Uncertainties and Risk Analysis on Ports Construction Projects Considering Technological and Market Strategic Factors: A Study in Emerging Countries and Regions

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Abstract

This article appropriates a new methodology for evaluating port projects involving not only economic analysis, but also strategic factors, technological and market, wich provide greater security and assertiveness on the search for the development of a Hub Port model as an option to optimize the logistics of port operations. To achieve the objectives of the proposal, a technical and economic analysis model was *developed to demonstrate the feasibility of the project with the inclusion of technological features (deep of ships, modes of transport linking the port to its region of land influence, expansion area) and market components (cargo demands, free trade zone, distance from the main centers of world trade) that decisively interfere in the attractiveness of the project. Linked to this proposal, a risk analysis was carried out, including uncertainties involving economic and strategic aspects, with market and technological variables. To achieve the objectives of the study, the Monte Carlo method operated by the software "@Risk^{TM}" was used, where the analyzes of positive and negative interferences in the project were carried out. To evaluate the proposed methodology, it was applied in two cases studies of the feasibility of a new logistics platform in Brazil and Africa, with the implementation of an offshore cargo concentrator port. One was in the State of Pará, in northern Brazil, and the other in Dakar, Senegal, which can integrate the entire South America and Africa, respectively. The results of those analysis show very favorable indicators for the implementation of the proposed projects. Considering that, strategic factors introduced in the study, the greatest influences were: transport modes that link the port to the land influence zone and the draft of the ships. For the offshore port of Pará, strategic factors boosted the viability result by approximately 55% for a 95% probability of success and for Dakar, in Africa, the results were 100%, both for a 14% rate and a life span of 30 years showing that strategic factors are elements very importatant, as they produced almost 100% and 70% elasticity in the results, respectively, so they should be considered in feasibility studies of hub ports in addition to traditional economic analysis,.*

Keywords: Port, Logistics, Risk, Uncertainties, Monte Carlo Method;

1. Introduction

Ports play a fundamental role in the growth and development of a region and a country, and the new trend in the global port scenario indicates the construction of large port complexes, where the challenge is the expansion and improvement of land and waterway infrastructure for receive the new demands of large ships, in addition to a retro area that serves the installation of companies that have synergy with the port activity. In order to serve today's modern ships, it is necessary for ports to have depths greater than 18 m and a geographic location close to large consumer centers, or on their route, to ensure the attraction of major international players.

Given the above, this study aims to characterize the elements that can decisively contribute to decision making regarding the implementation of a cargo concentrator port, through the analysis of market, technological and economic issues. To achieve the proposed objectives, analysis of risks and uncertainties is used as tools in the decision-making process, incorporating such elements.

Following the trend of the approach focus, this article proposes, as a case study, for the application of the proposed methodology, the implementation of a logistic platform located in the North of Brazil and another in the western part of Africa, two regions that, although not equal, neither homogeneous among themselves nor within themselves, they present many correspondences and common characteristics regarding the stage of economic development and potential for insertion in global markets and maritime trade.

2. Literature Review

According to Chin & Low (2010); Barros, Felício & Fernandes (2012) and Bottasso et al. (2018), ports are places that are connected to infrastructure and technical facilities to the sea, ocean or river through waterway connections. Ports not only manage a variety of cargoes for which they are specialized, but their basic functions also include providing shelter for ships, enabling the transfer of goods from one mode of transport to another, as well as serving as a link between sea and land. (OTHMAN et al., 2019).

The development of ports is closely associated with the development of the economy, since the functionality of ports can vary according to the differences in economic development (ADHITAMA E TAN, 2009 apud OTHMAN et al. 2019).

Port structures are characterized as a link between land transport and waterway transport, which supports an essential role in facilitating global trade and economic development (KHAN; TEE, 2015, 2016). Ports are responsible for 80% of world trade and provide many strategic areas for activities essential to the economy (FRANGOPOL; SOLIMAN, 2016).

The stability and quality of the port infrastructure needs to be fully analyzed, as it plays a crucial role in providing various types of services (KHAN; TEE, 2016). Infrastructure performance is especially one of the main concerns in maintaining the stability of port operations (LAM; BAI, 2016). However, many port infrastructures are highly deteriorated, a fact that generates not only a loss in ports, but also a possible shutdown of the entire supply chain (ZHANG et al., 2017).

When analyzing port logistics, it is necessary for a port and transport components to be productive and efficient in operating environments, as this allows them to highlight their potential to serve markets (Obed, 2013; Rahman et al., 2019). And considering that transport costs are directly impacted by productivity and efficiency, representing a significant portion of total logistics costs, reducing these costs is a key success factor for improving transport logistics (JUNG; KIM; SHIN, 2019). An economically viable operation depends on several factors, including mainly locational/geographic issues (SALLEH et al., 2017; OTHMAN et al., 2019).

All major nations are based on trade routes, which are frequently maritime (KOVAČIĆ, 2012). There are notable exceptions, as many countries are severely hampered by not having direct access to the sea, as they are situated in high mountain ranges; or by the lack of navigable rivers, long coasts, or good natural harbors (KOMCHORNRIT, 2017).

The concentration of maritime cargo routes, especially containerized ones, and the constant decrease in the number of ship stopovers, resulting from the growth in the size of new vessels, have made shipowners increasingly seek to use hub ports (VIEIRA; LUNA, 2016).

Hubs ports are large-scale structures in which different logistics service providers collaborate to offer value-added services by sharing assets. These hubs impact the efficiency of transportation systems, as they directly affect the flow of goods. To achieve greater efficiency, it is necessary to correctly place these hubs in a network. According to Li; Liu & Chen (2011), the objective of the adequate location of a hub port is to make products available to different markets through the best possible connections, allowing a better use of the infrastructure and transport available.

Concentration and distribution typologies are generally adopted serving a wide variety of sectors and products. This configuration is common in the transport of large volumes, according to Campbell & O'kelly (2012) where the goods are concentrated in a few nodes, that is, hubs, which function as connection points, instead of being sent directly from a supplier to their destinies reinforced Chen, Xu & Haralambides (2020). For Campbell & O'kelly (2012) this means that two main functions can be provided by hubs: i) consolidation/deconsolidation and ii) switching, classification or connection. Therefore, for Chen, Xu & Haralambides (2020), the decision on location should not be restricted by the definition of the number, location and capacity of facilities, but should also take into account the allocation of product flows and the network design itself, stated Campbell & O'kelly (2012).

Vieira et al (2016) already pointed out that among the criteria that impact the design of logistics hubs, location seemed to be a crucial element of decision. The choice of location affects the success not only of operational activities, but also of supply chain management and transportation network planning, influencing distribution systems as a whole (PAŠAGIĆ ŠKRINJAR; ROGIĆ; STANKOVIĆ, 2012).

In the last thirty years, fueled by the current globalization process, the maritime transport sector has experienced technological advances that have given rise to cargo specialization and other important changes in cargo handling facilities (BARROS; GIL-ALANA; WANKE, 2015; YANG; CHEN, 2016; ANEZIRIS; KOROMILA; NIVOLIANITOU, 2020). These changes contributed to the expansion of ports, transferring terminals to more peripheral locations in order to meet current standards of ship size and connections with the Hinterland (SAZ-SALAZAR; GARCÍA-MENÉNDEZ; MERK, 2013).

For Lourenço (2018), in the world market, large shipping companies, in order to become more competitive, have been building increasingly larger cargo ships and forming international joint ventures (agreement between two or more companies that establish strategic alliances for a common commercial objective for a given time) that allow the transport of cargoes of an increasing number of shipowners (companies that own ships), which is the global trend for which Brazil is not prepared, due to the lack of infrastructure, it does not have ports to receive these ships.

