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PORT CAPACITY EXPANSION UNDER REAL OPTIONS APPROACH: A CASE STUDY IN BRAZIL

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ABSTRACT

Investments in port container terminals are sensitive to uncertainties. Public investments in infrastructure have been significantly reduced in the last decade in developing countries. The Brazilian government infrastructure investment was only 1.85 % of GDP in 2019, representing the lowest level in the last fifty years. Nonetheless, the regulatory framework of the port sector in Brazil has undergone significant changes over time, increasing the number of private port container terminal leases. The expansion capacity of the private port facilities is strongly linked to the demand uncertainty, which impacts the financial return to the long run. In this scenario, the uncertainty of global cargo transportation can discourage infrastructure investments in this class of project in Brazil. To overcome these issues, the financial modelling applying real options approach is better suited than the traditional valuation methods based on Discounted Cash Flow (DCF) analysis. The present study aims to value flexibilities of anticipating, or postponing, or interrupting investments of an existing operational port terminal in Brazil with expansion capacity under the demand uncertainty. The financial decision to invest in a port expansion is modeled by an American option. The results demonstrate that the investor adds significant value to the project by having the possibility to postpone investments. The proposed model presents the contribution of optimizing the decision of sequential expansions of capacity in port terminals, at any time and according to scenarios' revelation. In addition, the model allows the government authorities to review lease contracts, considering the relevance of timing to invest in project expansion decisions. The proposed model can also be extended to other infrastructure projects in emerging economies.

Keywords: infrastructure; managerial flexibility; port expansion; real options; uncertainty.

1. INTRODUCTION

The volume of cargo handling in containers transported by sea in the world grew by 350 % in the period from 2000 to 2018, from 224 million to 792 million TEU (Twenty-foot Equivalent Unit). In 2018, the Asian continent stood out with a 64 % share of total container movement that year, while Europe contributed 16 %. North America had 8 % of participation and Latin America and the Caribbean with 7 % of the total, leaving 5 % of the total to the other countries, according to the United Nations Conference on Trade and Development (UNCTAD, 2019).

In Latin America and the Caribbean, the volume of containers handled grew by 6.1 % in 2017. Among Brazilian ports, Santos occupies second position in the ranking of port movements in Latin America (CEPAL, 2017). In Brazilian ports in 2019, more than 1 billion tons of general cargo were handled, 10 % of which represented container cargo, according to data from the National Waterway Transport Agency of Brazil (ANTAQ, 2020).

Despite the relative regional importance, Brazil occupies 21st position in the global container movement classification (UNCTAD, 2019). In terms of logistics operations, Brazil ranks only 56th out of 160 countries evaluated, according to the World Bank (WB, 2018). Notwithstanding the operational aspects, the competitiveness of port terminals is severely impacted by investments in infrastructure with a long maturation period, uncertain returns, and considerable market uncertainties.

As this is a strategic sector for infrastructure in the country, investments in ports have historically been guided by the government. These investments have been significantly reduced in the last decade in Latin America. In the case of Brazil, in 2017 public investment in ports was only 1.85 % of GDP, representing the lowest level in the last fifty years (Andrade et al., 2019).

Although Brazilian law nº. 12,815/2013 was approved with the intention of expanding private participation in port terminals, the sector has not yet developed as expected. This can be largely explained by the uncertainties that impact economic and financial viability and which are often not adequately considered in the analysis of these projects (Cruz & Marques, 2013; Herder et al., 2011).

The identification of factors of uncertainty and the development of optimization models that incorporate such uncertainties are fundamental in the process of evaluating and improving developments in the port sector (Chainas, 2017). Progressive adaptation due to changes in market conditions that affect such investments, is another determining factor for the economic and financial sustainability of such projects (Martins et al., 2015).

Additionally, port infrastructure projects have managerial flexibilities, which can add considerable value to these ventures, such as: choosing the optimal time to invest; expansions scheduled in stages; temporary stoppage; contractual term extension; and eventual abandonment of the project. Such flexibilities are not captured by traditional methods of economic and financial evaluation of projects. For this reason, this article proposes a model for financial analysis of expansion of a container port terminal in Brazil, incorporating uncertainties in the flexibility of expanding the project in stages.

The proposed model has as a contribution of optimizing the decision making of sequential expansions of capacity in port terminals, at any time and according to the revelation of scenarios. In addition, the model allows investments to be postponed if the observed scenarios are not suitable for making expansion decisions. The flexibility of expansion in stages in infrastructure projects has an option characteristic, and therefore, can be modelled from the theory of real options.

The worldwide demand for containers was considered the main uncertainty of the proposed model, which also represents the main variable to impact the revenue from cargo terminals. The World Container Index historical series from 2000 to 2019 was used, available on the Thomson and Reuters (T&R) system. The uncertainty was modelled as a Geometric Brownian motion (GBM) in a binomial tree for the present value of the project, which plays the role of the asset that is the object of the real options to be evaluated.

The model admits that decisions to expand or postpone the sequential expansions of the terminal can occur every year and at any time throughout the lease period of the port

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terminal, which allows the adoption of American-type options in discrete time. For the appropriate pricing in each binomial node, the model is calculated by dividend discount, which represents the adjustment for cash flows (CFs) in each period.

The assessment of managerial flexibilities by real options in infrastructure projects, has been widely observed in the literature. Rose (1998) evaluated through Monte Carlo simulation, multiple flexibilities (calls and puts) embedded in a contract between the government and the concessionaire of a highway project in Australia and observed that ignoring managerial flexibilities could considerably underestimate the value of the project.

