high draft vessels. In addition, the offshore operation proved to be viable and competitive compared to the activity in an onshore facility, especially when demand is not so high and when the useful life is considered low. This can be seen in the consideration of the optimistic scenario, which is more viable if the project life is 10 years and, from that point on, it is more advantageous to apply the capital in an onshore installation. In addition, in the moderate scenario, greater viability in offshore transshipment was noticed if the useful life is up to 14 years and, only in the pessimistic scenario, greater feasibility of the offshore activity was considered in any period of its useful life.

6. References

ALPCAN, Oğuz, "Efficiency and competitiveness analysis of port of Izmir" (2019). World Maritime University Dissertations. 1146.

AMERICAN ASSOCIATION OF PORT AUTHORITIES. (2019). Port Planning and Investment Toolkit. Module 2, pp. 13.

Agência Nacional de Transportes Aquaviários (ANTAQ). Resolução n° 55, 2012.

ARNAUD, A. S.; FIGUEIREDO, N. M. Análise de viabilidade financeira: estudo de caso de um projeto de floating crane para o porto organizado de Vila do Conde – PA. Paraná, Revista mundi, p. 2, 2019).

ASTON FFI. Aston improves the export infrastructure of the Port of Caucasus. Disponível em: <https://www.aston.ru/en/news/aston-uluchshaet-eksportnuyu-infrastrukturu-porta-kavkaz/>. Acesso em: 26 de agosto de 2021.

Bayan Resources.Kalimantan floating transfer barges. Disponível em: < https://www.bayan.com.sg/>. Acesso em: 30 de set. de 2021.

CENTRO DE EXCELÊNCIA PARA O MAR BRASILEIRO (CEMBRA). O Brasil e o Mar no Século XXI. Rio de Janeiro, 2017).

DAMEN. Transshipment barge: crane barge 6324. 2016. Disponível em: < https://products.damen.com/en/ranges/crane-barge/crane-barge-6324>. Acesso em: 12 de set. de 2021.

EMBRAPA. Visão 2030: O Futuro da Agricultura Brasileira. Brasília, p. 11, 2018.

ENERGY STAR. (2008). Building Upgrade Manual. United States, Environmental Protection Agency. Ch. 3, pp. 4–6.

Estudo de Viabilidade Técnica, Econômica e Ambiental (EVTEA). ELABORAÇÃO DO ESTUDO DE VIABILIDADE TÉCNICA, ECONÔMICA E AMBIENTAL, VISANDO ÀS LICITAÇÕES PARA ARRENDAMENTO DE ÁREAS E INSTALAÇÕES PORTUÁRIAS NO TERMINAL PORTUÁRIO DE OUTEIRO, SITUADO NO MUNICÍPIO DE BELÉM/PARÁ. 2012.

Estudo de Viabilidade Técnica, Econômica e Ambiental (EVTEA). Terminal de granel sólido da EMBRAPS – Empresa Brasileira de Portos de Santarém. 2015.

COECLERICI LOGISTICS S.P.A. Offshore storage and transhipment. Milan, 2011.

GÓMES-FUSTER, J. M.; JIMÉNEZ, P., 2020. Probabilistic risk modelling for port investments: A practical approach. Case Studies on Transport Policy, Elsevier Ltd., 822–831.

KONECRANES. Konecranes Gottwald - Cranes on Barge. Disponível em: <https://www.konecranes.com/sites/default/files/2019-04/Cranes-on-Barge_Brochure.pdf>. Acesso em: 21 dez 2020.

NEDA MARITIME AGENCY. Dry cargo bulk carriers. Disponível em: < https://www.nedamaritime.gr/img/media_room/brochures/32P-NEDA-DRY-CARGO.pdf>. Acesso em: 10 de ago. de 2021.

Plano Nacional de Logística Portuária (PNLP). Projeção de demanda e carregamento da malha. Brasília, 2017.

GUIMARÃES, Ana. Estudo da viabilidade de investimentos em uma franquia de ensino profissionalizante. Rio de Janeiro, p. 4, 2012)

Relatório de Impacto Ambiental para a Implantação do Terminal Portuário Graneleiro de Barcarena – Pará. TERFRON – Terminais Portuários Fronteira Norte. Barcarena: Planave, 2005.

Roa, I., Peña, Y., Amante, B., & Goretti, M. (2013). Ports: definition and study of types, sizes and business models. Journal of Industrial Engineering and Management, 6(4), 1055-1064.

SCHORR, Matheus. Viabilidade econômica de empreendimentos imobiliários. 2015. Monografia (Graduação em Engenharia Civil) – Universidade do Vale do Taquari - Univates, Lajeado.

SILVA, P. H. O.; JANNI, V. Relação da taxa mínima de atratividade no cenário econômico atual com a viabilidade econômica de projetos. Rio de Janeiro, p. 6, 2021.

SNIZEK JÚNIOR, P. N.; FIOR, E. M.; SILVA, M. C.; TADASHI, H.; LEANDRO, T. S. Como o "arco norte" irá afetar a logística e exportações do estado do Mato Grosso. Mato Grosso, p. 1, 2017.

URTADO, E. S.; SANTO, V. da S.; QUINTAIROS, P. C. R.; OLIVEIRA, E. A. de A. Q. Aplicação do método do valor presente líquido (VPL) na análise da viabilidade econômica de projetos na indústria metal mecânica: um estudo de caso. São José dos Campos, p. 1-4, 2009.

WANG, Yijun. Operability study of floating bulk transhipment operation. Royal Haskoning DHV & TU Delft, p. 1-30, 2015.

WANG, Y.; DEYZEN, A. D.; PAUW, W.; HUIJSMANS, R. A methodology to assess the downtime of a multi-phase offshore floating bulk transshipment operation. Busan, p. 1, 2016.