For UNCTAD (2012), the changes in production and distribution make it necessary to re-examine the role of ports. The contemporary production system needs ports that are more than just a link in the transport chain. Due to their strategic location and their prominent position in the distribution chain, ports must assume a leading role in the organization of international trade and in the exchange of information. This presupposes not only the modernization of services traditionally offered by ports, but also their capacity for logistical services that generate comparative advantages in relation to other transport infrastructures.

De Lima et al. (2018) stated that the fact that Brazil is a continental country and that the main production areas are located far from the ports, generates the need of a storage, transport, and port infrastructure an important factor in quality and logistical competitiveness. Therefore, problems such as poor transport of production to ports, queues at ports, delays in shipments and failure to meet deadlines (ZHANG et al., 2017), generate higher operating costs and loss of market share (MACKELPRANG; MALHOTRA, 2015; CARTER et al., 2016; HAILE; KALKUHL; BRAUN, 2016).

The port market until the 60s evolved slowly and predictably, which meant that the lifespan of ports reached 100 years, but with the specialization of cargo in the form of containers or bulk cargo (solid and liquid) , this transformation in the way of transporting, moving and storing cargo has made port evolution much more dynamic and new trends and equipment are constantly emerging.

Two determinant components in the quest for this balance are: scale and productivity. The trend is to increase vessel sizes or build smaller and faster ships, as well as accelerate its performance through alternative fuels.

The economic and financial analysis of projects seeks to relate the expected benefits of a given project with its costs and investments in order not only to show its intrinsic feasibility of functioning and validity of its implementation, but also to support decisions on how the project should or should not Be done. In a global market increasingly competitive and open to opportunities, this analysis is increasingly important both for the survival of the project against the competition and the choice of the best project to be carried out.

A more complete approach to economic analysis is the use of net present value, which can be defined as the algebraic sum of the discounted cash flow values associated with the project, which would consist in the construction of a discounted cash flow at an attractiveness rate, taking into consideration, therefore, the value of the resources committed over time and being dependent only on the expected cash flow and the opportunity cost of the capital, having two critical disadvantages, which would be the determination of the minimum attractiveness rate and the impossibility of reapplication of project benefits of success (ZAGO; WEISE; HORNBURG, 2009).

Another analysis is through the Internal Rate of Return, which consists of calculating the internal rate that would nullify the net present value of the cash flow of the project studied, representing the discount rate at which the balance between discounted inputs and outputs results in a present value net equal to zero.

A sophistication of these analyzes involves the consideration of the risk involved in investments, which would be the possibility of financial loss or simply the variability of expected returns on a given asset, according to SCORCIAPINO (2005). To estimate and avoid this risk, an uncertain cash flow can then be used, which involves analysis of error estimates to present a final result within a relevant confidence interval, in addition to allowing the estimation of the possible range of variation of values. expected for investments.

Technical risks are related to the quality that will be developed to the product or service, and if this type of risk occurs, implementing a project becomes a difficult or even impossible task because this type of risk usually involves problems with the interface, design, implementation, verification, and maintenance that threaten the timeliness and quality of the project. Finally, we have the business risks that refer to the project's feasibility and in this type of risk, if any, the project can be canceled due to the contribution of some factors such as the change of the project manager; production of a product even if excellent, but not viable due to lack of demand or to produce a product that does not fit the type of market (GRAY; LARSON, 2018).

According to Vargas (2018), we can classify total risk into non-technical internal risk, which can be reduced or controlled by the leader under direct decision-making, such as developing contingency plans. This risk is part of the limitations foreseen for the project through the creation of goals, so the project will likely be successful if the planned schedule is met based on costs, deadlines, potential losses and cash flow.

According to Vargas (2018), Organizations can have two types of risk: legal and technical. Legal risk is associated with claims against third parties, third party claims, contractual changes, patent laws and the use of licenses. Technical risks, on the other hand, involve the complexity of the project, the prototype, the performance or, if any, technological changes.

A series of scientific works and research were developed in order to assess and manage the risks of a given event in the context of waterway transport (CHEN et al., 2019), as in Qu, Meng & Suyi (2011), Valdez Banda et al. (2015), Goerlandt & Kujala (2011) and others.

When looking at the research carried out on risk management, there is a growing focus on creating risk analysis frameworks, focusing on issues such as understanding and describing risks and how to use risk analysis in decision making (AVEN; ZIO, 2014). In addition, there have been calls for the creation of methods to communicate uncertainties in risk analysis (PSARAFTIS, 2012). In the maritime transport application area, there are some theoretical landmarks, such as the ones based on system simulation (Harrald et al., 1998), traffic conflict technique (DEBNATH; CHIN, 2010) and Bayesian Networks (BNs) (MONTEWKA et al., al., 2010).

To apply the new way of approaching the feasibility study of a Hub Port, the Monte Carlo Simulation Methodology was used, which works with simulations, analyzing different ways of carrying out the activities of a project.

It should be noted that in one of the activities there is a certain probability to be related, which is directly linked to project uncertainties. The treatment of each one of them is preventive, contributing significantly so that no major problems occur during the project's execution phase.

3. Research Methodology

The analysis of the economic feasibility of the project is essential for a correct and assertive decision-making, indicating, in a reasoned and rational way, whether it can or even should be implemented due to its feasibility or unfeasibility.

The Discounted Cash Flow (DCF) method, in which parameters and indicators such as Net Present Value (NPV), Internal Rate of Return (TIR), Investment Return Time (TIR), Cost/Benefit Ratio can be identified (C/B), among others, is the most used to perform this analysis.

JAYANTHI AND DAMAYANTI (2015), TROUMPETAS ET AL (2016), CAMBRIDGE SYSTEMATICS (2018) and ADITYA ET AL (2019) present the breadth, depth and versatility of this method when applied to the analysis of port projects.

According to TEKER, 2020 and GRUBBA ET AL, 2017, the method (FCD) may have some limitations and caveats, mainly because it assumes very strong assumptions, generally arbitrary and often too biased and optimistic, not fitting well into the reality of facts. However, SCHUMANN, 2006, BARONI ET AL, 2006, OLIVEIRA and MEDEIROS, 2013 and CLASSEN ET AL, 2019 emphasize that this method, when well structured, incorporating the risks and uncertainties, working them, as well as the variables, with a probabilistic approach, with robust numerical methods, such as Monte Carlo, it produces very assertive and consistent results.

This article developed the Economic Analysis with the DCF consolidated Method, incorporating Risk Analysis as the probabilistic approach (Monte Carlo & RISK) and introduced components not previously identified in the technical literature, which are here called strategic factors, so that the results are as realistic as possible, significantly minimizing the limitations and restrictions inherent to the FCD, especially those placed by TEKER (2020).

3.1 Economic Analysis

The analysis of the economic feasibility of the project is essential for a correct and assertive decision-making, whether it can or should be implemented when considering estimates and forecasts based on current conditions or whether changes should be sought to combine the need to improve the rates of productivity of the operation to the need of the company to remain economically viable.

The method chosen for the economic analysis was the analysis of the operation's cash flow and comparison of economic indicators such as payback time, net present value, and internal rate of return on investment.

3.2 Modeling

The model established for the construction of the income statement was adopted according to the specific parameters of the operation and the project studied, in the most relevant items, seeking to stick to a level of complexity and adherence to reality at a sufficient level for a more accurate statement. as close to the real thing as possible.

Based on terminal cash flow models and the port project proposal presented, an economic analysis model was proposed as follows.

Gross revenue comes from port operation services (storage and cargo handling). The costs of services are divided into variable and fixed, the first involving parameters such as fuel, electricity, subcontracting, transport costs, among other costs that affect the amount of services provided, while the fixed ones involve salaries, insurance, security and others that regardless of the services being provided or not. That will be called Gross Operating Income.

3.3 Risk and Uncertainty Analysis

At this stage, risks are identified, analyzed and evaluated according to previously established criteria. It is carried out in 3 phases: risk identification, risk analysis, and risk assessment.

In identifying the risks, the activities are directed towards identifying the main risks that affect the project, and their result is materialized in a list that contains these risks or risk scenarios.