Bowe and Lee (2004) analysed options for expansion, postponement, reduction, and abandonment in a project to build a high-speed train in Taiwan. Cheah and Liu (2006) proposed a model for real options, using Monte Carlo simulation to price the guarantee of minimum revenue, as a flexible incentive mechanism for the design of a toll bridge in Malaysia.

Huang and Chou (2006) also used a real options approach to assess the minimum revenue guarantee, but in this case with a focus on the option of abandoning a high-speed train project in Taiwan. Chiara et al. (2007) proposed an evaluation model for built-operate-transfer (BOT) concessions using a minimum revenue guarantee, with pricing by Bermudian and Australian options. Alonso-Conde and Brown (2007) used the theory of options as an instrument to evaluate contractual guarantees in a concession in Australia.

In Brazil, Brandão and Saraiva (2008) evaluated guarantees of minimum traffic with spending limits (caps), to attract private investments and limit government exposure on a toll road in Brazil. Brandão et al. (2012a) evaluated the impact of government incentives for guarantees of minimum traffic with coverage levels, in the concession of Line 4 of the São Paulo Metro. Blank et al. (2016) modelled abandonment options in a road concession in Brazil with minimal traffic guarantee. The authors proposed different minimum and maximum levels, resulting in a significant option value for evaluating this class of projects.

Kruger (2012) analysed the option of expanding a highway in Sweden and the flexibilities created, based on the theory of incomplete contracts. In a different way, Rocha Armada et al. (2012) proposed a model for investment subsidies and revenues, in addition to guarantees of minimum demand, with the option of extending the contractual term in an infrastructure project.

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Martins et al. (2014) developed a model for decision making in infrastructure projects both in the structuring and investment phases, as well as in the operational phase of the projects, using the real options methodology. In a simplified way, Rakić and Rađenović (2014) compared the value of the American abandon option and the European abandon option from the perspective of the private initiative, to model Public-Private Partnerships (PPPs).

On the other hand, Xiong and Zhang (2014) proposed the use of real options as a mechanism for improving contractual renegotiations in infrastructure projects. The authors emphasize the importance of modelling contractual flexibilities to assist in increasing rewards in strategic bargaining games. Feng et al. (2015) developed a model to evaluate minimum revenue guarantee, minimum traffic guarantee, and price compensation guarantee, thus determining the optimal toll price in road projects.

Attarzadeh et al. (2017) evaluated revenue guarantees in infrastructure projects, using fuzzy logic to model uncertainties. Buyukyoran and Gundes (2018) modelled a minimum highway revenue guarantee, identifying the upper and lower limits of the option barriers. Carbonara and Pellegrino (2018) evaluated optimal floor and ceiling revenue limits to create a “win-win” condition for the concessionaire and government in infrastructure projects.

Despite the extensive literature on real options applied to infrastructure projects, the pricing of flexibilities in port projects is still scarce. Defilippi (2004) uses regulation theory and real options by Monte Carlo simulation to analyse alternatives for the concession of the port of Callao in Peru, between single or multi-operators, analysing different decision scenarios. The author compares the concession alternatives from the perspective of maximizing the regulator's return.

Bendall and Stent (2005) modelled the strategic decisions of ship operators in port terminals, as options for exchanging between risky revenue streams. Juan et al. (2008) proposed a dynamic contractual framework for PPPs in port terminals with guaranteed minimum income for investors, for greenfield projects in emerging countries. Taneja et al. (2012) evaluated the construction of the port of Rotterdam in stages, incorporating into the contract the flexibility of optimum shutdown and interruption of the expansion program, if demand did not increase as expected.

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Rocha and Brito (2015) used Monte Carlo simulation to price the value of new port projects in Brazil. Based on projected revenues and grant amounts to be captured by the granting authority in these ventures, the authors proposed to allocate part of the revenue to the formation of a permanent fund for sector financing by the port authority.

Zheng and Negenborn (2017) evaluated the option of waiting to invest in the expansion of a maritime terminal for steel cargo in Bengbu, China, from the perspective of the investor. The authors used the Monte Carlo least squares method (LSM) following Longstaff and Schwartz (2001) to analyse carrier cargo routing decisions and competition between rival ports.

Martins et al. (2017) modelled the flexibility to expand the Ferrol container terminal in Spain using a binomial tree model. The authors also evaluated how sensitive the value of the project is to the variables of uncertainty that impact the expansion. Randrianarisoa and Zhang (2019) evaluated the waiting option, with adaptation to the effects of climate change and competition between ports. Balliauw et al. (2019) modelled options and the impact of competition between ports in their decision to invest in increasing capacity, having the flexibility to postpone investments.

The authors identified that increased competition between ports reduces the value of the postponement option. The individual port´s optimal investment decision without competition was modelled in Balliauw et al. (2020). In this last study, the authors focused on the impact of congestion costs on a port´s optimal time to invest in a greenfield terminal. The capacity expansion flexibility was modelled, considering the demand uncertainty follows a geometric Brownian Motion (GBM).

In a different and more intuitive way to the observed literature, in the present study the flexibility to anticipate and postpone the expansion of the port terminal’s capacity was modelled by a binomial tree with dividend discount, a necessary characteristic for the pricing of American-type options at discrete time. The model is also applied to the real case of an existing container terminal in Brazil, in which few studies in real options have been observed in the port sector.

The next section provides an overview of port terminals in Brazil; section three presents the methodology used in the present study; in section four the applied case is

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demonstrated, using the methodology and addressing the main results; section 5 highlights the main conclusions.

2. PORT TERMINALS IN BRAZIL

Ports represent fundamental infrastructure for the Brazilian economy, since they are responsible for the flow of more than 95 % of exports and more than 90 % of imports. Brazil has 8,500 kilometres of navigable coast and the port sector handles approximately 1 billion tons annually (ANTAQ, 2020; NES, 2016) Technological development in container transport and improvements in global transport can contribute to an increase in port demand, especially in emerging countries (Alderton, 2020; Notteboom & Rodrigue, 2008). According to an analysis contained in the ports report of the Brazilian Administrative Council for Economic Defence (CADE, 2017), one of the effects of mergers and acquisitions between shipowners was the increase in the capacity of container ships in Brazil.

However, Brazil is ranked 162nd in the ranking of 264 countries in terms of quality of port infrastructure (WB, 2018). The high logistical costs associated with delays and too long to unload are factors that hinder the competitiveness of Brazilian ports (Andrade et al., 2019). Infrastructure problems associated with excessive bureaucracy have historically been the main causes of inefficiency in this sector in Brazil (Bonelli & Dittrich, 2013).

To circumvent the problems related to the inefficiency of ports, Brazilian law 8630/93, which came into force in 1993, established the first legal framework for private investments through lease agreements. In 1995, law 8907/95 established the main rules for the privatization of the sector and by 2016 more than US$ 1 billion had already been invested in the acquisition of equipment, training, and infrastructure improvement (NES, 2016). In addition, container handling costs were reduced by approximately 53 % between 1997 and 2003, in addition to other improvements observed in the sector's efficiency standards (Bonelli & Dittrich, 2013).

The regulation of the port sector in Brazil has undergone significant changes over time, although relatively recent. The other laws that demonstrate the evolution of the regulatory framework of the port sector in Brazil, in summary, can be observed in Figure 1.

Brazil has 37 public ports and 144 private use terminals, which are maritime and fluvial infrastructure. Public ports in Brazil are administered by the National Secretariat of Ports and Water Transport (SNPTA), of the Ministry of Transport. The private use terminals

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operate under authorization from the National Waterway Transport Agency of Brazil (ANTAQ, 2020) and the Brazilian Ministry of Transport (MT, 2020).

Several factors of uncertainty impact the planning of this class of projects (Bendall & Stent, 2005). The unpredictability of demand, the limitation of capacity in ports, the constant regulatory changes, and the volatility of global economic activity are variables of uncertainty which require significant changes and adaptations in the port infrastructure. In addition, it should be noted that congestion in existing ports, depth, and the constantly changing requirements of the shipping industry require significant changes in port infrastructure (Taneja et al., 2012).

These uncertainties often impact investment decision making in ports in Brazil, whose capacity is still limited to meet international demands. It is also expected that the entry into operation of large ships (approx. 20,000 TEU) will displace ships currently in use on the main world routes (United States/Asia, Europe/Far East), with a capacity of 12,000 to 15,000 TEU for routes serving Brazilian ports. Such ships require port access channels at least 14 meters deep. Currently in Brazil only the ports of Itaguaí (RJ), Suape (PE) and Pecém (CE), which account for approximately 15 % of the cargo in containers handled in Brazilian ports, are those able to receive such ships, which indicates the need for investments in improving the country’s port infrastructure (Andrade et al., 2019).

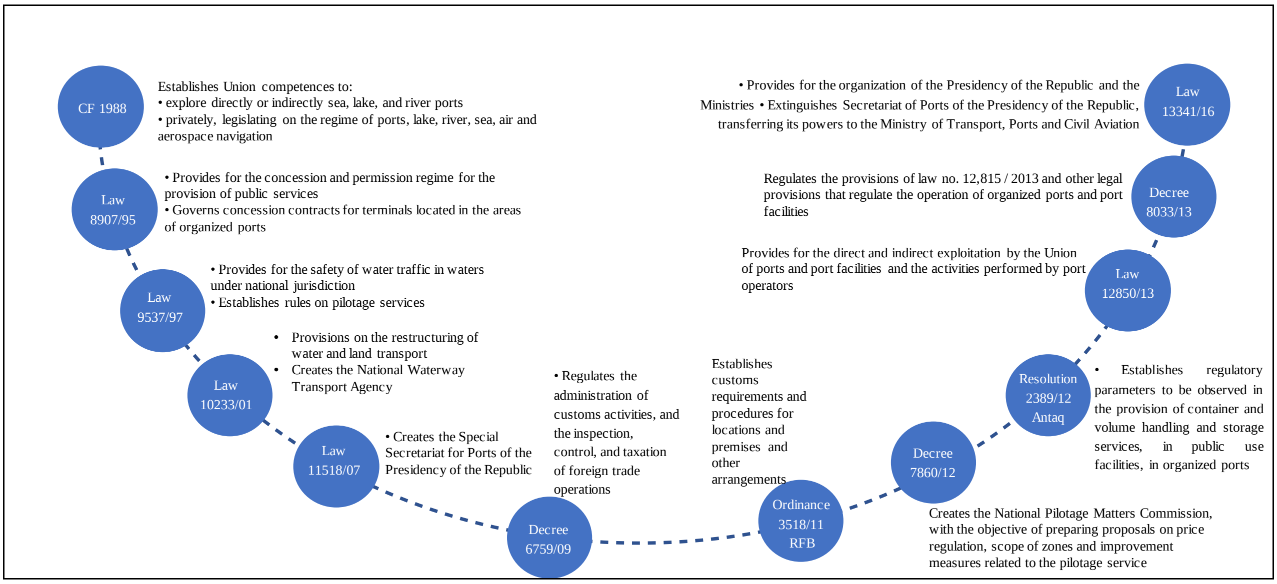

Figure 1: Evolution of the regulatory framework for the Ports sector in Brazil
Source: elaborated by the authors

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3. METHODOLOGY

The traditional assessment of infrastructure projects fails to incorporate uncertainties and adaptability over time. When developing a real options valuation model, as proposed in the present study, it is possible to incorporate the modelling of uncertainties and flexibilities into the traditional viability methods. For the development of the real options model, the most relevant uncertainties for this class of projects were initially identified.