Risk analysis develops an understanding of the risks and their impacts on the activities involved, in order to guide the best strategies for handling the risks within the cost-benefit ratio.

In the risk assessment, a comparison is made between the classification of each risk analyzed and the assessment criteria established when choosing the assessment method.

To achieve the objectives proposed in this article, Monte Carlo simulation is used to show several possible results and inform the probability of their occurrence. Monte Carlo simulation is a computerized mathematical technique that makes it possible to take into account risk in quantitative analysis and decision making. Monte Carlo simulation provides the decision maker with a range of possible outcomes and the probabilities of these outcomes occurring according to the action chosen as the decision.

To operationalize the analyzes in a simpler and faster way, the **@RISK™** software was chosen, which performs risk analyzes through Monte Carlo simulation to show several possible results in the spreadsheet model and inform the probability of their occurrence. The program performs calculations, mathematically and objectively, and allows you to track several possible future scenarios; then it reports the probabilities and risks associated with each scenario. This means that you are then in a position to assess what risks you want to take or avoid, and based on that, make the best possible decisions in situations of uncertainty.

@RISK^{TM} also helps you plan the best risk management strategies through integration with RISKOptimizer, which brings together the power of Monte Carlo simulation and the highest technology of "solvers" or solvers.

The search for synergy between parameters and decision criteria aims, through the inclusion of location and infrastructure factors, to enhance the financial result obtained from the simulation proposed in this thesis, seeking to add value to the result obtained.

In this methodology, the port is considered as the set of strategic and operational means that optimize the intermodal functions in the logistic chain. For this purpose, an approach is made that makes the viability variables of a port faster and more efficient than a simple economic viability approach.

According to the different methodologies for approaching port feasibility, six (6) elements were found that are indispensable or significantly contribute to the feasibility of a port project. Table 1 presents the six elements to be known.

Table 1. Elements that constitute port feaseability

Port Feaseability	[1] Economic feaseability (function of cargo demand)
	[2] Draught (to comply with large ships)
	[3] Expansion Area
	[4] Modes of transport linking the port to its region of influence
	[5] Location (proximity to consumer centers and major world routes)
	[6] Free Trade Zone

Source: Author (2020).

As the methodological proposal of this thesis links the economic viability of a port structure to technological and market factors, such as: **ship draught**, which, according to the new world trend in shipbuilding, has grown a lot due to the increase in the size of ships , **expansion area** in the port area available for the implementation of industries and storage near the port, **location** or distance to the main consumer centers in the world and proximity to the highest traffic density in the world, **free trade zones** to increase the attractiveness of cargo in transit to other countries, aiming to be a hub and distributor of international cargo, in addition to the **modes of transport that access the ports**, where the cargo will be attracted to the port as more economical the transport modal for land access to the port. These items are extremely important decision variables, and constitute or can be represented as an effective index of attractiveness for a port, these being the strategic factors to enhance the viability of a port.

4. Case Study of port projects introducing analysis with strategic logistic, technological and market factors

The importance of maritime transport in multimodal chains means that the port's competitiveness is measured by its ability to attract transport services. The transformation that the modern consumer is going through also has a strong impact on port policy. The consumer, more demanding and qualified, starts to demand a better level of service. Thus, it becomes necessary to add value to the service provided by the ports, generating more efficiency and quality (Porto, 1999). The port is now evaluated in a more global context, where connections with the internal / external market and the level of maritime service available are some of the main evaluation parameters. Within this vision, the use of concentrator and feeder ports is included as a way to facilitate the connection between various points in a given area of influence and improve the interface with international markets.

The attributes or strategic factors selected for the assessment are: **Draught, Port expansion area, Modes of transport linking the port to its region of influence, Free trade zone, Maritime distance to major consumer centers.**

4.1 Ship Draught (m):

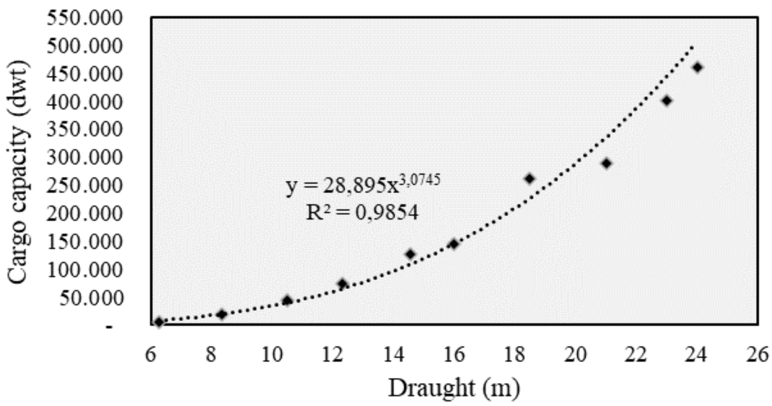
To define the weight that the draught gains represent in the definition of the physical criteria that will guide the choice of a port enterprise, it was attributed according to Table 2 that generated the graph in Figure 1, where the capacity gains of the ships are verified. due to the increase in draught.

Table 2. Technical characteristics by type of ship

Tipo de navio	Calado médio (m)	Capacidade media (t)
MINI BULKER	6,2	6.500
HANDSIZE	8,3	20000
HANDMAX	10,5	45000
PANAMAX	12,3	73.500
SUEZMAX	16,0	145.500
CAPESIZE	14,5	127.500
VLBC	18,5	262.500
VLCC	21,0	289.500
VALEMAX	23,0	400.000
ULCC	24,0	460.000

Source: Author (2020).

Figure 1 – Cargo Capacity x Draught



Source: Author (2020).

From the values shown in Table 2 and the graph in Figure 1, the equation that constitutes the trend line of the values was obtained. Therefore, the load capacity gains due to the draught can be predicted according to Equation 3.

$$Dwt = 28{,}895 \; x \; draught^{3{,}0745} \qquad (3)$$

So, the relation of ships' capacity gains for depths from 12 m to 24 m was measured, as shown in Table 3.

Table 3. Capacity gains due to draught

Draught	12	14	16	18	20	22	24
Dwt	60.085	96.515	145.509	209.006	288.961	387.348	506.153
Weight for capacity gain (Wcg)	1,0	1,6	2,4	3,5	4,8	6,45	8,42

Source: Author (2020).

4.2 Port expansion area:

The port expansion area is linked to the port, it is not located in densely populated areas, nor is it found in regions already congested by industries and the city interface within retro-port zones. These interfaces have not been harmonious throughout world history.

Cities, in general and over the centuries, were born and developed at crossroads of trade routes, that is, cargo flows. As time goes by, the circulation of vehicles near port areas is seen by the population, society and government as a nuisance and as "an evil to be eradicated". That is why public policies, in relation to loads, are, in general, only restrictive: Temporal restriction (prohibited in this period of time); geographic (prohibited in this region); technological (prohibited with this type of vehicle).

Thus, we sought to classify the potential influence in the decision to implement new port projects, through weights that represent the capacity to expand areas destined for port and retro-port facilities, as shown in Table 4.

Table 4. Weight for expansion area

Expansion Area (m2)						
%	0%	20%	40%	60%	80%	100%
Weight of expansion area (Wea)	**1**	1,2	1,4	1,6	1,8	2

Source: Author (2020).

4.3 Modes of transport linking the port to its region of influence:

In order to define the weights of the modes of transport that link the port with its land influence zone, a list of already established average cost indices was searched in the literature. The percentages of economic gain were obtained directly from Table 4 or when the combinations of modes of transport were added to the indexes verified in Table5.

Table 5. Comparative indexes between modes of transport

Mode of transport	Index
Waterway	1
Railway	3
Road	6 a 9
Airway	15

Source: EPL (2020) adapted by Author (2020).

It was highlighted in Table 6 the weights of economic gain by mode of transport or combinations.