Subsequently, the historical series of the main variable of uncertainty was tested to understand the stochastic process, probability distribution, and suitability for modelling. The development of the options model involved the identification of the main strategic flexibilities involved in this type of enterprise. Finally, the net present values (NPVs) are calculated with and without flexibility, to assess the value that the flexibilities add to the project and their relevance, and in addition, if it is possible to be applied in other projects.

The valuation of flexibilities was initially disseminated through the theory of financial options introduced by Black & Scholes (1973) and Merton (1973). An option is the right, but not the obligation, to make a decision to invest, sell, defer or otherwise dispose of an asset at a predetermined price during a certain time period (Copeland & Antikarov, 2001). Over the recent years, ROA has found several applications in infrastructure projects, such as transportation, highways, ports and airports.

The proposed model was applied in the evaluation of the option to expand the capacity of port terminals, as an expanded approach from Cox et al. (1979). The binomial model for calculating the value of European options was adapted, contemplating dividends, to allow decision-making flexibility to occur at any time during the life of the project, being therefore suitable for the pricing of American options in discrete time, as proposed by Copeland and Antikarov (2001).

The calculation of dividends, as the project’s cash flow (CF) each year, considers the return on investment on real assets (port terminal) at each moment and binomial node. At each binomial node, upward movements reveal the upside value of the project and downward movements demonstrate its downside value, according to market uncertainties.

Using a binomial model with dividend calculation seeks to incorporate conditions into the modelling, in which the early exercise of options would be optimal (Black & Scholes,

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1973; Merton, 1973) and therefore, for each binomial node an approximation is obtained for the calculation of American options.

For the calculation of the model with options, the uncertainty of demand for container handling was understood as that which most impacts the project's viability. For this reason, historical data of containerized cargo were analysed, through the monthly container movement index in the World Container Index, in the period from 2000 to 2019, released by Thomson and Reuters (2019). Historical data can be seen graphically in Figure 2.

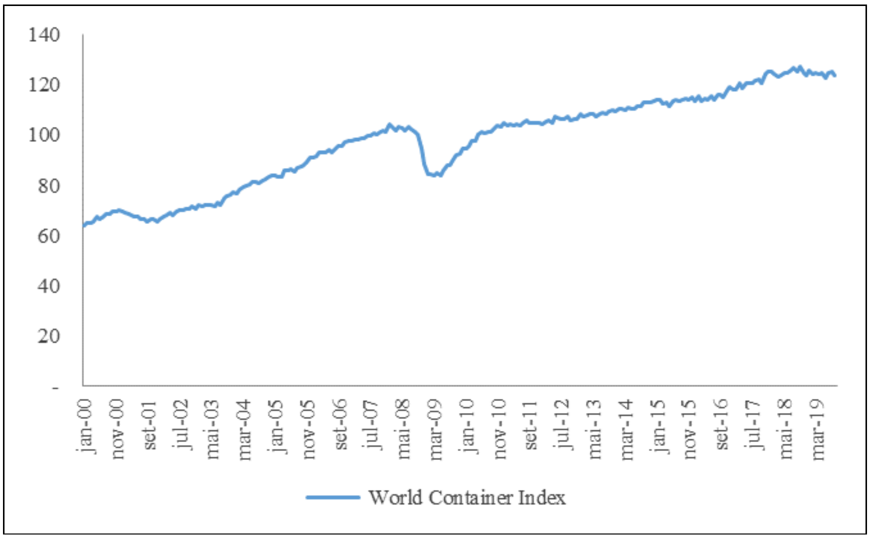

Figure 2: World Container Index, between 2000 and 2019.
Source: Thomson and Reuters (2019)

This series was chosen due to the container terminal chosen for the application of the proposed model to present predominantly long-haul navigation, with a relative participation of 77 % in the movement of the year 2019. Additionally, it should be noted that even with data on container movement in Brazil released by ANTAQ, the use of the World Container Index historical series of data was assumed. The justification for using this historical series is the great representativeness of long-distance navigation for export purposes, in the demand for handling by the terminal.

In the literature on the application of real options in infrastructure and ports, the uncertainty of cargo demand has been largely modelled as a geometric Brownian motion (GBM). Dixit and Pindyck (1994) suggest the execution of stationarity tests on the uncertainty variables, before the determination of the stochastic process.

Initially, the presence of unit roots was analysed, as an indication of non-stationarity in the behaviour of the historical series, and therefore, making it possible to assess whether

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there is evidence of random walk. The test used to identify unit root was the Augmented Dickey-Fuller (ADF). According to tests carried out in E-views software, the null hypothesis H_0 could not be rejected, showing evidence that the underlying stochastic process follows the GBM.

In the variance ratio test which was also applied, it was observed that the difference in variance may increase over time. Thus, due to the signs of non-stationarity observed in the tests performed, it was assumed the stochastic process follows a Geometric Brownian Motion (GBM) diffusion process. This fact is corroborated by the expectation of specialists in the sector, who foresee the growth of the volume of ships to Brazilian ports in the coming years (interview with Robert Grantham, *Solve Shipping Intelligence Specialists*, 29 May 2017).

The GBM is also known as a random walk process with trend, whose stochastic differential equation is given by:

$$dS = \mu S dt + \sigma S dz \quad (1)$$

where S is the value of the modelled variable, μ is the growth rate of S (trend), σ is the volatility parameter of S, the time increment is given by dt, and dz is the increment of a Wiener process or standard brownian motion. This classic stochastic process has a normal distribution with zero mean and volatility (standard deviation) proportional to $\sqrt{dt}$.

Modelling the flexibility of the project can be assessed using the binomial method for pricing options. However, Copeland and Antikarov (2001) demonstrated that the volatility of the underlying asset and the project is different, as the project is impacted by operational and leverage aspects that alter the uncertainty regarding its cash flows.

Thus, in addition to assessing the behaviour of the container handling historical series that initially impacts cash flow projection, in this article the model proposed by Brandão et al. (2012b) was adopted to estimate the volatility of the project. By this approach, volatility was obtained by Monte Carlo simulation, from the calculation of the project's rate of return ($\tilde{\gamma}$) in several scenarios by:

$$\tilde{\gamma} = \ln\left(\frac{\tilde{V}_1}{V_0}\right) = \ln\left(\frac{\tilde{F}_1 + \sum_{t=2}^{n} E[\tilde{F}_t] e^{-\mu(t-1)}}{\sum_{t=1}^{n} E[\tilde{F}_t] e^{-\mu t}}\right) \quad (2)$$

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where V_0 and V_1 are the respective present values of the initial cash flows, based on conditional expectations for each period $\tilde{F}_t$. At the end of period 1, the best unbiased estimates of F_2-F_n are the expected values, conditional on the result for F_1. The estimated volatility for the project is therefore given by the standard deviation of $\tilde{\gamma}$.

In this case, with the volatility estimate σ, the present value (*PV*) of the infrastructure project expansion can be calculated following the binomial model of Cox et al. (1979), in which upward (*u*) and downward (*d*) movements, according to equation (3) and according to equation (4).

$$u = e^{\sigma\sqrt{\Delta t}} \tag{3}$$

$$d = e^{-\sigma\sqrt{\Delta t}} = 1/u \tag{4}$$

where Δt is the time interval of the decision process. For the present study, it was considered that the investment decision-making can occur every year, depending on the market conditions for the continuity of the enterprise. For this, Δt equal to 1 year was considered.

In the binomial tree, for each possible scenario, at each node, the probability influences the final evaluation of the project. The probability of each result at first, is determined for the deterministic cash flow of the project, being: $q = \frac{e^k - d}{u-d}$, and: $1 - q = \frac{u - e^k}{u-d}$, where q is the probability. The input variables of the model are its risk-adjusted cost of capital k and its volatility σ, with the subjective probabilities q and $(1-q)$.

As it is a binomial tree with dividend discount in t (Div_t), there was a need to calculate the present value of ex-ante dividends (PV_a) and the present value of ex-post dividends (PV_p), as proposed by Copeland and Antikarov (2001). For all projection periods, the projected cash flows must be obtained and the *PVs* calculated, according to equation (5).

$$CF_1 = PVa_1 - PVp_1 , \;..\; CF_n = PVa_n - PVp_n \tag{5}$$

The dividend rate vector (δ) is now defined as in equation (6):

$$\delta_1 = CF_1 / VPa_1 , \;...\; \delta_n = CF_n \;/ PVa_n , \tag{6}$$

in which:

PVa_t : is the PV before dividends and before the option in t.

PVp_t : is the PV after dividend discount and before the option in t.

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The PVp_t is equal to PVa_t .(*1- δt*) and the observed dividend rate is given by equation (7).

$$Div_t = PVa_t - PVp_t = PVp_t \times (1/(1-\delta_t) - 1) = PVp_t \times \delta_t / (1-\delta_t) \quad (7)$$

The event tree projected from the dividend discount can be seen in Figure 3 below, in which the first two periods of the binomial tree are illustrated. The binomial tree constructed in this way assumes differentiated *k* discount rates for each binomial node, according to the risk at each stage, given that the exercise of options alters the risk of the project.

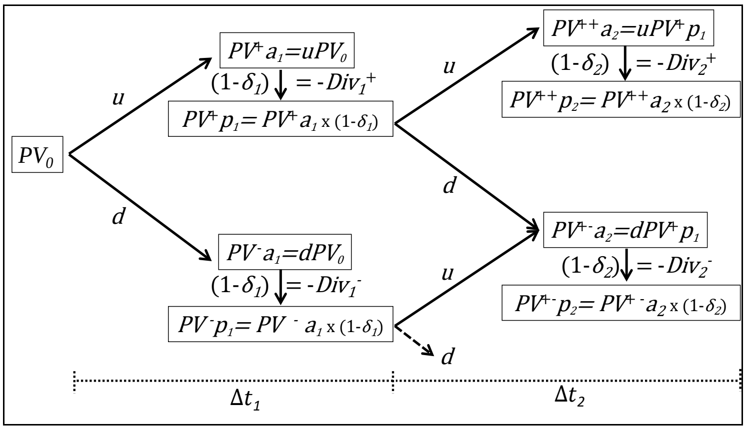

Figure 3: Binomial tree of projected present value with dividend discount and without option
Source: adapted from Copeland and Antikarov (2001)

On the other hand, so that it is not necessary to use different discount rates at each step of the binomial, the risk-neutral approach is used. The risk-neutral approach simulates what would happen if the project had an expected return equivalent to the risk-free rate in all decision nodes so that the *PV* is always the same with respect to that obtained by the binomial tree with risk.