Table 6. Weight for economic gain by mode of transporto r combination

Mode of Transport	Road	Railway	Waterway	Rail - Road	Road - Waterway	Rail - Waterway	All
Weight of economic gain with mode of transport (Wmt)	1	3	6	4	7	9	10

Source: Author (2020).

4.4-Free trade zone:

As noted in this chapter, the free trade zone has been enhancing the viability of cargo concentrating ports (hub ports). As already mentioned in this chapter, the main cargo hubs in the world have a great appeal in the free trade zone as a major driver of their activities and attracting cargo to the port. Thus, the fact that the port is a free trade zone becomes more attractive, as it is the integrating and cost-reducing element of international trade, than a port without this attribute. Table 7 shows the score for the existence or not of a Free Trade Zone.

Table 7. Score for the free trade zone

Free Trade Zone	Does not have	Have
Weight of the Free Trade Zone (Wftz)	1	2

Source: Author (2020).

4.5- Maritime distance to major consumer centers

To identify the weight of the distance to large world consumer centers, in the analysis of the implementation of a port complex, we sought to identify a range of distances between the preferred ports in the north and northeast, in the southeast and south of Brazil, as well as the ports in northwest, west and southwest Africa. These weights were determined as a function of travel time by the average distance traveled to the main ports in the world in the USA (Miami), Europe (Rotterdam) and Asia (Yangshan-Shanghai) adopting an average speed of 12 knots (21, 84 km / h) for ships. In this case, the shorter travel times are more important (higher score) because they have the lowest operational costs.

4.5.1-Brazil:

- **Miami:**

In Table 8 is shown the weights of the maritime distance to USA (Miami).

Table 8. Distance and time to USA (Miami)

Item	North and Northeast 4.000 – 6000 (km) (9,50 days)	Southeast 6.100 – 8.000 (km) (13,55 days)	South 8.100 – 11.000 (km) (18,22 days)
Weight of maritime distance (Wmd)	18,22/9,50 = 1,92	18,22/13,55 = 1,35	18,22/18,22 = 1,0

Source: Author (2020).

- **Rotterdam:**

In Table 9 is shown the weights of the maritime distance to Rotterdam, in Europe.

Table 9. Distance and time to Europe (Rotterdam)

Item	North and Northeast 7.000 – 8.000 (km) (14,34 days)	Southeast 8.100 – 10.000 (km) (17,26 days)	South 10.100 – 13.000 (km) (22 days)
Weight of maritime distance (Wmd)	22/14,34= 1,52	22/17,26 = 1,28	22/22 = 1,0

Source: Author (2020).

- **Xangai:**

In Table 10 is shown the weights of the maritime distance to Shanghai, in Asia

Table 10. Distance and time to Asia (Yangshan-Shanghai)

Item	North and Northeast 20.000 – 22.000 (km) (40 days)	Southeast 22.100 – 24.000 (km) (44 days)	South 24.000 (km) (45 days)
Weight of maritime distance (Wmd)	45/40 = 1,16	45/44 = 1,02	45/45= 1,0

Source: Author (2020)

4.5.2 Africa:

- **Miami:**

In Table 11 is shown the weights of the maritime distance from Africa to the USA (Miami).

Table 11. Distance and time to USA (Miami)

Item	Northwest Africa 6.000 – 7000 (km) (12.4 days)	West Africa 8.000 – 10.000 (km) (17,2 days)	Southeast/South 11.000 – 12.000 (km) (22 days)
Weight of maritime distance (Wmd)	22/12,4 = 1,77	22/17,20 = 1,28	22/22 = 1,0

Source: Author (2020)

- **Rotterdam:**

In Table 12 is shown the weights of the maritime distance from Africa to Rotterrdam, Europe.

Table 12. Distance and time to Europe (Rotterdam)

Item	Northwest Africa 2.000 – 4.000 (km) (5,7 days)	West Africa 5.000 – 9.000 (km) (13,4 days)	Southeast/South 10.000 – 11.000 (km) (20 days)
Weight of maritime distance (Wmd)	20/5,7= 3,5	20/13,4 = 1,50	20/20 = 1,0

Source: Author (2020).

- **Shanghai:**

In Table13 is shown the weights of the maritime distance from Africa to Shanghai, in Asia

Table 13. Distance and time to Asia (Yangshan-Xangai)

Item	Northwest Africa 17.000 – 20.000 (km) (35,3days) (Through Suez Canal)	West Africa 17.000 – 20.000 (km) (35,3 days) (Through Cape of Good Hope)	Southeast/South 16.000 (km) (30,5 days) (Through Cape of Good Hope)
Weight of maritime distance (Wmd)	35,3/35,3 = 1,0	35,3/35,3 = 1,0	35,3/30,5 = 1,20

Source: Author (2020)

To analyze the implementation of large cargo concentrating port projects, through a logistical, technological and market analysis, the five parameters listed above were sought to obtain a more qualitative response from the port enterprise, presented according to Equation 4.

$$W_{ltm} = W_{cg} + W_{ea} + W_{mt} + W_{ftz} + W_{md} \quad (4)$$

Where:

Wltm = Weight of Logistical, Technological and Market analysis;
Wcg = Weight of capacity gain due to draught;
Wea = Weight of expansion area;
Wmt = Weight of economic gain with mode of transport;
Wftz = Weight of Free Trade Zone;
Wmd = Weight of maritime distance

From the criteria established to determine the qualification of ports to become cargo concentrators, it was possible to carry out a qualitative analysis of the main Brazilian ports and an evaluation of each one of them considering the strategic factors mentioned above.

Table 14. Brazilian ports used in the analysis

Analyzed Ports		
Port	**Characteristics**	**Variable**
OFFSHORE PORT OF PARÁ (North and Northeast)	Maximum Ship Draught:	24,00 meters
	Expansion Area:	100%
	Free trade zone:	YES
	Access:	WATER
	Distance range:	USA: 4.000 – 6000 (km) EUROPE:7.000–8.000 (km) ASIA: 20.000 – 22.000 (km)
	Score	**23,02**
ITAQUI PORT COMPLEX (MARANHÃO) (North and Northeast)	Maximum Ship Draught:	22 meters
	expansion Area:	100%
	Free trade zone:	NO
	Access:	ROAD – RAIL
	Distance range:	USA: 4.000 – 6000 (km) EUROPE: 7.000 – 8.000 (km) ASIA: 20.000 – 22.000 (km)
	Score	**20,02**
PECÉM PORT (CEARÁ) (North and Northeast)	Maximum Ship Draught:	15,0 meters
	expansion Area:	100%
	Free trade zone:	NO
	Access:	ROAD – RAIL
	Distance range:	USA: 4.000 – 6000 (km) EUROPE: 7.000 – 8.000 (km) ASIA: 20.000 – 22.000 (km)
	Score	**15,10**
	Maximum Ship Draught:	24,00 meters

AÇU PORT (Rio de janeiro) (Southeast)	expansion Area:	100%
	Free trade zone:	NO
	Access:	ROAD – RAIL
	Distance range:	USA: 6.100 – 8.000 (km) EUROPE: 8.100 – 10.000 (km) ASIA: 20.000 – 22.000 (km)
	Score	**19,07**
SANTOS PORT (São Paulo) (Southeast)	Maximum Ship Draught:	13,50 meters
	expansion Area:	20%
	Free trade zone:	NO
	Access:	ROAD – RAIL
	Distance range:	USA: 6.100 – 8.000 (km) EUROPE: 8.100 – 10.000 (km) ASIA: 20.000 – 22.000 (km)
	Score	**11,25**
PARANÁ AND SANTA CATARINA PORT COMPLEX (South)	Maximum Ship Draught:	11,00 meters
	expansion Area:	100%
	Free trade zone:	NO
	Access:	ROAD – RAIL
	Distance range:	USA: 8.100 – 11.000 (km) EUROPE: 10.100 – 13.000 (km) ASIA: 20.000 – 22.000 (km)
	Score	**10,00**
RIO GRANDE PORT COMPLEX (RIO GRANDE DO SUL)	Maximum Ship Draught:	12,8 meters
	expansion Area:	100%
	Free trade zone:	NO
	Access:	ROAD – WATER

(South)	Distance range:	USA: 8.100 – 11.000 (km) EUROPE: 10.100 – 13.000 (km) ASIA: 20.000 – 22.000 (km)
	Score	**14,00**

Source: Author (2020).