Thus, in line with the assumptions of the binomial model by Cox et al. (1979), complete markets are assumed, so that the project's *PV* is an estimator of its market value based on risk-neutral probabilities. Being: r_f the risk-free rate, we have that *p* and *(1-p)* are given by equation (8) and equation (9).

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$$p = \frac{e^{r_f} - d}{u - d} \tag{8}$$

and

$$(1 - p) = \frac{u - e^{r_f}}{u - d} \tag{9}$$

which are called risk neutral probabilities. In the absence of arbitrage opportunities, the project's expanded present value at date zero (PV_{exp0}) with options can be discounted at the risk-free rate r_f, as seen in Figure 4.

The evaluation of the option for the binomial tree following Cox et al. (1979) makes the result of the option value independent of the objective probabilities q and $(1-q)$ and allows the use of the risk-free rate as a discount rate in all nodes in the binomial tree. Thus, the real options can be modelled on the binomial tree, using backward induction. The final payoffs can be discounted at a risk-free rate, period by period, up to the initial value, to obtain the expanded present value of the project.

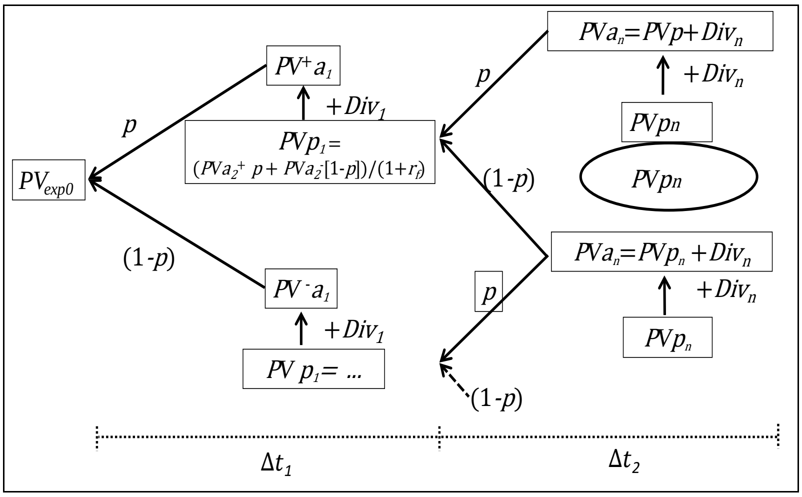

Figure 4: Binomial tree with backward calculation of the present value expanded with dividends
Source: adapted from Copeland and Antikarov (2001)

The value of the PVp_0 option can be calculated by the equation (10).

$$PVp_0 = PV_{exp0} - PV_0 \tag{10}$$

To achieve this expanded value in $t = 0$, at each moment and binomial node, the rule of maximization between the exercise of expansion and deferment options is used

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simultaneously, which also gives the flexibility of early exercise or postponement of investments. The value of the options (ξ), on date zero, will be given by equation (11).

$$\xi_0^{Call} = \sum_{t=1}^{n}\left(max\left(PV^{+}_{POS-DIV}\cdot\chi_E - I;\left(PV^{+}_{POS-DIV}\cdot p + PV^{-}_{POS-DIV}\cdot(1-p)\right).e^{-r_f}\right)\right) \quad (11)$$

in which $PV^{+}_{POS-DIV} = PV_{pt \times \delta t}/(1-\delta t)$ is multiplied by the expected growth in expanded cash flow, here seen as the χ_E cash flow expansion factor. The model incorporates to each binomial node the maximization rule between the option to postpone the investment, based on the present value of the postponement discounted in continuous time (e^{-r_f}), and the other values of post-discount dividend expansion.

4. APPLICATION OF THE MODEL AND RESULTS

The proposed evaluation model was applied to the analysis of a private port container terminal lease, currently in operation and located in north-eastern Brazil. This lease received a contractual amendment in November 2016, contemplating the early extension of the lease, with the closing previously scheduled for 2025, to be considered for 2050, as shown in Figure 5. For the present study, the first expansion phases considered 2020 as the starting point for the expansions.

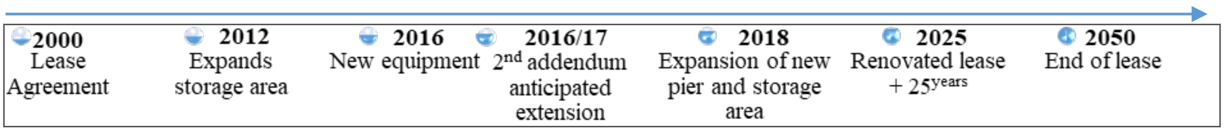

Figure 5: Timeline of changes to the lease
Source: Elaborated by the authors

The lease contract provided the concessionaire with the flexibility to extend the contractual term, with the counterpart being the obligation to make investments to expand the terminal, based on milestones established by the granting authority.

The commitment to carry out the expansion initially contemplated an increase in the storage area by 28,159 m² and subsequently by 88,803 m², in addition to an increase in the main pier by 423 m, and the acquisition of cargo handling equipment. This expansion would allow larger ships of around 366 m to anchor in the port, according to the Dock Company of Bahia (CODEBA, 2019).

According to a report by the Brazilian Ministry of Infrastructure (MI, 2018), the handling of the Salvador and Aratu-Candeias port complex, when added up, corresponded to 302 thousand TEU in 2016, which was the highest value observed in recent years. Between

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2012 and 2016, the movement of containers in the complex increased on average by 4.1 % per year. The predominant type of navigation is long-haul, with a relative participation of 63 % in handling in 2016. In the MI report, the projection of cargo handling demand by 2060 should positively impact the growth of container handling at an average rate of 1.9 % per year, reaching 715 thousand TEU at the end of the period.

However, between 2018 and 2019 there was a drop in the worldwide movement of containers (T&R, 2019). In 2020, due to the pandemic crisis, which severely impacted the global economic scenario, the uncertainties for investments in ports may intensify even more.

There was already a forecast of a change in the Chinese economy for the period 2019-2024, with the prospect of moderate growth in container movement in the world (UNCTAD, 2019). Such predictions were based on the acceleration of technological innovations in the supply chain and possibilities of natural disasters due to climate change.

4.1. The project

The investments, as shown in the second amendment to the contract signed with the Dock Company of Bahia (CODEBA) are divided into three main stages (1, 2, 3), with each stage representing an increase in capacity and a specific investment. Stage 1 comprises the construction of docks to increase the area for mooring ships. In Stage 2, the paving of the area is planned, and in Stage 3 the construction of a landfill is planned to expand the storage area and movement at the port.

For the preliminary application of the model proposed in this study, investments are brought to present value from 2020. The second amendment to the lease agreement signed with the granting authority provided for deadlines for investments in the terminal, with stage 1 up to two years from the beginning of the works, thus it was considered until 2022 and the other stages until 2030 and 2034, respectively.

Operating revenues and costs were evaluated in TEU, which represents a standard measure widely used to calculate movement, based on the volume of the container. Such assumptions were estimated based on references from industry experts in December 2018 and obtained from the existing operations in ports in Brazil with similar operating conditions, in addition to data provided by CODEBA (2019). The cost of capital was calculated from data available in Damodaran (2019). Table 1 illustrates the main assumptions used to structure the project's base model.

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Table 1: Assumptions of the expansion project

Conditions	Details
General conditions for project expansion	• Operated by the Wilson Sons group • Amendment 2 to the lease signed in Nov/16, extended the lease for another 25 years (until 2050) • Extension of the main pier: 423 m • Stage 1: 314,000 TEU capacity increase • Stage 2: 35,000 TEU capacity increase • Stage 3: 141,000 TEU capacity increase
Expansion Costs	• Stage 1: U$$ 62.84 million by 2022 • Stage 2: US$ 6.91 million, storage area, until 2030 • Stage 3: US$ 28.15 million, expansion of storage area, until 2034
Other projection data	• Average TEU revenue: US$ 129.64 • Container handling in 2019: 301,377 TEU • Estimated annual growth rate for handling: 1.9 % p.a • Variable cost: US$ 70.73 (average in TEU) • Fixed cost: approximately 20 % of revenue • Risk-free rate: 4.13 % p.a (T-Bond USA) • WACC (Shipping & Marine): 12.06 % p.a • Currency exchange (U$ Dollar-BRL): R$ 5.50

Source: Elaborated by the authors

In the base case scenario, the evaluation of the project using the discounted cash flow (DCF) methodology is considered, estimating the rate of demand growth as provided in the Ministry of Infrastructure Master Plan (2018), i.e. 1.9 % per year, taking into account that the investments will necessarily occur as planned, without considering any managerial flexibilities.

This approach is in line with the commonly observed planning for infrastructure projects, using the DCF methodology with a risk-adjusted discount rate, and whose expansion plan for port terminals follows a fixed investment schedule, limited until the year 2034. Following the DCF methodology, the present value (*PV*) of future cash flows is US$ 86.89 million in 2020. The total investments that would be made in the same year, for the amount of US$ 98.04 million. The net present value (NPV) of the project without flexibility would be negative by US$ 11.5 million, presenting an internal rate of return (IRR) of 6.3 % p.a. Such information clearly demonstrates the project is not financially feasible when considering all expansion investments being made in 2020 and projections until 2050.

Since the IRR is a relevant variable to be considered in concessions or leases by the granting authority and was below the cost of capital of 12.06 %. This differential between rates could result in the need for economic and financial rebalancing of the contract or even discontinuation of expansion plans. To evaluate an alternative scenario, also using the DCF methodology, the completion of the 3 stages of expansion works was considered, according to deadlines (expansions until 2030, and 2034) and the 1.9 % cargo growth was maintained,

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as proposed in the master plan of the project. For this scenario, the project's NPV would be negative by US$ 1.65 million, seeking to reflect the contract fixed investment schedule, even without the proper pricing of this flexibility.

4.2. Project evaluation with flexibility

When evaluating the terminal expansion project with the flexibility to postpone or anticipate the expansion steps at any time throughout the lease term and no longer as a contractual obligation, the proposed model incorporates to the project optimal decision making under uncertainty when modelling demand. The lessee carries out the expansions only in favourable scenarios and to the extent that the information is revealed.

For modelling of the project's demand uncertainty, the longest possible available historical time series of the monthly world container movement index between 2000 and 2019 was used (T&R, 2019). From this series, load movement growth rate (α) and volatility (σ) parameters were extracted. Volatility was further adjusted, as proposed by Brandão, Dyer, Hahn (2012b). When using these parameters, the upward (u) and downward (d) movements were calculated, as well as the probabilities (p and $1-p$), for each binomial node in the binomial model, following Cox et al. (1979). The data are summarized in Table 2.