Table 15 shows the general classification of the ports according to the score.

Table 15. Overall classification of brazilian ports according to the score

Classification	Ports	Score
1º	Offshore Port Pará	23,02
2 º	Itaqui Port Complex (Maranhão)	20,02
3 º	Açu Port (Rio de janeiro)	19,07
4 º	Pecém Port (Ceará)	15,10
5 º	Rio Grande Port Complex (Rio Grande do Sul)	14,00
6 º	Santos Port (São Paulo)	11,25
7º	Paraná e Santa Catarina Port Complex	10,00

Fonte: Author (2020).

Table 15 classifies the main Brazilian ports with potential to become a cargo concentrator port for Brazil and South America. It is also observed the great advantage of the Offshore Port of Pará in relation to other ports in Brazil. It is also verified that the second place, the Port Complex of Itaqui in Maranhão, has similar characteristics and can also partially serve the same area of influence as the Offshore Port of Pará, which highlights the great advantage of ports located in the north of the country. Another decisive factor in the analysis of the first three places is the offer of large draughts to ships.

Considering the same analysis, the methodology was applied in West Africa, seeking to evaluate the regions with the highest scores for the installation of a cargo concentrator port, using the same criteria adopted for the Brazilian case. Three West African regions were analyzed: the southwest, the west and the northwest.

Table 16. African Regions used in the analysis

Analyzed Ports		
Port	**Characteristics**	**Variable**
AFRICAN SOUTHEAST/SOUTH PORT (Luanda Port in Angola)	Maximum Ship Draught:	12,0 meters
	expansion Area:	60%
	Free trade zone:	NO
	Access:	ROAD – RAIL
	Distance range:	USA: 11.000 – 12.000 (km) EUROPE: 10.000 – 11.000 (km) ASIA: 16.000 (km)
	Score	**10,80**
AFRICAN WEST PORT (Cotonou Port in Benin)	Maximum Ship Draught:	15,00 meters
	expansion Area:	60%
	Free trade zone:	NO
	Access:	ROAD – RAIL
	Distance range:	USA: 8.000 – 10.000 (km) EUROPE: 5.000 – 9.000 (km) ASIA: 17.000 – 20.000 (km)
	Score	**12,78**
AFRICAN NORTHWEST PORT (Dakar Port in Senegal)	Maximum Ship Draught:	15,0 meters
	expansion Area:	60%
	Free trade zone:	NO
	Access:	ROAD – RAIL
	Distance range:	USA: 6.000 – 7.000 (km) EUROPE: 2.000 – 4.000 (km) ASIA: 17.000 – 20.000 (km)
	Score	**15,70**

Table 17. Overall classification of the African ports according to the score

Classification	Ports	Score

1º	Northwest african port (Dakar Port in Senegal)	15,70
2 º	West african port (Cotonou Port in Benim)	12,78
3 º	Southwest african port (Luanda Port in Angola)	10,80

Source: Author (2020).

In the analysis of the scores of African ports, we identified that the port located in the northwest of Africa, in the analyzed case, the port of Dakar, in Senegal, presented the best conditions for the implementation of a hub Port in the western part of Africa. The higher score obtained in strategic factors for the ports of the northwest African region is justified by the greater proximity to the main world centers (United States and Europe), since the other strategic parameters do not distinguish differences and Asia can be accessed both through the channel from Suez and the cape of good hope in southern Africa.

6. Application of risk and uncertainties analysis considering strategic factors for the implementation of a Hub Port in Brazil and Africa

In the context of analyzing the implementation of large port projects, it was pursued to deepen the risk and uncertainty analysis considering not only the financial feasibility of the project, but also adding new factors (strategic factors), aiming to create new attributes that confirm the recommended hypotheses for setting up the venture's cash flow, in order to help in decision making and enable the entrepreneur to understand the size of the market that will operate, in addition to identifying the parameters that leverage greater profitability, new trends, the performance of its services with the identification of the quantity or volume that the port is able to absorb and what it will be able to leverage considering the strategic factors selected for the assessment such as: **Draught, Port expansion area, Modes of transport that link the port to its region of influence, Free trade zone, Maritime distance to major consumer centers.**

This new way of approaching the problem allows the port to better allocate its services, location and infrastructure, which are fundamental factors for success. The port enterprise needs to be updated on every movement in the sector. Both to identify new opportunities and to protect itself from possible threats.

For the operationalization of the model, the method of risk and uncertainty analysis was used to assess the projects, considering the strategic factors, and evaluating them as impacting the search for demand for different combinations of variables, which offer the decision maker different projects situations. The combination of strategic factors with the financial results arising from the variation in demand for cargoes and market rates was carried out with the combination of risk analysis using the Monte Carlo Method. To evaluate the model, we used a Brazilian case, the Offshore port of Pará, and a case from West Africa, the Port of Dakar in Senegal, since these port alternatives achieved higher scores considering the strategic factors.

6.1 Risk Investment Analysis on a Hub Port in Brazil (Offshore Port of Pará)

The Offshore Port of Pará is located close to the Atlantic Ocean, next to the delta of the Amazon, Tocantins and Pará rivers that cross and interconnect virtually the entire Amazon to the Central Plateau, close to Brasília, as well as enabling the connection between Peru and Bolivia and from Colombia to the Atlantic Ocean via waterway (rivers from the Amazon basin), as shown in the maps in Figure2.

Figure 2. Rivers of the Amazon basin

Source: Brazil's Ministry of Transports.

The Offshore port of Pará may be the "gateway" of entry and exit from Brazil to the world, as it allows for a more efficient integration of the main areas of mineral and agricultural production in Brazil with the main consumer markets in the world.

Due to this privileged location, the Offshore Port of Pará may be the gateway to South America, a role that the port of Rotterdam, in the Netherlands, plays today in Europe, as it offers the shortest distances, in waterways, and the resources necessary for the flow of production from this vast mining, agricultural and pastoral region with fluidity, low costs and impacts.

In this context, the port should be seen as one of the most strategic ports for the national economy, especially whilst Brazil intends to take a big leap in exports, as well as encourage the country's internal trade.

The analysis used the Monte Carlo method through a computerized calculus tool, software @RISKTM, to evaluate the enterprise and provide to the decision maker more confidence in the decision-making process The variables used in the model for the brazilian case are shown in Table 16 and 17.

Table 16. Annual Demands

Type of load	Pessimist	Average	Optimistic
Conteiner (unit)	476.436	1.081.269	1.686.103
Liquid Bulk (t)	7.000.000	13.500.000	20.000.000
Mineral Solid Bulk (t)	30.000.000	50.000.000	70.000.000
Agricultural Solid Bulk (t)	10.000.000	25.000.000	40.000.000

Source: Author (2021).