Table 2: Parameters for the flexible scenario

Items	Values
Initial demand (year zero: 2020)	301 thousand TEUs
Growth rate of cargo handling (α)	1.90 %
Volatility (σ)	4.43 %
Volatility (σ) BDH (Brandão, Dyer, Hahn, 2012b) Model	3.59 %
Upward movement (u)	1.045
Downward movement (d)	0.957
Probability (p)	0.954
Risk-free rate (r_f-T-Bond USA)	4.13 %

Source: Elaborated by the authors

By adding the flexibility to postpone or anticipate expansions and carry out the project in stages, the NPV becomes positive, based on the disclosure of favourable scenarios, within the term allowed in the contract. As shown in Table 3, the option to postpone and expand only the first stage at any time throughout the lease term, would generate a positive expanded NPV ($NPV_{OptionExp1}$) of US$ 71.5 million. When assessing the flexibility to expand stage 2 at any time, composed of the flexibility to expand stage 1 ($NPV_{OptionExp2\ e\ 1}$), the project's NPV is also positive by US$ 77.3 million. Also having the composite option of expanding stage 3, at any time in a compound and optimized way for flexible decision making in stages 1 and 2 ($NPV_{OptionExp3,2\ e\ 1}$), the project will have a positive expanded NPV of US$ 84.3 million.

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Table 3: Comparison between the net present value of the project without and with options.

Scenarios	$NPV_{without\ option}$	$NPV_{without\ option\ (in\ stages)}$	$NPV_{OptionExp1}$	$NPV_{OptionExp2\ and\ 1}$	$NPV_{OptionExp3,\ 2\ and\ 1}$
NPV (US$ million)	-11.1	-1.7	71.5	77.3	84.3

Source: Elaborated by the authors

The analysis by real options applied to this case study of a port terminal in Brazil demonstrates that the flexibility of expansion in stages adds significant value to the project, when properly modelled. Such flexibility, when evaluated from the perspective of encouraging private investors, can represent an important contribution to the improvement of contractual clauses for port leases or even to boost investments in the sector, especially by allowing expansions to take place over a longer time horizon without predetermined dates. The optimal exercise of the expansion flexibility would occur, according to the possible scenarios for expansion.

5. CONCLUSIONS

Port infrastructure planning in Brazil requires studies that address new models and flexibilities in contracts. Considering the uncertainties that can impact a port infrastructure project, the demand uncertainty can be considered one of the most relevant. Associating the analysis of this uncertainty together with contractual flexibilities in a single model can be a decisive factor in identifying the financial viability of a project.

The dynamics of maritime trade, new technologies, the consolidation of cargo from large shipowners, and the commercial pressure from ports tend to increase the risk of demand for cargo handling. In addition, investments in terminals are capital intensive, and uncertainty about demand (cargo) can significantly impact the viability of these projects.

The traditional approach to investment planning in terminals, based on predetermined dates, needs to be combined with a more flexible approach, especially in emerging countries such as Brazil. The decision-making approach under uncertainty, according to the real options theory (ROT), can allow both the lessee to add value to the projects and the granting authority to attract new investments to this sector.

The model proposed in the present study, applied to the case of a container terminal in Brazil corroborates the hypothesis that it is possible to obtain greater value for a port project, if there is contractual flexibility. Such flexibility is aligned with expansion planning, following the behaviour of the load demand (the uncertainty variable). The use of flexible models allows the investor to program their investments, obtaining a greater return on the project and mitigating risks, according to the change of variables over time.

The American option of anticipating and postponing investments allows re-evaluating projects that previously would have been considered unattractive from a financial point of view. In this context more robust modelling is needed, especially when evaluating sequential expansion options. The approach proposed in this study can also contribute to the reformulation of contractual practices, currently imposed by the granting authority for investments in infrastructure in emerging countries such as Brazil. The granting authority's flexibility in terms of investment can even mitigate the need for contractual financial rebalances in infrastructure concessions and leases.

However, it is worth noting that the present study has some limitations. The volatility calculated for the model uses an annual historical average of container movement not segregated by continents. Even though an adjustment model was applied for the project's volatility, high volatility scenarios could significantly change the value of the project. In addition, when evaluating the growth rate of the risk-adjusted project used in the present study, it is observed that despite conservatism when assuming annual growth of less than 2 %, in a post-pandemic crisis scenario, emerging economies can be severely impacted. In this sense, the present study did not portray the possibility of incorporating a negative growth rate.

In future studies, a financial modelling can be developed to incorporates other uncertainties not yet observed in port projects, such as costs and regulatory impacts. The flexibility of early renewal of port lease contracts (upon investment requirement) already exists in Brazil, but this option has not yet been fully modelled. It could be incorporated into the modelling proposed in the present study and thereby allowing deployment into a more complete model for infrastructure projects. The development of studies combining game theory and the real options theory in the port sector would also contribute to assess the impact of competition between terminals.

There is also a wide range of studies on real options for other infrastructure projects, such as: i) pricing for the early renewal of infrastructure contracts for railways and highways; ii) demand guarantees (how the demand risk mitigation mechanism can represent flexibility for the investor); iii) the abandonment option incorporates the deferral option; iv) modelling of regulatory uncertainties by differentiated stochastic processes; v) pricing of options with two uncertainty variables; vi) incorporation of multicriteria methods into a model integrated to the pricing of flexibilities by real options.

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