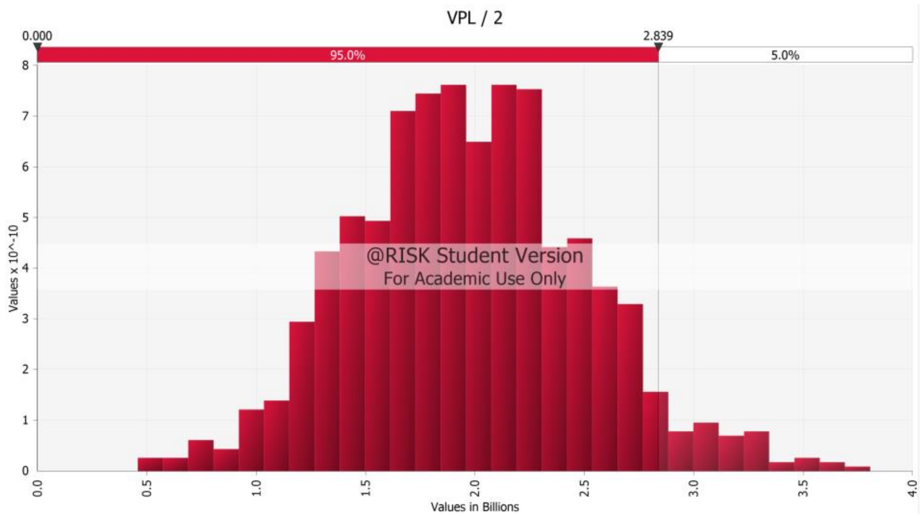
Table 17. Strategic Factors

Strategic Factors	Weights		
	Minimum	Average	Maximum
Draught	1	4.71	8,42
Expansion Area	1	1.5	2
Modes of Transport to access the port	1	5.5	10
Free Trade Zone (Wftz)	1	1.5	2
Maritime Distance (Wmd) - Miami	1	1.46	1,92
Maritime Distance (Wmd) -Rotterdam	1	1.26	1,52
Maritime Distance (Wmd) – Shanghai	1	1,08	1,16

Source: Author (2021).

It was aimed by analyzing the cash flow, considering discount rates from 10%, to identify the influence of strategic factors as enhancers of the project's viability, finding the following results:
Figure 3 shows the NPV curve and the project risk for a 10% discount rate considering the impact of strategic factors on the Net Present Value (NPV).

Figure 3. Enterprise risk probability for 10% discount rate

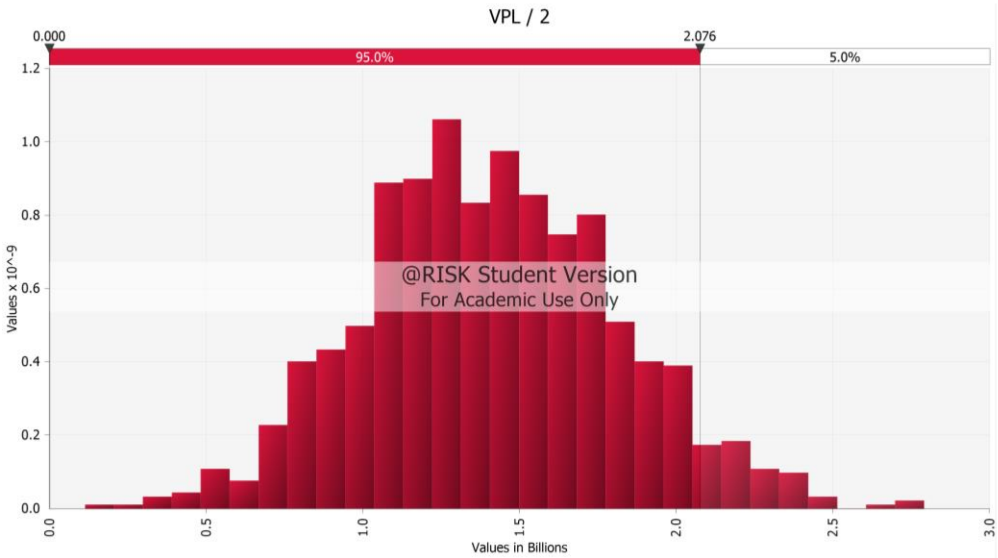


Source: Author (2020).

As shown in the graph in Figure 3, for a 10% discount rate, the probability of success of the venture is 100%. It is also observed that there is a 5% probability of obtaining amounts greater than 6 billion dollars.

Figure 4 shows the NPV curve and the project risk for a 12% discount rate considering the impact of strategic factors on the Net Present Value (NPV).

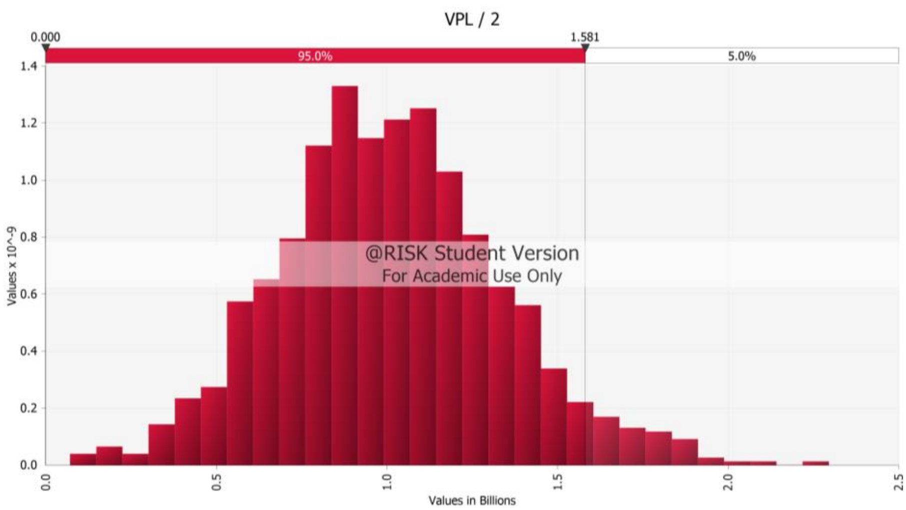
Figure 4. Enterprise probability risk for 12% discount rate



Source: Author (2020).

As shown in the graph in Figure 4, for a 12% discount rate, the probability of success of the venture is also 100%. It is also observed that there is a 5% probability of obtaining values greater than 4 billion dollars. Figure 5 shows the NPV curve and the project risk for a discount rate of 14% considering the impact of strategic factors on the Net Present Value (NPV).

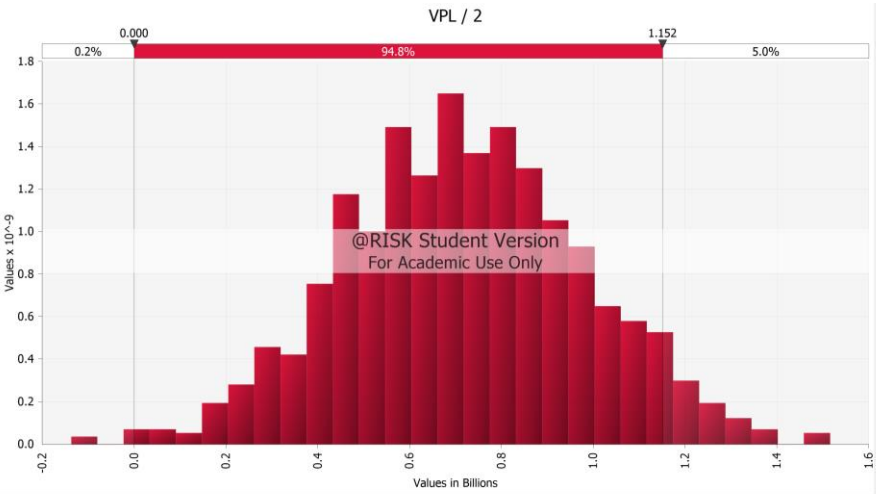
Figure 5. Enterprise probability risk for 14% discount rate



Source: Author (2020).

As shown in the graph in Figure 5, for a discount rate of 14%, the probability of success of the project is 95%. The graph shows that the project has a 5% probability of obtaining amounts greater than R$3 billion. Figure 6 shows the NPV curve and the project risk for a discount rate of 16% considering the impact of strategic factors on the Net Present Value (NPV).

Figure 6. Enterprise probability risk for 16% discount rate

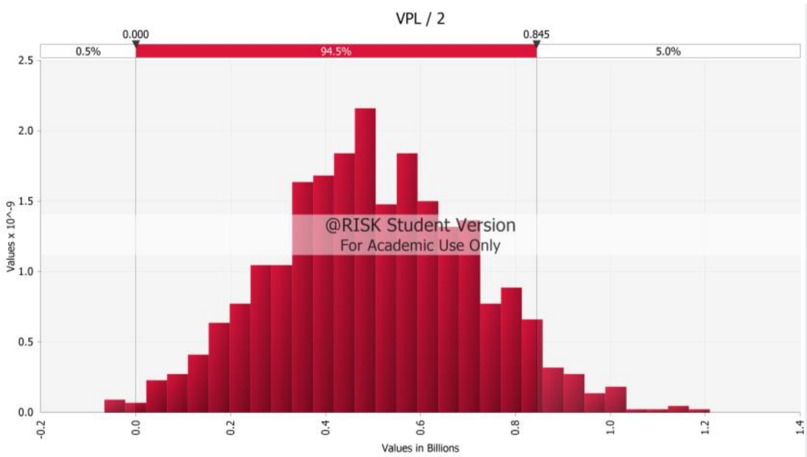


Source: Author (2020).

As shown in Figure 6, for a discount rate of 16%, the probability of success of the project is still very high, reaching 99.8%. The graph shows that the project has a 5% chance of results above 2 billion dollars, with only 0.2% of negative cash flow results.

Figure 7 shows the NPV curve and the project risk for a discount rate of 18% considering the impact of strategic factors on the Net Present Value (NPV).

Figure 3. Enterprise probability risk for 18% discount rate



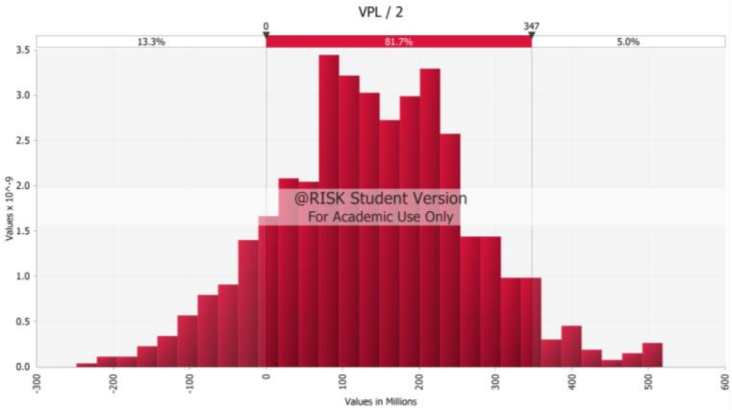
Source: Author (2020).

As shown in the graph in Figure 7, for a discount rate of 18%, the probability of success of the project is 99.5%. The graph shows that the project has a 5% chance of results above $2 billion, with only 0.5% of negative cash flow results.

In order to find a rate to stop the cash flow (revenues = costs) the rate of 24% was found. With this rate, the enterprise starts to have negative results.

Figure 8 shows the NPV curve and the project risk for a discount rate of 24% considering the impact of strategic factors on the Net Present Value (NPV).

Figure 4. Enterprise probability risk for 24% discount rate



Source: Author (2020).

As shown in the graph in Figure 8, for a discount rate of 24%, the probability of success of the project is 86.7%. The graph shows that the project has a 5% chance of results above 600 million dollars, but already has a higher risk of 13.3% of obtaining a negative result for the cash flow.

With the results of the financial analyzes leveraged with the strategic factors, it appears that the implementation of the project of a port in northern Brazil was very favorable, since in addition to the very positive results of the cash flow, it adds to this the prominent score when evaluating the strategic factors considered in the analysis. In a traditional approach, with negative cash flow, the project would already be unfeasible, but with this new approach to the problem, the decision maker has one more tool to help in his decision.

6.2 Investment Risk Analysis of a Hub Port in Africa (Dakar Port in Senegal)

Among the African ports, the port chosen for analysis was the Port of Dakar, in Senegal, as it obtained the highest score in the strategic factors criterion, when it comes to a cargo concentrating port and with multiple-use characteristics.

Figure 9. African ports location

Source: Fahamu | Networks for Social Justice 2021

Because the strategic factors are different for the case of the chosen port (DAKAR), the strategic factors used for the analysis were according to the ranges of values in Table 18.

Table 18. Strategic Factors

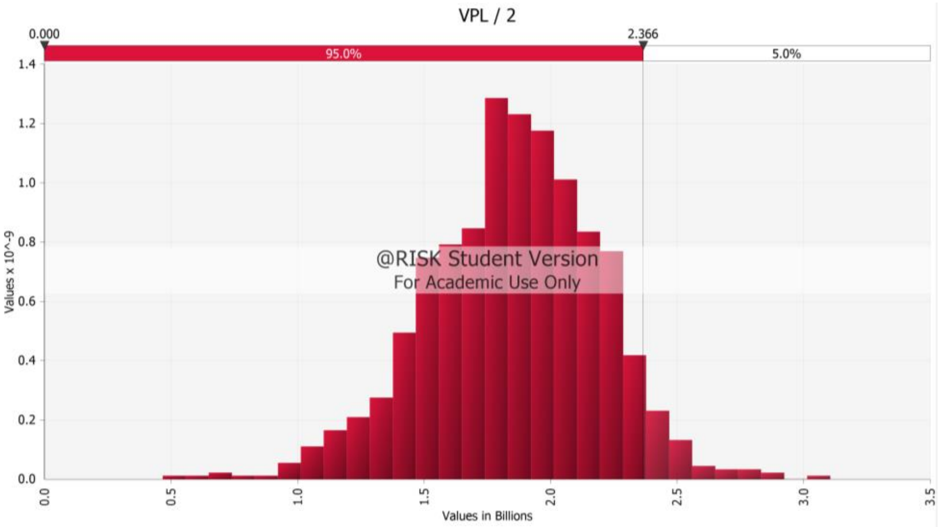
Strategic Factors	Weights		
	Minimum	Average	Maximum
Draught	1	1,2	2,4
Expansion Area	1	0,8	1,6
Modes of transport to access the port	1	2	4
Free Trade Zone (Wftz)	0	1	2
Maritime Distance (Wmd) - Miami	1	0,88	1,77
Maritime Distance (Wmd) -Rotterdam	1	1,75	3,5
Maritime Distance (Wmd) – Shanghai	0	0,5	1,0

Source: Author (2020).

Analyzing the cash flow, considering discount rates from 10% in the case of the chosen African port, the following results were found:

Figure 10 shows the NPV curve and the project risk for a 10% discount rate considering the impact of strategic factors on the Net Present Value (NPV).

Figure 10. Enterprise probability risk for 10% discount rate

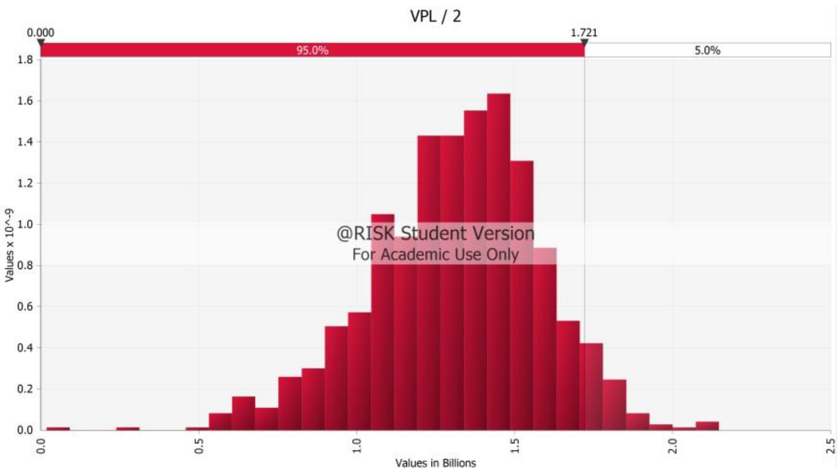


Source: Author (2020).

As shown in the graph in Figure 10, for a 10% discount rate, the probability of success of the venture is 100%. It is also observed that there is a 5% probability of obtaining values greater than 5 billion dollars. It appears that despite having excellent viability, the profitability values are lower than those obtained at the Offshore Port of Pará, located in northern Brazil.

Figure 11 shows the NPV curve and the project risk for a 12% discount rate considering the impact of strategic factors on the Net Present Value (NPV).

Figure 11. Enterprise probability risk for 12% discount rate

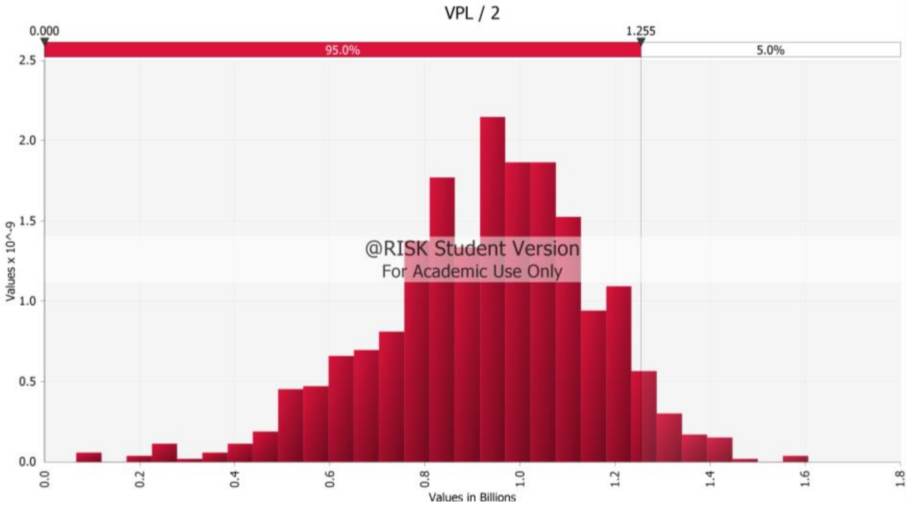


Source: Author (2020).

As shown in the graph in Figure 11, for a 12% discount rate, the probability of success of the project is 100%. It is also observed that there is a 5% probability of obtaining amounts greater than 2 billion dollars.

Figure 12 shows the NPV curve and the project risk for a discount rate of 14% considering the impact of strategic factors on the Net Present Value (NPV).

Figure 12. Enterprise probability risk for 14% discount rate

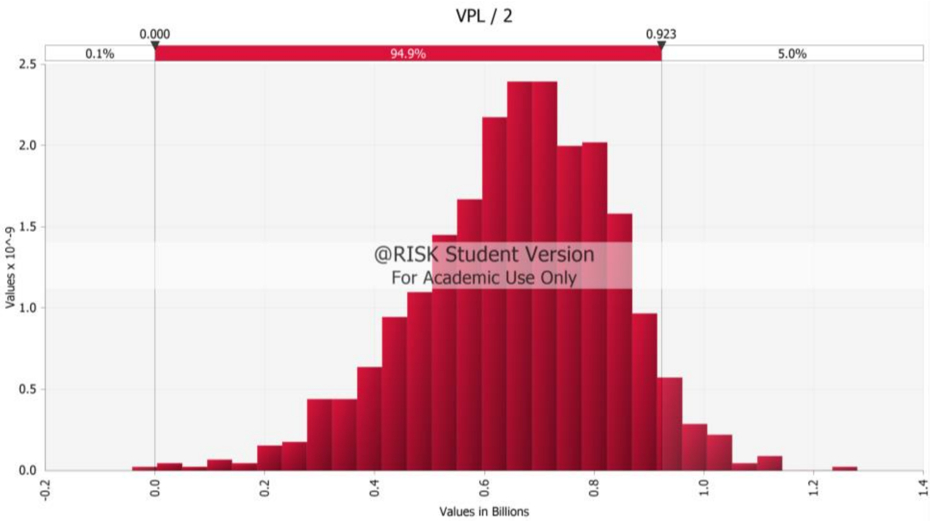


Source: Author (2020)

As shown in the graph in Figure 12, for a discount rate of 14%, the probability of success of the venture is also 100%. The graph shows that there is a probability that 5% of the project's profitability will reach values above 2.5 billion dollars.

Figure 13 shows the NPV curve and the project risk for a discount rate of 16% considering the impact of strategic factors on the Net Present Value (NPV).

Figure 13. Enterprise probability risk for 16% discount rate

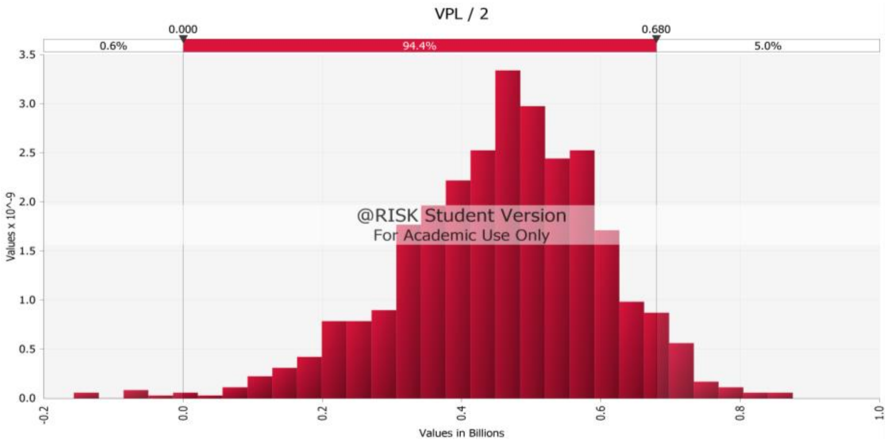


Source: Author (2020)

As shown in the graph in Figure 13, for a discount rate of 16%, the probability of success of the venture is 99.9%. The graph shows that the project's profitability has a 5% chance of presenting values above 1.8 billion dollars. It is also observed that there is a 0.1% probability of obtaining negative values for the NPV. It appears that, despite the high feasibility for this rate, the risks of failure begin to appear.

Figure 18 shows the NPV curve and the project risk for a discount rate of 18% considering the impact of strategic factors on the Net Present Value (NPV).

Figure 18. Enterprise probability risk for 18% discount rate



Source: Author (2020)

The graph in Figure 18 was obtained for a discount rate of 18%, it appears that even though the probability of success of the project is still very high, with 99.4%, the cash flow result begins to show a negative result, with 5% probability of results greater than 1.2 billion dollars and the low probability of failure, as seen in the graph, of 0.6%.

7. Conclusion

The economic feasibility analysis to support decision making regarding the implementation of large-scale projects, such as port investments with cargo concentrating logistic platforms, should not be restricted to the traditional approach of economic engineering, as there are elements and variables that are usually not addressed, but which can, and should, be incorporated into the analysis.

The present study named these elements as Strategic Factors, dividing them into technological factors (draft, expansion area and access modes) and market factors (Free Trade Zone and Distances to consumer poles), which, when applied in projects to implementation of hub ports in two emerging economy regions (North Brazil and West Africa), changed the economic indicators, especially the Internal Rate of Return (IRR) by 56% and 35%, respectively, when considered.

The strategic factors that proved to be the most important, that is, those that caused most impact to the economic viability indicators were the draft (technological) and proximity to consumer centers (marketing), with different intensities in each case studied, but very significant in both.

This paper showed that the introduction of strategic factors to economic analysis produces results that are more compatible with reality, especially in long-term projects that require large investments. This mainly happens because it incorporates regional and global singularities, particularities and generalities, such as, for example, technological and market issues specific to each location, like the depth and existence of a free trade zone – taxation and customs –, as well as global issues, for instance, routes and their distances, which have or may have a very significant impact on the results.

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